Chapter 2
Perceived Exertion

Perceived exertion can be defined as *the subjective intensity of effort, strain, discomfort and/or fatigue that is felt during exercise* (Robertson and Noble 1997). The exertional experience involves detecting and interpreting sensations arising from the body during any type of PA (Noble and Robertson 1996). The underlying processes that are subjectively monitored during PA, referred to as exertional mediators, are classified as physiological, psychosocial, performance-related and symptomatic in nature. Perceived exertion can be assessed during aerobic and resistance exercise, leisure time or daily living activities, occupational physical activity, or a wide variety of recreational and competitive sport activities. Individuals can rate their level of perceived exertion by selecting a number, or rating of perceived exertion (RPE), from a range of numerical categories displayed on a perceived exertion scale. These RPE scales may include verbal and pictorial descriptors that are placed in juxtaposition to numerical categories representing the range of perceptual responsiveness from very low to very high intensity. The Borg RPE Scale and OMNI RPE Scales have been used in perceptual paradigms designed to quantify and predict physiological responses to acute exercise and adaptations to exercise training. RPE is an important variable used to monitor exercise programming, ensuring the attainment of optimal exercise intensity for the achievement of health-fitness benefits and to promote PA adherence.

2.1 Mediators of Exertional Perceptions

Over the past 50 years, the perceived exertion knowledge base has grown exponentially. Research has studied many aspects of this gestalt-like perceptual response to exercise, described so because it is a complex pattern of physical, biological, and psychological phenomena. The Global Explanatory Model for Perceived exertion (Fig. 2.1) illustrates the mechanisms, both internal and external, by which an exercise stimulus results in an individual's unique perceptual response (Noble et al. 1986;

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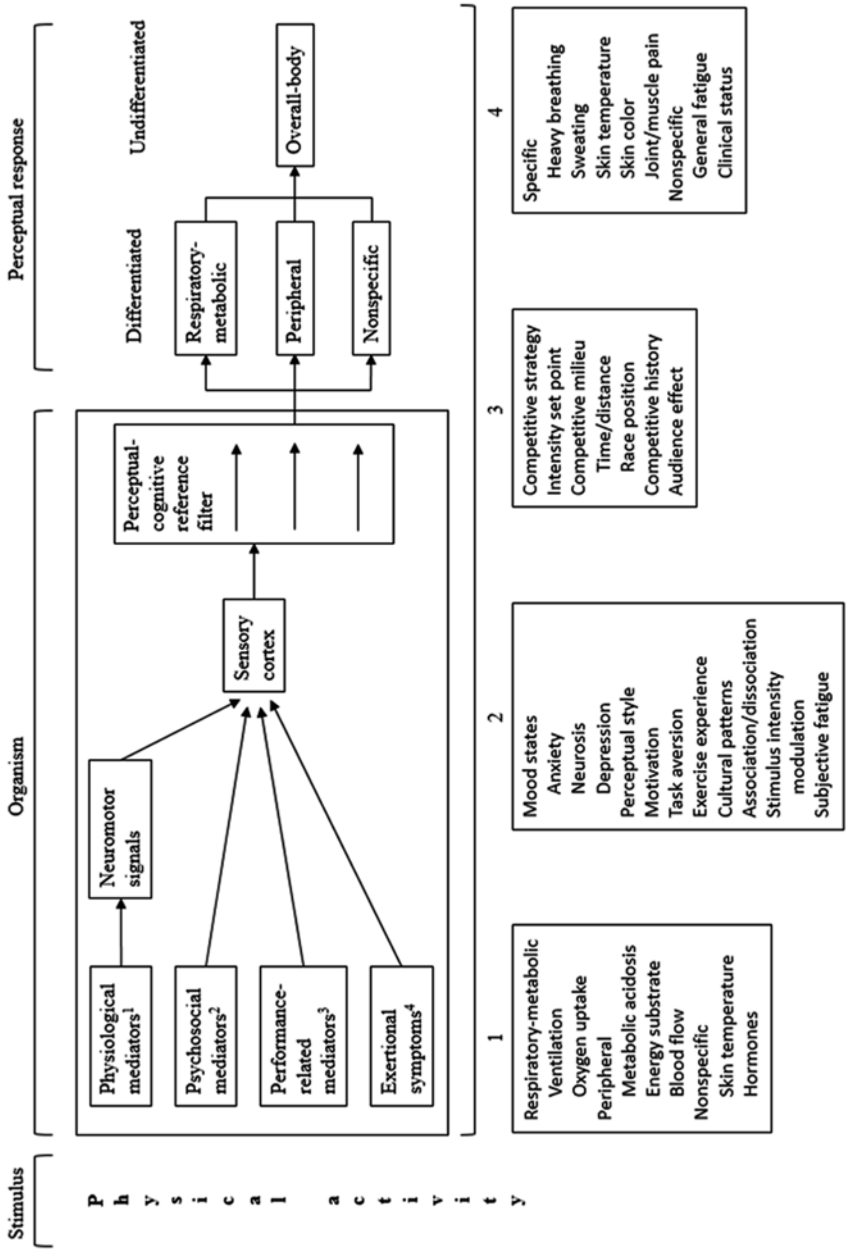

Fig 2.1 Global explanatory model of perceived exertion (adapted from Noble and Robertson 1996)

Noble and Robertson 1996; Robertson et al. 1986). Exertional mediators are the underlying physiological, psychosocial, performance-related and symptomatic processes that an individual subjectively monitors during PA. These mediators function collectively and interactively to ultimately shape the RPE response. Gaining knowledge about how these exertional mediators act to influence adoption and maintenance of PA has been a primary focus of perceived exertion research and its application in both health-fitness and clinical settings.

2.1.1 Physiological Mediators

Physiological mediators of exertional perceptions can be subdivided into *respiratory-metabolic, peripheral*, and *nonspecific* categories. Respiratory-metabolic physiological mediators include those processes that are influenced by aerobic metabolic demand during PA. These include pulmonary ventilation (V_E), oxygen uptake (VO_2), carbon dioxide production (VCO_2), HR and BP. Peripheral physiological mediators include factors such as metabolic acidosis (pH, lactic acid), muscle blood flow, muscle fiber type and glycogen content, as well as plasma glucose and free fatty acid concentrations. Nonspecific physiological mediators include systemic events that occur during exercise, such as hormonal regulation and increases in both skin and body core temperature.

Physiological mediators of exertional perceptions play a primary role in shaping the effort sense due to their effect of altering tension-producing properties of skeletal muscle. Muscle contractions are monitored through a neurophysiological pathway between the motor and sensory cortex (Robertson 2001). Developed tension in both peripheral and respiratory muscle is monitored and ultimately interpreted as effort sensation. As PA intensity increases, a feed-forward mechanism rooted in the motor cortex increases skeletal muscle motor unit recruitment and firing frequency. Corollary signals branching from the motor efferents and terminating in the sensory cortex also increase in frequency, intensifying perception of effort. These efferent signals are integrated with afferent proprioceptive feedback from muscles and joints that help fine-tune the RPE response.

2.1.2 Psychosocial Mediators

Physiological mediators of exertion generally function similarly for most individuals and have been a major focus of RPE research since conception of the discipline by Borg. However, experimental research focusing on the identification of psychosocial mediators that may account for inter-individual differences in the perceived exertion response is gaining substantial interest. Morgan (2001) separated the psychosocial mediators of exertional perceptions into four distinct classifications: (1) affective mediators that are linked to emotions and mood states, including anxiety, depression, introversion, and extroversion; (2) cognitive mediators that include association/dissociation, self-efficacy, and personality type; (3) perceptual process mediators that include pain tolerance, somatic perception, perceptual augmentation, and perceptual reduction; (4) social/situational mediators that include music, sex of the counselor or test administrator, and social setting. Recently, there have been substantial increases in the knowledge base concerning the AR to exercise and its relation to RPE, largely due to the work of Ekkakakis (2003) and his colleagues. This work has identified affect as a potential factor mediating the adoption and maintenance of PA. As such, AR is one of the primary variables employed in this laboratory manual.

2.1.3 Performance-Related Mediators

Performance-related exertional mediators can be defined as variables that describe and provide feedback regarding the intensity of an acute exercise bout and the prediction of exercise performance outcomes. Measures of these variables may be provided to the individual by a coach or teammate or may be monitored by the individual using a watch or digital display of an exercise machine. Variables such as time/distance traveled, time/distance remaining, speed/pace or even characteristics of a competitor's exercise performance may affect the RPE response.

2.1.4 Exertional Symptoms

Exertional symptoms, ultimately, are the final outward expression of the internal physiological and psychological processes that are experienced by an individual during PA and exercise. Physiological, psychological and/or performance-related exertional mediators are uniquely integrated such that exertional symptoms are linked to the individual's conscious perceptual report. Exertional symptoms can be divided into two separate classifications: somatic and psychological. The most pronounced of the somatic exertional symptoms and, arguably, all symptoms, is fatigue. Thus, fatigue is a primary term in the definition of perceived exertion. Aches, cramps, muscle and joint pain, feelings of heaviness and dyspnea (breathlessness) are somatic symptoms felt in varying degrees when performing many different exercise modalities. Psychological symptoms that may directly affect the perceptual response include task aversion and low motivation.

2.2 Perceptual-Cognitive Reference Filter

The final step in the formation of the perceptual response is the overall integration of the various signals generated by exertional mediators that pass through the perceptual-cognitive reference filter. It is proposed that this filter is located in the sensory cortex and provides a sensory weighting to past and present PA experiences and environments. These are ultimately expressed as an individual's perceptual style with the weighting often dominated by specific physiological or psychosocial exertional mediators. In this final step, the exertional signals that arise from the physiological responses to an acute exercise performance are mediated by the array of stored information in the perceptual-cognitive reference filter. This mediating process ultimately shapes the intensity of perceived exertion that is rated by the individual using a category metric (Robertson 2001).

2.3 Rating Perceived Exertion

The origin of perceived exertion is rooted in psychophysics. This science studies human sensation by establishing a mathematical relation between physical stimuli and sensory responses (Noble and Robertson 1996). More specifically, psychophysics has been defined as the study of the relation between sensation and stimulus when both are measured as quantities (Marks 1974). Gunnar Borg, a Swedish psychologist, sought to do just that when he pioneered the measurement of perceived exertion and developed the first RPE scale. His initial work in the late 1950s and throughout the 1960s sought to define perceived exertion as it applied to individuals' subjective adaptation to various types of exercise and occupational activities (Borg 1962a, 1962b, 1970, 1971; Borg et al. 1971). Borg introduced his 15-category (i.e. 6–20) RPE scale (Fig. 2.2) in the mid 1960s while on a sabbatical visit to the

6	No exertion at all	
7	Extremely light	
8		
9	Very light	
10		
11	Light	
12		
13	Somewhat hard	
14		
15	Hard	(heavy)
16		
17	Very hard	
18		
19	Extremely hard	
20	Maximal exertion	

Fig 2.2 Borg RPE scale (Borg 1998) © Gunnar Borg 1998

University of Pittsburgh and the Pennsylvania State University. The Borg Scale is used to measure RPE and determine the relation between exertional perceptions and a wide array of physical, physiological and psychosocial factors that are linked to exercise performance. RPE, measured using Borg's scale as well as other, newer category scales such as Robertson's OMNI Scale, is one of the most commonly employed variables assessed in exercise science research.

Borg designed the numerical format of the first perceived exertion scales to align closely with HR responses, which were taken as a good general indicator of physical strain during PA. This physiological response is easily measured and, therefore, often used as a primary variable for exercise intensity prescription. Borg's initial category metric did not yield perceptual responses that met the expected linear relation between HR and RPE as measured using a 21-category scale. The scale included numerical categories that ranged from 0 to 20 with verbal descriptors linked to every odd integer from 3 to 19, such as "Extremely light" at 3 and "Extremely laborious" at 19 (Borg 1962a, 1962b, 1970). Borg then fine-tuned the original scale, shortening it to 15 categories that ranged from 6 to 20 with the goal of predicting exercise HR from RPE responses of a normal, healthy, middle-aged man performing cycle ergometry. This prediction was accomplished by multiplying the RPE response by 10 (e.g., an RPE of $13 \times 10 =$ exercise HR of 130 $b \cdot min^{-1}$) (Borg 1985; Borg and Lindblad 1976). This 6–20 scale, commonly known as the Borg Scale (Fig. 2.2), is used in clinical and health-fitness settings where cycle ergometry is employed worldwide. However, the validity of predicting HR from RPE responses using a simple multiplication factor of 10 was never truly realized due to the great inter-individual variability in HR responses under varying types of exercise, clinical and environmental conditions. This fact notwithstanding, many studies have shown a linear relation between workload, HR and RPE, establishing validity of the Borg (6–20) RPE Scale.

2.4 Perceived Exertion Scales for Children

Prior to 2000, relatively few investigations studied RPE responses of children. Oded Bar-Or pioneered the study of children's perception of effort in a 1977 study involving cycle ergometer exercise where RPE was measured using Borg's 6–20 category metric validated for adults (Bar-Or 1977). However, subsequent research demonstrated that the Borg (6–20) RPE Scale may be unsuitable for children (Lamb and Eston 1997a). Not until 1994 was consideration given to the design of a child-specific RPE scale. Roger Eston and colleagues (Eston et al. 1994; Williams et al. 1994) designed the Children's Effort Rating Table (CERT) to address the semantic limitations of children when they attempted to use RPE scales that were formatted using adult vocabulary. Verbal descriptors for CERT were chosen by children because they were commonly used expressions understood as descriptions of exertion during PA. Ten descriptors were placed along a numerical rating range from 1 to 10. This resulted in a more familiar rating scale format as opposed to the adult oriented 6–20 Borg Scale. However, a follow-on investigation found a nonlinear relation between perceptual and physiological responses. CERT had a diminished sensitivity across the upper HR range during dynamic exercise (Lamb and Eston 1997b; Robertson et al. 2000).

2.5 The OMNI Scale

In response to growing clinical and experimental interest in investigating children's perceptions of effort and in recognition of the potential methodological and semantic limitations of available RPE scales, Robertson and colleagues developed the OMNI picture system for rating effort in children (Robertson 2004; Robertson et al. 2000). For the 0–10 OMNI RPE scale, both verbal and pictorial descriptors were chosen by children to aid in linking exertional symptoms with the perceptual rating. The name OMNI is a contemporary contraction of the word omnibus, meaning "of, relating to, or providing for many things at once" (Merriam-Webster Online 2014). By extension, when used in the context of exertion scaling the word OMNI refers to a category metric having broadly generalizable properties. This was of practical importance because the OMNI scales were designed for use by individuals of varying ages participating in a wide range of PA modalities. The first OMNI scale (Fig. 2.3), developed for cycle ergometer exercise, demonstrated a high level of validity for use by male and female children of mixed race (Robertson et al. 2000). Later, the adult format of the OMNI-Cycle RPE scale (Fig. 2.4) was developed using age appropriate verbal and pictorial descriptors (Robertson 2004; Robertson et al. 2004). The Adult OMNI-Cycle RPE Scale demonstrated high concurrent and construct validity for use by both men and women (Robertson 2004; Robertson et al. 2004). Subsequently, different OMNI Scale formats were developed and

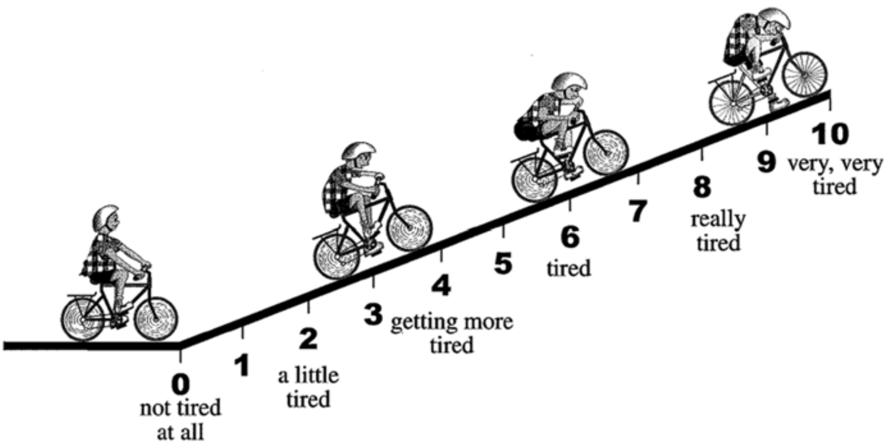

Fig 2.3 Children's OMNI-cycle RPE scale Robertson 2004)

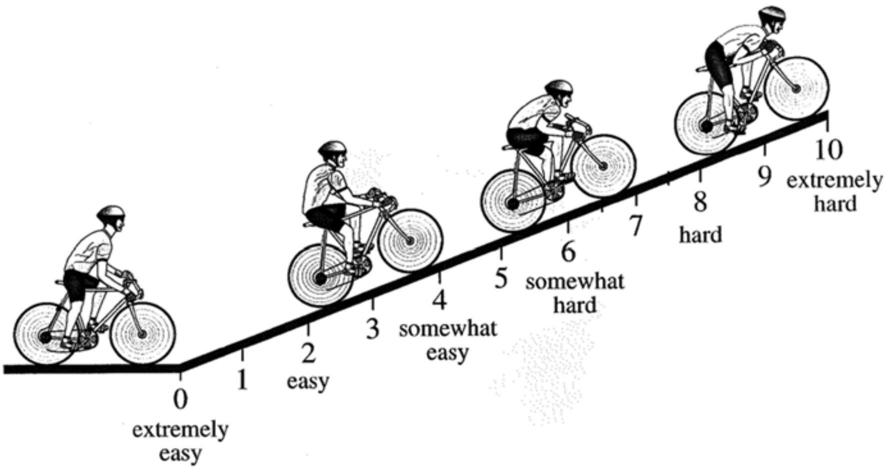

Fig 2.4 Adult OMNI-cycle RPE scale (Robertson 2004)

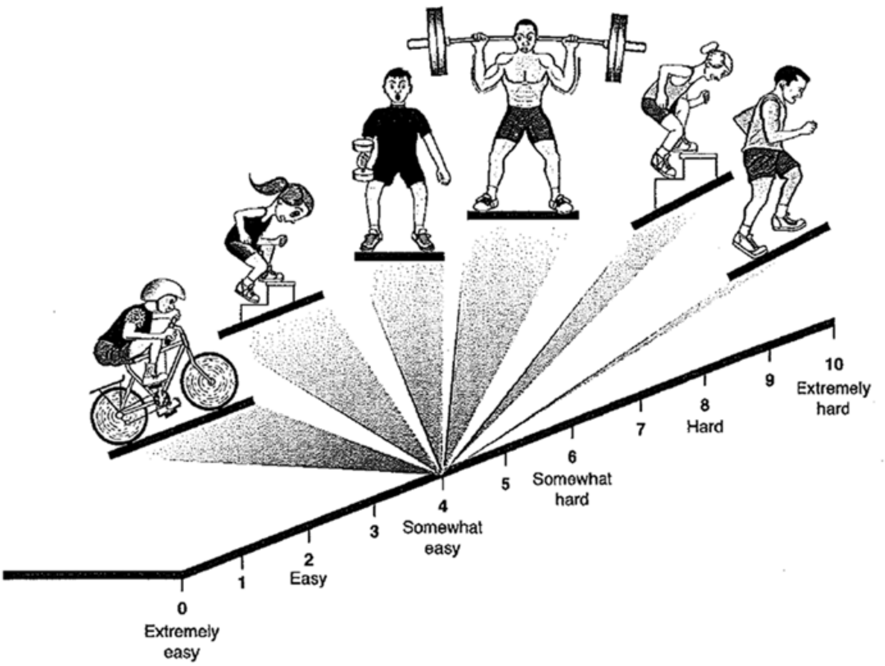

Fig 2.5 Montage of pictorial descriptors for the OMNI RPE scales (Robertson 2004)

validated for use by children and/or adults performing such PA modalities as walking and running (Utter et al. 2002, 2004; Robertson 2004), resistance exercise (Lagally and Robertson 2006; Robertson et al. 2003, 2004, 2005), stepping (Krause et al. 2012; Robertson et al. 2004, 2005), and elliptical ergometry (Mays et al. 2010) (Fig. 2.5; see Appendix A for figures of additional OMNI Scale formats).

2.6 Use of RPE Scales

The field of perceived exertion was originated by Gunnar Borg as he sought a new way to describe adaptations to exercise, initially in an occupational setting and later fitness and sport settings. Borg hypothesized that an individual's perceptual responses to exercise testing could provide information to both quantify and predict physiological and performance adaptations. In addition, RPE is a measurable construct that most individuals can understand and use after proper instructions from an exercise scientist or coach. This fact is largely responsible for the growth of the perceived exertion knowledge base in the published literature and its continued popularity in clinical and sport settings. The uses of RPE presented in this laboratory manual include, but are not limited to, the following: (1) the determination of maximal work capacity during fitness testing, (2) the indication of impending exercise test termination, (3) the prediction of maximal aerobic power or one-repetition maximum from submaximal exercise responses, (4) the identification of physiological responses such as the ventilatory threshold, and subsequent use of these measures to prescribe a "target" RPE for exercise conditioning, (5) exercise intensity self-regulation and monitoring of exercise intensity self-regulation error, and (6) monitoring exercise programs to determine if the exercise intensity is appropriate to achieve an overload training stimulus.

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