A Production Trial of the Omnibus Ratings of Perceived Exertion Scale in Treadmill Exercise

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A research project submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy, Unitec Institute of Technology, 2012

Declaration

Name of candidate: Cheri Quinton

This Research Project entitled “A Production Trial of the Omnibus Ratings of Perceived Exertion Scale in Treadmill Exercise” is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

CANDIDATES DECLARATION I confirm that:

- This Thesis/Dissertation/Research Project represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2011-1237

Candidate Signature: ..... Date: .....

Student number: 1297043

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Contents

List of Figures

List of Tables

Introduction to Thesis

Exercise is an essential component of health and wellbeing as it has the ability to reduce morbidity and improve quality of life. Within the clinical setting, exercise prescription methods typically employ physiological or psychophysical indices of exertion to regulate exercise intensity, to ensure exercise is safe and effective. Additionally, ratings of perceived exertion (RPE) scales provide a method that is easily understandable for both the practitioner and patient, and can be used without disrupting exercise. Prescribing exercise based on RPE is a commonly observed practice and although the reliability of RPE scales is typically excellent, the utility as a prescription tool has not been thoroughly explored.

The purpose of this thesis is to review relevant literature and to determine the applicability of the Omnibus (OMNI) RPE walk/run 0 – 10 category scale, for exercise prescription in healthy adults of different age, sex and fitness during treadmill exercise. The OMNI RPE scale was chosen, as it is an intuitive and linear scale that closely reflects common clinical tools for rating perceptions (e.g. Likert and visual analogue scales).

This thesis has been conducted to meet the requirements of a 90-credit thesis for the Master of Osteopathy (MOst) degree. This thesis is presented in three sections. *Section one* consists of a review of relevant literature and highlights the need for further research into the adult OMNI RPE walk/run scale for exercise

prescription. *Section two* is presented in a manuscript format for the Medicine & Science in Sports & Exercise Journal. *Section three* contains appendices.

Section 1: Literature Review

Introduction.

Exercise is prescribed by many health care professionals, in situations where general health, obesity or mental health are of interest, particularly in disciplines involving musculoskeletal rehabilitation or manual therapy. Historically, ratings of perceived exertion (RPE) scales have yielded excellent correlations with physiological variables and have displayed very positive validity and reliability (Birk & Birk, 1987; Chen, Fan, & Moe, 2002). In turn, RPE scales provide an excellent complimentary method for intensity monitoring and regulation during exercise (Garber et al., 2011). However, the utility of these scales for exercise prescription is less clear. This literature review aims to present and discuss relevant research regarding perceptual regulation for exercise prescription purposes and to highlight the need for future research into the effectiveness of psychophysical scaling methods, with focus on the OMNI RPE walk/run scale in the adult population. The review is presented in three parts. Part one introduces exercise prescription and associated measurement tools; part two reviews RPE scales for psychophysical measurement; and part three discusses the application of RPE for exercise prescription.

Part one: Exercise Prescription and Measures of Intensity

Background to exercise prescription.

The American College of Sport Medicine's (ACSM) position stand highlights the fact that, for the majority of adults, the benefits of exercise clearly outweigh the risks (Garber et al., 2011). Exercise prescription is the mechanism by which exercise is safely and effectively advised, and enables the exercise programme to be tailored to meet the individuals' health and fitness levels/requirements (Dishman, 1994; Noble & Robertson, 1996). Thus, effective exercise prescription addresses cardiorespiratory, flexibility, neuromuscular and strength fitness goals, whilst ensuring the individuals' safety (Garber et al., 2011; Noble & Robertson, 1996).

To evoke favourable physiological change, the exercise prescription principles of intensity, duration, frequency, progression and activity mode must be followed and adjusted accordingly for each participant (Pollock et al., 1998). Within this list, intensity is the most important prescription principle, with the accurate adjustment of intensity level imperative, in order to reach an individuals' cardiorespiratory *target* levels (American College of Sports Medicine, 2014; Birk & Birk, 1987; Burke, 1979; Dishman, 1994; Heyward, 2002; Noble & Robertson, 1996; Robertson, 2001). Typically during a prescribed exercise programme, an important notion is the presumption that an individual will train at a predetermined target exercise intensity, usually quantified in terms of volume of oxygen uptake ($\dot{V}O_2$) or heart rate (HR) (Noble & Robertson, 1996).

Importance of exercise intensity.

Establishing an ideal intensity is essential for an exercise programme to achieve desirable physiological outcomes and prevent the development of adverse effects (Birk & Birk, 1987). When the level of exercise intensity is adequate, oxygen transportation will be sufficiently taxed to a degree that produces safe physiological overload, improving aerobic fitness (Birk & Birk, 1987; Brooks & Fahey, 1984; Robertson, 2001). However, if intensity is consistently too high then diminished returns following effort may result and the risks of musculoskeletal injury and cardiovascular dysfunction increase (Birk & Birk, 1987; Garber et al., 2011). A review of the literature conducted by Burke and Collins (1984) recommended that the key to a successful outcome is to maintain an intensity that allows $\dot{V}O_2$ to fall within 50 to 85% of Maximum $\dot{V}O_2$ ($\dot{V}O_{2max}$) and 65 to 90% of Maximum HR (HR_{max}). More recently, the ACSM exercise intensity guidelines produced similar ideal intensities, recommending that exercise should be conducted within 40 to 85% of $\dot{V}O_{2max}$ reserve ($\dot{V}O_2$ R) for a safe and effective cardiovascular training stimulus within the general population (American College of Sports Medicine, 2006a, 2006b).

Exercise compliance and intensity preference.

Exercise intensity has been considered a major determinate of exercise behaviour (how an individual perceives exertion, their affective response and compliance to exercise) and has historically been of great interest within research (Dishman, 1988, 1994; Ekkekakis, Lind, & Joens-Matre, 2006; King, Blair, Bild, & Dishman, 1992). A review by Dishman (1994) concluded that decreased attraction to exercise and in turn poor exercise compliance has been found to occur when individuals of low-level fitness are prescribed a level of intensity that they perceived as being too effortful.

Likewise, if the prescribed intensity level is too low, individuals may adhere but not comply, exercising above the conventional training zone (60 to 85% of $\dot{V}O_{2max}$) (Dishman, 1994; Pollock et al., 1991; Robertson, 2001; Schafer, 2007). Lastly, Dishman stated that problems in exercise prescription might occur with an individual's inability to accurately self-regulate exercise, whether measurement is via a subjective measurement tool (e.g. RPE) or an objective physiological measurement tool (e.g. HR).

The affective response to exercise (feelings of enjoyment, dissatisfaction, energy and fatigue) has been implicated in short and long term exercise motivation and compliance (Ekkekakis, Parfitt, & Petruzzello, 2011). Dishman, Sallis and Orenstein (1985) and Parfitt, Rose and Burgess (2006) suggest that when exercise 'feels good' and is 'enjoyable', individuals are more likely to continue. Additionally, feelings of enjoyment appear to have a greater effect on motivation, than the knowledge of the health benefits exercise provides (Dishman et al., 1985).

It has been demonstrated that an individual's affective response and compliance to exercise is improved when there is an opportunity to select a 'preferred intensity'. Additionally, greater tolerance to higher intensity workloads has been highlighted when exercise intensity was self-selected rather than prescribed (Dishman, 1987; Ekkekakis, 2009; Ekkekakis et al., 2011; Parfitt et al., 2006). Parfitt et al. (2006) demonstrated that 11 out of their 12 participants preferred to self-select exercise, with their participants stating "it felt better when I had control over what I was doing" and "it allowed me to exercise within my own capabilities and I could extend myself if I wanted to".

Many authors have demonstrated that individuals prefer to exercise at intensities within the conventional training zone (Dishman, 1994; Ekkekakis, 2009; Farrell, Gates, Maksud, & Morgan, 1982; Glass & Chvala, 2001; Murtagh, Boreham, & Murphy, 2002; Pollock et al., 1991; Schafer, 2007). In turn, multiple studies have highlighted that participants chose to exercise between 60 to 80% of $\dot{V}O_{2max}$, with a majority of studies favouring between 60 to 75 %$\dot{V}O_{2max}$ when participants were asked to exercise at their preferred intensity (Dishman, 1994; Farrell et al., 1982; King, Haskell, Taylor, Kraemer, & DeBusk, 1991; Purvis & Cukiton, 1981). It is important to note that the exercise intensities within the aforementioned research are consistent with the ACSM recommendations for safe and effective training (American College of Sports Medicine, 2014; Garber et al., 2011).

Research conducted by King et al. (1991) and Cox, Burke, Gorely, Beilin and Puddey (2003) demonstrated that participants tended to deviate to an apparent 'preferred' intensity level from prescribed levels whilst exercising, when the prescribed intensity was not within the preferred intensity range. Following a one-year randomised trial on sedentary middle-aged adults (160 females; 197 males, 50 to 65 years of age, sedentary and free of cardiovascular disease) King et al. compared the effectiveness of low and high intensity during prescribed treadmill exercise, determining that both intensities demonstrated comparable improvements in the treadmill exercise test performance, however, with no effect on cardiovascular disease risk factors. Furthermore, King et al. highlighted similar initial adherence to prescribed exercise employing RPE, within the low intensity (60 to 70% HR_{max}) and the high intensity (73 to 88% HR_{max}) groups, however both groups regressed to exercising at Borg RPE values correlating to 64 to 76% HR_{max}.

Physiological indices of exertion.

Physiological measures of exertion have empirically been well established as successful tools that objectively measure exercise intensity. Variables commonly employed include blood or muscle lactate, $\dot{V}O_2$, HR, ventilation ($\dot{V}_E$), carbon dioxide production, blood pressure, and respiratory rate (Pandolf, 1983; Robertson et al., 2004; Robertson & Noble, 1997; Schafer, 2007).

Heart rate methodology.

Prescribing exercise that employs HR as a measure of physiological intensity is recommended as it has previously demonstrated to be linearly correlated with $\dot{V}O_2$ consumption and workload production, and is associated with desirable improvements in an individual's cardiorespiratory fitness (Garber et al., 2011; Pollock et al., 1998). The ACSM recommends that a programme created for an individual involves direct measurement (for HR and $\dot{V}O_2$), however if equipment is unobtainable then estimations are acceptable (Garber et al., 2011). Furthermore, the linear relationship between HR and $\dot{V}O_2$ makes it is easy to estimate $\dot{V}O_2$ for a given level of intensity from HR values (Pollock et al., 1998). Using relative HR reserve (HRR) as a prescription target is becoming increasingly popular in comparison to expressing HR as a percentage of maximum HR (%HR_{max}), as the resulting %$\dot{V}O_{2max}$ is more variable when %HR_{max} is employed (Brawner, Keteyian, & Ehrman, 2002; Byrne & Hills, 2002; Garber et al., 2011; Lounana, Campion, Noakes, & Medelli, 2007). For example, $\dot{V}O_2$ can be underestimated by approximately 10% when a %HR_{max} is employed (Noble & Robertson, 1996).

The reliability of HRR and %HR_{max} can be dependant on the method used to determine HR_{max}. With the use of age-predicted HR_{max}, using the traditional HR_{max} equation (HR_{max}= 220-age), a standard deviation of approximately 11 beats•min^{-1} over the true maximum can occur within 30% of the population, even when factors that influence variability (age, sex, training levels and mode of testing) are controlled (Buckworth & Dishman, 2002; Dishman, 1994; Londeree & Moeschberger, 1982; Noble & Robertson, 1996). Regression equations such as the Tanaka equation (HR_{max}= 208 - 0.7•age) for prediction of HR_{max} have been developed to limit the inaccuracy of the commonly used traditional age-predicted HR calculation (220-age) through taking into consideration the effect of age and gender (Garber et al., 2011; Tanaka, Monahan, & Seals, 2001). These equations are thought to be superior to the commonly used age-predicted HR calculation, however further research is required to determine the extent of their application within diverse populations (Garber et al., 2011).

Although the value of HR-based exercise prescription is clear, there are certainly limitations that should be considered. There is strong empirical evidence to demonstrate that exogenous variables such as psychological stresses, hormone levels, temperature, humidity, caffeine and medications can affect exercising HR (Kiviniemi et al., 2010; Noble & Robertson, 1996; Pandolf, 1983; Wisniewski, 2012). Furthermore, Robertson and Noble (1996) noted that as HR is typically recorded via palpation, calculation errors resulting from difficulty in locating and maintaining palpation sites are common, and reliable HR monitoring equipment can be too expensive for every day use.

Psychophysical indices of exertion.

Global model.

An individual's psychophysiological response following an exercise stimulus is complex and relatively unknown, yet many models have attempted to document their interactions. The Fourth Generation Model of Noble and Robertson (1996) has attempted to create a simplistic method for incorporating the physiological, psychological and performance components of perceived exertion, with influential internal and external environmental factors to describe how an individual perceives an exercise stimulus (Noble & Robertson, 1996; Pandolf, 1983; Robertson & Noble, 1997; Schafer, 2007; Wisniewski, 2012).

The global model describes how the physiological responses of ventilation, temperature, pain, catecholamines, glucose, heart rate, oxygen intake, muscular tension and lactic acid serve as initial mediators to exercise perception (Robertson & Noble, 1997). These physiological responses subsequently act to alter the tension producing properties of skeletal muscles. The degree of muscular tension relies on the quantity of central feed-forward commands that arise from the motor cortex (Eston, 2012; Noble, Kraemer, Allen, Plank, & Woodard, 1986; Robertson & Noble, 1997). These central responses to exercise are carried via corollary pathways to the sensory cortex, which are then interpreted as perceptual signals of exertion. Noble et al. (1986) supported by Noble and Robertson (1996) describe how the integration of these signals form the symptoms of heavy breathing, joint pain, increased temperature, perspiration, general fatigue, muscular tension and altered oxygen intake. Lastly, to refine the signals arising from the sensory cortex, the signals are then modulated within a proposed Cognitive Reference Filter to adjust the

individual's response according to their personality and to past or present events (Robertson & Noble, 1997). The physiological changes are then influenced by psychological factors involving an individual's personality, motivation, task aversion, health, culture and previous experiences. The gestalt of an individual's psychophysiological response determines the level of perceived exertion and comprises of subjective differentiated (e.g. chest, legs, arms) or undifferentiated (overall) perceptions (Birk & Birk, 1987; Borg, 1982; Eston, 2012; Robertson & Noble, 1997).

Measuring perceived exertion.

Whilst Robertson and Noble (1997) defined perceived exertion as the amount of effort, strain, discomfort and/or fatigue experienced by an individual during activity, the initial concept of perceived exertion to subjectively measure how strenuous a physical task was arose in the 1950s (Borg, 1998; Borg, 1973; Noble & Robertson, 1996; Robertson & Noble, 1997). The pioneering work conducted by Stevens (1957) and Ekman (1958) on ratio-scaling methods, was the first to incorporate physics and physiology into a scale with a numerical range. This initial work lead Gunnar A. V. Borg to develop the first RPE category scale to quantify an individual's perceived exertion during exercise (Borg, 1973; Eston, 2012; O'Sullivan, 1984). After the initial development of the Borg 6 – 20 RPE category scale, research focused on developing and validating perceptual scaling methods, and in turn the development of many new psychophysical scales ensued (Borg, 1973; Borg, 1982; O'Sullivan, 1984). Focus was also placed on the identification of the physiological and psychological mediators in effort perception for clinical, sporting and educational purposes, with clinical applications usually involving a collective process of exercise

assessment and prescription (Faulkner & Eston, 2008; Noble & Robertson, 1996; Robertson, 2001; Robertson & Noble, 1997).

Prescribing exercise employing perceived exertion.

Exercise prescription employing a RPE scale to subjectively measure exertion is usually conducted following estimation-production or a production only paradigm exercise test, depending on the individual's health status (Robertson, 2001; Robertson & Noble, 1997). For the estimation-production paradigm the estimation component consists of a GXT, which allows physiological exertional markers to be compared against RPE values. Whereas, the production component allows for target RPE values to be produced, following exercise that provides appropriate physiological stimulation (Noble & Robertson, 1996; Robertson, 2001; Robertson & Noble, 1997). The estimation-production paradigm is more suited for individuals who are clinically impaired or requiring cardiorespiratory or orthopaedic rehabilitation (Noble & Robertson, 1996; Robertson, 2001). Robertson (2001) justified this, stating that to be medically safe, yet effective RPE should be compared to clinical events that occur during the estimation component of a paradigm. Furthermore, exercise testing in this manner assists to improve memory recall of the required intensity during future exercise productions (Winter, Jones, Davison, Bromley, & Mercer, 2006). In contrast, during the production-only paradigm participants produce a target intensity that has been identified prior to exercise testing. This method contains no GXT, increasing its methodological efficiency (Robertson, 2001). However, as participants' responses have not been analysed prior it is only recommended in individuals that are clinically healthy, with low medical risks (Robertson, 2001; Robertson & Noble, 1997).

The effect of psychological factors on RPE.

It is important to emphasise the likely effects of psychological conditions (depression) and altered psychological states (anxiety), on physiological and psychological responses during exercise. O'Sullivan (1984) has implicated depression and anxiety in abnormal autonomic nervous system regulation which, in theory, also has the ability to affect the reliability and validity of physiological variables such as HR and blood pressure during exercise. A review into the advances of perceived exertion research conducted by Pandolf (1983) concluded that it appears the degree of RPE accuracy is dictated by the degree of psychopathology. Pandolf's conclusions were drawn from research conducted by Morgan (1973), who highlighted that the individuals who misjudged RPE were neurotic or anxious, with the greatest misjudgements made by an individual who was neurotic, anxious and depressed. The individuals within their study demonstrated that they tended to under-regulate exercise (under exert themselves), especially at moderate intensities. However, the case-series conducted by Morgan is now fairly dated, and fails to clearly outline the diagnostic criteria for participation and participant sample size within their experiments.

More recently, research has demonstrated over-estimations of perceived exertion for exercise workloads in individuals with depression and chronic fatigue syndrome (CFS). Fulcher and White (2000) compared the strength and physiological responses of sedentary adults (n = 30) to those with depression (n = 15) and CFS (n = 66) during a graded walking test (treadmill-based) that terminated at the individuals discretion (participants were recommended to continue to their maximum). Fulcher and White showed that for each stage in testing there were differences in HR (p =

.06), $\dot{V}O_2$ (p = .02) and RPE (Borg 6 – 20 RPE category scale) (p < .005). Furthermore, RPE values were significantly greater for lower oxygen consumptions at each stage of the test for the CFS (p = .004) and depression (p = .01) groups, in comparison to the sedentary controls. The depression group generally expressed less difference for the outcome variables, than the CFS group in comparison to the control group. The production RPE values that were higher than normal (CFS group in comparison to the controls) for workload intensities was reaffirmed by Cook et al. (2003) within their sample of female participants (n = 19, CFS participants and n = 20 healthy controls) during a maximal walking treadmill exercise test.

Part two: Perceived Exertion Scales

Borg 6 – 20 RPE category Scale.

The Borg 6 – 20 RPE scale is the traditional method for regulating exercise intensity during activity (Figure 1a). Borg (1970, 1982, 1998) claims that the scale works on the assumption that HR and $\dot{V}O_2$ increase linearly with RPE, with the scale beginning at a value of 6 and terminating at a value of 20. Theoretically, the RPE value 6 correlates to an average resting HR of 60 beats•min^{-1}, whereas, the RPE value of 20 represents an "absolute maximum", correlating to a HR of 200 beats•min^{-1} (approximately appropriate for a 20-year-old). Following this concept, RPE scales generally have become extremely popular due to their simplicity. However, it has been argued that because of its closed scale approach (definite start and finish, occurring with all ordinal scales), RPE is limited as it renders to condensation of values at the upper end of the scale, increasing the possibility of misrepresentation of physiological workloads (Zamunér et al., 2011).

Validity and reliability of the Borg 6 – 20 RPE category scale.

The Borg RPE scale demonstrated validity early since studies conducted by Borg in the 1960's producing correlations of r = .85 between RPE and HR on a bicycle ergometer during progressive increasing intensities (Borg, 1962; Borg, 1998). These high correlations were presented as an overall correlation value for all intensities over the entire exercise period. Correlations similar to this value have been found in both males and females during the exercise modes of treadmill and cycle, in research conducted by Skinner, Borg and Buskirk (1969), Skinner, Hutsler,

Bergsteinova and Buskirk (1973) and Bryant (1976). Bar-Or, Skinner, Burskirk and Borg (1972) produced moderate to high correlations (r = .77 and .80) between HR and Borg RPE on a cycle ergometer and treadmill. Similarly, the relationship between HR and Borg RPE has been demonstrated by many studies, producing correlation coefficients between r = .80 and .90 during cycle, treadmill and specific arm and leg work during continuous or intermittent exercise, at moderate to hard intensity (Borg & Noble, 1974; Robertson, 1982; Sidney & Shephard, 1977; Skinner et al., 1973).

The CR-10 scale.

Advances in psychophysical category scaling methods have lead to the development of the CR-10 RPE scale, a category scale with ratio properties (Figure 1b) (Borg & Kaijser, 2006; Zamunér et al., 2011). The primary numerical range of the scale is from 0 to 10, however with no fixed endpoint it aims to measure perceived exertion or pain in a manner that represents real life situations (Borg, 2007). This is an important benefit of the scale as it assists to represent the maximum an individual identifies with at a specific point in time, as a current maximum may not represent the absolute maximum of past experiences (Borg, 2007). Additionally, it reduces the limitation of condensation of workload or pain intensities at the endpoint of ordinal scales as addressed by Zamunér et al. (2011). As with all other category-scaling methods the CR-10 RPE scale benefits the user during clinical exercise regulation, as it is relatively low cost in comparison to spiroergometry equipment.

The CR-10 RPE scale has the ability to accurately correlate with the physiological mediators of exertion that increase with intensity in a linear fashion (HR and $\dot{V}O_2$)

(via mathematical power functions) and more accurately with variables increasing in a non-linear fashion (i.e. lactate production and excessive ventilation) (Borg & Kaijser, 2006; Borg, 1980). Whilst the scale is most applicable to differentiated, peripheral effort determinations, it can be employed to estimate undifferentiated RPE as shown by Mihevic (1981) and Zamunér et al. (2011). However the ratio properties remove the simplicity of traditional RPE scales. This lack of simplicity limits the scale's application for exercise prescription, as the unequal increments enhances the difficulty of accurately assigning CR-10 values that correspond to physiologically-indexed exercise exertion, prior to extensive training with a practitioner. In particular, the CR-10 scale is limited as it does not linearly correlate with the most commonly measured central physiological variables of HR and $\dot{V}O_2$ and requires a power equation to determine the relationships before comparisons can be made (Borg & Kaijser, 2006).

Figure 1 Borg 6 – 20 Category and Borg CR-10 Category-Ratio RPE Scales

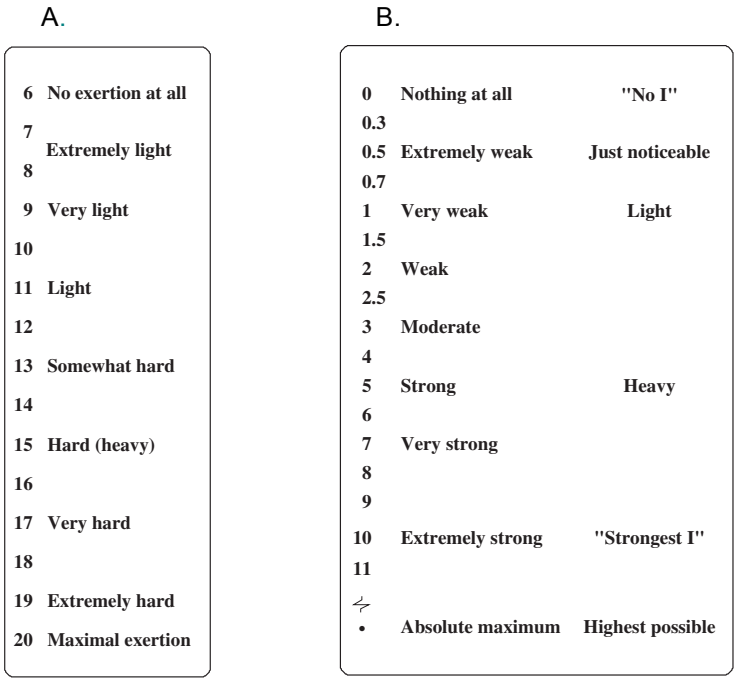

Figure 1. Borg 6 – 20 RPE scale and Borg CR-10 Category-Ratio RPE Scales. Reproduced from "A comparison between three rating scales for perceived exertion and two different work tests" by Borg, E. and Kaijser, L., 2006, *Scand J Med Sci Sports, Exercise and Sports Science Reviews, 16(1),* p. 58. Copyright 2005 © Blackwell Munksgaard.

OMNI picture system.

The cognitive effect on RPE production accuracy and the development of RPE scaling methods.

Initially poor results were demonstrated for the correlation between the Borg 6 – 20 RPE scale and physiological measures of exertion in children, resulting in Nystad, Oseid and Mellbye (1989) incorporating pictorial descriptors into the scale. However, children still had difficulties estimating and producing exercise intensities for

specified RPE values (Nystad et al., 1989). Many authors have stated that for children under the age of 11 the difficultly arose with interpreting and assigning the verbal cues of the Borg 6 – 20 RPE scale, which are not part of their every-day vocabulary, to the numeral values (Eston, 2009; Faulkner & Eston, 2008; Williams, Eston, & Stretch, 1991). Through extensive review on child-specific RPE research, Faulkner and Eston (2008) concluded that the cognitive ability of children (reading ability, exertion experience and RPE scale concept understanding) affected their ability to use the Borg 6 – 20 category scale correctly. A surge in development of child specific psychophysical scales ensued (Children's Effort Rating Table (CERT), Bug and Bag Effort (BABE) scale, Cart and Load Effort Rating (CALER) scale, E-P (Eston-Parfitt) scale and the OMNI RPE scale) (Eston, 2012; Eston, Lamb, Bain, Williams, & Williams, 1994; Eston, Parfitt, Campbell, & Lamb, 2000; Faulkner & Eston, 2008; Parfitt, Shepherd, & Eston, 2007; Williams, Eston, & Furlong, 1994).

OMNI RPE scale background.

The OMNI RPE scale, short for *omnibus*, is applicable to individuals from a wide range of exercise backgrounds (Robertson et al., 2004) (Figure 2). Initially Robert, J. Robertson proposed the OMNI RPE scale, specifically for use for children and adolescents, but because of its simplicity and effectiveness within children it is now one of the most recent tools for measuring perceived exertion within adults (Robertson et al., 2004; Robertson et al., 2000).

The OMNI RPE category scale was developed similarly to the Borg 6 – 20 RPE scale, with numerical and verbal cues to indicate an increase in perceived exertion. Although, as stated by Robertson et al. (2004) and Schafer (2007), the OMNI RPE

scale of perceived exertion has better clinical applicability, with a favourable narrow 0 – 10 numerical range similar to other ten-point scales used commonly within other areas of clinical practice and daily living. This format makes it easily understandable, for patients and practitioners alike. The pictorial anchors of the OMNI RPE scale are a unique quality of the scale, to visually display a gradual increase in exercise intensity (Robertson et al., 2004). The verbal and pictorial cues differ between the child and the adult versions to match the cognitive levels of the individual using the scale (Figure 3). Furthermore, the pictures are interchangeable to fit the mode of exercise and assist in the memory recall of the intensity required for each level of perceived exertion (Robertson et al., 2004).

Figure 2 The adult version of the OMNI walk-run RPE scale

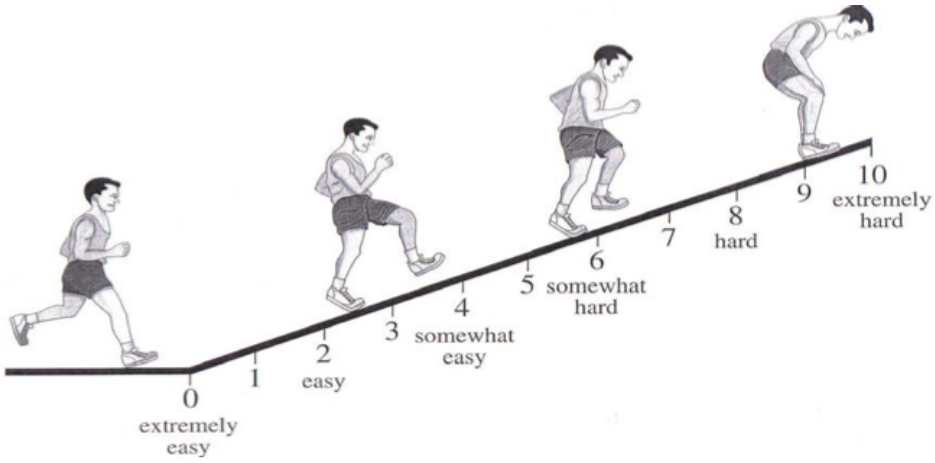

Figure 2. OMNI-walk/run scale of perceived exertion for adults. From "Validation of the adult OMNI scale of perceived exertion for walking/running exercise," by Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McCanulty, S. R., & Nieman, D. C., 2004, *Med Sci Sports Exerc, 36,*(10), p. 1777. Copyright 2004 by the American College of Sports Medicine.

Figure 3 The verbal cues for the adult and child version of the OMNI RPE scale

	0	2	4	6	8	10
Adult	Extremely easy	Easy	Somewhat easy	Somewhat hard	Hard	Extremely hard
Child	Not tired at all	A little tired	Getting more tired	Tired	Really tired	Very, very tired

Figure 3. Differing verbal cues for OMNI RPE scale. From *perceived exertion for practitioners: Rating effort with the OMNI picture system* (p. 12), Robertson, R. J., 2004, United States of America: Human kinetics.

Validity of the OMNI RPE walk/run scale.

Since the development of the OMNI RPE scale there has been an abundance of research over a wide range of exercise modes in participants of all ages, fitness level and of different health statuses (healthy, obese, metabolic syndrome). However, there are still a limited number of investigations surrounding the adult OMNI RPE walk/run scale, with no cross-modal scale validation for treadmill exercise (Utter et al., 2004).

Validation of the children's OMNI RPE walk/run scale.

Initial validation research by Utter et al. (2002) for the OMNI RPE walk/run scale demonstrated partial concurrent validity over a wide range of exercise intensities for walking and running within children. Utter et al. examined 63 healthy boys and girls aged between 6 and 13 years of age, with a perceptual estimation paradigm using a maximal graded exercise test (GXT). Throughout the test of several measures of respiration and oxygen consumption, HR and RPE were recorded every minute. Significant correlations ($p < .001$) between RPE and the respiratory and oxygen physiological variables were demonstrated, with HR and $\dot{V}O_2$ producing the largest correlations (HR: $r = .26$ to $.52$, $p < .01$; $\dot{V}O_2$: $r = .41$ to $.60$, $p < .001$). Utter et al. (2002) concluded that there was no significant effect of age on RPE correlations with physiological variables. However, correlations between RPE and the physiological markers of exertion during treadmill exercise were lower than earlier research by Robertson et al. (2000) during cycle exercise ($r = .85$ to $.94$; $p < .01$). The lower correlations within Utter's et al. research, in comparison to Robertson's et al. could have resulted from the differences in participant's ages (at an age where there is significant cognitive development), paradigms employed or the differences in

exercise mode between studies. Furthermore, correlation values could have been affected by the transition from walking to running in Utter's et al. research, or because the scale misled participants, by depicting only uphill running when exercise including walking and running (Utter et al., 2002).

Further strengthening concurrent validity of the Child's OMNI walk/run scale, Pfeiffer, Womack, Reeves and Malina (2002) followed on from Utter et al. (2002) producing significantly high validity and reliability values in adolescent girls. Pfeiffer et al. compared the reliability and validity of the OMNI walk/run and Borg RPE scales in 57 adolescent girls aged between 13 and 18 years of age, during two exercise tests conducted one week apart. The girls were randomly assigned to one of three submaximal conditions - walking (3.2 $km \bullet h^{-1}$, 0% grade), walking uphill (4.8$km \bullet hr^{-1}$, 5.0% grade) or jogging (7.2 $km \bullet hr^{-1}$, 0% grade) along with the assignment of either the Borg 6 – 20 RPE scale or OMNI walk/run RPE scale, creating six different experimental conditions. During the first test participants produced the randomly assigned intensity for the first 6 minutes, verbalising an RPE value within the last 30 seconds. Then the girls completed 2 to 5 minutes of the other submaximal intensities. During the second test the girls repeated the 6-minute submaximal randomly assigned intensity, producing an RPE value, and then continued on to volitional exhaustion to determine $\dot{V}O_{2max}$.

The results from Pferiffer et al. (2002) demonstrated greater validity for the OMNI RPE scale, as $\%HR_{max}$ and $\%\dot{V}O_{2max}$ correlations were stronger (r = .86 and .89), compared with the Borg RPE scale (r = .66 and .70). Little differences were highlighted between the two tests, conducted one week apart for the OMNI RPE

scale (*r* = .95) compared to the Borg 6-20 RPE scale (*r* = .78). Same-day reliability was again higher for the OMNI RPE scale (*r* = .91) compared with the Borg RPE scale (*r* = .64). The OMNI RPE scale demonstrated greater validity and reliability than the Borg RPE scale in this population of adolescent girls, however it is not known if these results are generalisable to boys and adults.

Roemmich et al. (2006) illustrated similarly strong correlations to Pfeiffer et al. (2002) for the OMNI RPE scale with HR and $\dot{V}O_2$. Roemmich et al. investigated the validity of the pictorial CERT and OMNI walk/run RPE scales on a young mixed gender sample (boys, n = 26, aged 11.2 ± 1.6; girls n = 25, aged 11.1 ± 1.4). An estimation paradigm was employed to complete an exertion treadmill test, with five incremental stages to measure undifferentiated RPE values. Correlation values for the PCERT and OMNI scales with physiological variables were high (HR, *r* = .89 and .92, *p* < .001, and with $\dot{V}O_2$, *r* = .90 and .92 *p* < .01). There were no significant differences for RPE values with HR or $\dot{V}O_2$ between sexes (*p* = .32).

Validity of the adult OMNI RPE walk/run scale.

Compared with the children's OMNI scale a smaller quantity of research has been conducted to validate the adult OMNI RPE walk/run scale. Utter et al. (2004) conducted the initial OMNI RPE walk/run research, investigating 67 young healthy adults (males, *n* = 33; females, *n* = 34) aged between 18 and 36 years old, through a perceptual estimation paradigm utilising the Bruce protocol (maximal GXT). During the test participants provided their undifferentiated RPE from the Borg 6 – 20 RPE and OMNI RPE scales, in counterbalanced order. Additionally, physiological variables including HR and $\%\dot{V}O_{2max}$ were measured, to serve as criterion variables

for concurrent validity. Results highlighted concurrent validity for the OMNI RPE scale, with criterion measures displaying a positive linear function with the OMNI RPE values (r = .67 to .88, p < .05). These moderately strong correlations have concurred with other adult OMNI-cycle investigations (Robertson, 2004; Utter, Kang, Nieman, Dumke & McAnulty 2006). Furthermore construct validity was determined with comparison of OMNI and Borg RPE values, which demonstrated a positive-linear relationship between the two RPE scales (r = .96, p < .01). These results are consistent with a previous adult OMNI RPE cycle scale investigation conducted by Robertson et al. (2004), who produced correlation coefficients ranging from r = .92 to .97 for differentiated and undifferentiated RPE of the OMNI RPE cycle scale with the Borg 6 – 20 RPE scale, respectively.

The validity of the OMNI RPE cycle scale has been demonstrated in elderly adults through a study conducted by Guidetti et al. (2011), however no research employing the walk/run version was found within the current literature search. Through their research Guidetti et al. established concurrent and construct validity in 76 elderly adults (males n = 34, aged 69 ± 5.6; females n = 42, aged 68.6 ± 5.9) that was similar to Utter's et al. (2004) research on the walk/run scale in young healthy adults. The OMNI RPE cycle scale demonstrated positive linear relationship with the Borg 6 – 20 RPE scale (p < .01) in males (r = .97) and females (r = .96) and with all physiological measures (r = .81 to .92, p < .05). The significant relationships showed by Guidetti's et al. study indicates the possible utility of the scale in elderly adults. However as research is limited to only one study it increases the requirements for future research into the OMNI RPE scale over a broader age range in healthy individuals, for all exercise modes.

Wisniewski (2012) investigated validity of the OMNI RPE walk/run scale in overweight and obese adults. Sixty adults (males, *n* = 22 aged 37 ± 9.7; females, *n* = 38 aged 34 ± 7.9) completed a single estimation trial, whereby a submaximal GXT to 85% of age-predicted HR_{max} (APMHR) was achieved. Throughout the test $\dot{V}O_2$ was measured every 20 seconds, HR immediately after termination of the GXT and the Borg and OMNI RPE values in the last 15 seconds of each minute, in counterbalanced order. Wisniewski (2012) determined concurrent validity via regression of HR and $\dot{V}O_2$ against OMNI RPE responses from every 2 minutes. The OMNI RPE demonstrated a very strong relationship with HR (r = .86, p < .001) and $\dot{V}O_2$ (r = .73, p < .001) at 50%, 70% and 85% APMHR. Construct validity was determined by regressing OMNI and Borg RPE responses against each other, highlighting a nearly perfect relationship (r = .963, p < .001). Wisniewski (2012) reported similar findings to previous authors who had conducted construct and concurrent validity of the OMNI RPE walk/run scale in healthy individuals and those with metabolic syndrome (Irving et al., 2006; Utter et al., 2004).

Irving et al. (2006) determined the applicability of the OMNI RPE walk/run and Borg 6 – 20 RPE scales through measuring blood lactate concentration response in individuals with metabolic syndrome. Irving et al. investigated 36 participants with abdominal obesity during an estimation paradigm, continuous treadmill test. RPE were measured in counterbalanced order at 2 minutes, 15 seconds and 2 minutes, 45 seconds of each 3-minute stage until volitional exhaustion was achieved. Concurrent validity was determined with very large correlations between RPE and exercise intensity with lactate responses (Borg and OMNI RPE: r = .82, p < .01). Construct validity was determined by correlation values of .82 to .93 (p < .01)

between the Borg and OMNI RPE scales at velocities associated with 2.5, 4.0 and peak blood lactate concentration. In turn, Irving et al. (2006) demonstrated that the OMNI RPE could be a beneficial tool in estimating blood lactate responses to exercise, however, future research is required to further develop the relationship between lactate and the OMNI RPE scale.

Part three: RPE-based Exercise Prescription

RPE and exercise prescription.

Ekkekakis et al. (2006) proposed a paradigm shift in exercise prescription methods, from the use of physiological to psychological indices. This paradigm shift is partly because RPE is a simple and easily understood method, providing a measurement tool that does not require the use of expensive equipment and does not interrupt exercise (Dishman, 1994). Johnson and Phipps (2006) demonstrated that, even without knowledge of RPE, the majority of women (100 female participants, 22.3 ± 0.44 years of age, that had been exercising for at least three months prior to the study) within their research, preferred and employed perceptually based exercise regulation instead of HR. Johnson and Phipps' results demonstrated that only 7% used HR alone in comparison to 88% of women who used a form of effort perception to estimate exercise intensity, whilst 7% of the studied population used a combination of HR and RPE. Furthermore, 55% of participants had some knowledge of HR_{max} in comparison to only 16% who had any knowledge of RPE. Johnson and Phipps proposed that these outcomes were possibly a result of individuals becoming more familiar with exercise over time, and their desired level of intensity, therefore changing their method of regulation from the HR method to a perceptual method of regulation.

Although Wisnieski (2012) demonstrated results similar to those reported by Johnson and Phipps (2006), with 88.2% of participants reporting that they regulated exercise using perceptual methods, their participants stated that they would change to the HR method of regulation for future self-regulated exercise. These results

differed from the findings of Johnson and Phipps, who identified perceptual regulation as the preferred method for future use. Furthermore, the findings from the research conducted by Johnson and Phipps imply that future prescription employing a form of perceptual regulation could improve long-term exercise adherence. No reason could be found to explain these differences between Wisnieski and Johnson and Phipps research, justifying the need for future research.

The popularity of perceived exertion for exercise regulation reported by Johnson and Phipps (2006) and Wisnieski (2012) demonstrates the practical utility RPE could have in future prescription of exercise. Ekkekakis (2009) discussed that in the absence of validated RPE scales, similar to the methods employed by Johnson and Phipps and Wisnieski's participants, perception-based self-regulation of exercise intensity may improve the flexibility of exercise production and in turn, improve exercise adherence. Additionally, as previously outlined within this review, participants tend to exercise at a "preferred intensity" similar to the standards outlined by the ACSM for safe and effective exercise (American College of Sports Medicine, 2006a; Garber et al., 2011). Thus, the necessity of exercise to be prescribed within the traditional confines of the ACSM guidelines for exercise prescription could be arguable. However, this research does not show that exercise will always occur within this range for all individuals and it limits the ability to quantify exercise intensity, when monitoring is required. Furthermore, it decreases the ability to alter exercise intensity in individuals that require exercise to be within a very specific range or outside of the general ACSM recommendations (i.e. athletes, who require very specific and greater exercise intensities). Subsequently, to determine the utility of regulating exercise based on methods of perceived exertion, further

exploration is required to firmly establish the compliance and precision when employing RPE, to ensure danger is not imposed onto individuals by exercising outside of the recommended intensity range.

Accuracy of exercise intensity prediction using RPE.

Attempts have been made to determine the precision of RPE during exercise production over a wide range of exercise intensities. In turn, extensive reviews into RPE research from the past 50 years have been conducted, establishing that RPE can rival HR for the prediction of $\dot{V}O_{2max}$, with $\dot{V}O_{2max}$ predictions better than or equal to HR (Faulkner & Eston, 2007, 2008; Morgan & Borg, 1976). Furthermore, if RPE is employed in conjunction with HR then reliability of intensity production has been shown to increase, in comparison to either being employed separately (Dishman, 1994; Morgan & Borg, 1976; Pollock, Jackson, & Foster, 1986). Morgan and Borg (1976) demonstrated this ability of RPE prediction of $\dot{V}O_{2max}$ to rival HR, producing correlations for RPE (multiple r = .65) and for HR (multiple r = .62). In addition, Morgan and Borg demonstrated that if RPE and HR were used in conjunction, then the RPE and HR correlation increased to r = .73. More recently, the ASCM position stand highlights that there is still a degree of doubt that RPE measurement is effective enough to replace HR regulation during exercise (Garber et al., 2011). In turn, it is still recommended that either the Borg 6 – 20 RPE scale or the OMNI RPE scale should be employed in conjunction with HR, but not as a primary measurement tool during exercise regulation (American College of Sports Medicine, 2006a; Garber et al., 2011; Wisniewski, 2012).

Inconsistencies are present within the current literature for the exercise intensity that most accurately correlates RPE with physiological variables. Past research employing the Borg 6 – 20 RPE scale has determined excellent validity of RPE measurement at both 50% and 70% $\dot{V}O_{2max}$ for cycle ergometer exercise (Borg, 1973; Dunbar, Robertson, Baun, & Blandin, 1992; Lollgen, Ulmer, Cross, Wilbert, & Niedling, 1975). Recent research conducted by Schafer (2007) employing the OMNI RPE walk/run scale has also produced treadmill results demonstrating validity at both 50% and 70% $\dot{V}O_2R$. However, these studies have contradicted other research that has shown greater accuracy at either low or high workload intensities.

Ceci and Hassmen (1991) produced greater accuracy at lower exercise intensities during indoor and outdoor production trials in 11 male participants (33 to 65 years of age) when producing estimated workload intensities for the Borg RPE values 11 (two trials at 3 minutes in duration), 13 (11 minutes) and 15 (5 minutes). Each trial was conducted on the same day, in a randomised sequence order. Ceci and Hassmen demonstrated high retest reliability (alpha > .9) for HR and blood lactate concentrations between the two RPE 11 trials and significant differences for HR, blood lactate concentrations and velocities between all RPE intensities.
Supporting the results of Ceci and Hassmen, Dunbar et al. (1992) established acceptable validity of RPE measurement (Borg 6 – 20 RPE scale) during treadmill exercise at the low intensity of 50% $\dot{V}O_{2max}$, but not at 70% $\dot{V}O_{2max}$. Dunbar et al. examined participants' abilities to regulate treadmill and cycle exercise (inter and intra-modularly) at 50% and 70% $\dot{V}O_{2max}$ in 17 men, aged 17 to 35 years old using the Borg 6 – 20 RPE scale. Utilising the estimation-production paradigm for each individual, RPE values were determined for each %$\dot{V}O_{2max}$ from the estimation trials.

The exercise intensities equating to the RPE values were then produced in the production trials. Dunbar et al. established validity through comparing HR and $\dot{V}O_2$ between trials. On average, Dunbar et al. demonstrated less than 2% difference at 50% and 70% between the target $\dot{V}O_{2max}$ and the $\dot{V}O_{2max}$ produced, when participants were asked to reproduce the corresponding RPE values. The importance of intensity production accuracy increases as the intensity of exercise increases, whereby the adverse effects of exercising are more likely (for example, acute cardiovascular event) (Garber et al., 2011). As accuracy has decreased between RPE and physiological variables within the aforementioned studies it highlights potential danger, with increased risk of exercise exceeding the recommended intensity ranges.

Conflicting research by Smutok, Skrinar & Pandolf (1980) displayed better accuracy between RPE and HR correlations at higher intensities, whilst investigating the ability of 10 'normal' men to self-regulate treadmill exercise intensity. Participants completed three trials, whereby the first required participants to report RPE values for the treadmill speeds of 4.7, 6.5, 9.7, 11.3 and 12.9km•hr^{-1}. Trials two and three required participants to reproduce exercise intensities for the RPE values given at each treadmill speed during trial one. The reliability of HR was demonstrated during running ($p < .05$), but not walking ($p > .05$). Smutok et al. concluded that when HR was less than 150 beats•min^{-1}, there was a high rate of error. Moreover, Eston, Davies and Williams (1987) observed higher accuracy of the Borg 6 – 20 RPE scale in young healthy adults during treadmill exercise for values between RPE 13 and 17, producing better accuracy at moderate to high exercise intensities in comparison to the lower intensities. Additional research by Horstman, Morgan, Cymerman and

Stokes (1979) and Bayles et al. (1990) demonstrated similar conclusions to Smutok et al., indicating greater reliability of RPE at higher levels of perceived exertion. HR is known to fluctuate significantly between the exercise modes of walking and running, therefore as the transition period between the two is likely to occur at lower exercise intensities this could account for the inaccuracy (workload variability between participants) displayed within the research conducted by Smutok et al. (1980), Eston et al. (1987) and Bayles et al. (1990) at lower intensities (Dunbar et al., 1992; Noble et al., 1973). However, as this trend is not always apparent it indicates the influence of other variables, such as the population under investigation (age, gender, fitness level), instructions given prior to exercise testing and the exercise protocols employed by researchers. Furthermore, Dunbar et al. (1992) have described the wide variation in research protocols as being an inherent limitation of research as the treadmill speed and grade can influence sensory input during the conduction of exercise.

Intensity discrimination with RPE.

Regulation of exercise intensity is dependent on an individual's ability to discriminate between intensities required for a RPE value. Research conducted by Robertson et al. (2002) on children and Weiser, Wojciechowicz, Funck, and Robertson (2007) on adults, determined that participants could discriminate between exercise intensities when using the OMNI RPE cycle scale and Borg 6 – 20 RPE scale, respectively. Robertson et al. (2002) demonstrated this in 36 children aged 8 to 12 years old with an estimation-production paradigm during cycle exercise. The authors concluded that participants could differentiate between RPE 2 and RPE 6 on the child's OMNI

RPE cycle scale and that gender and order sequence did not affect the children's abilities to reproduce RPE intensities correctly ($p < .01$). Likewise, Weiser et al. (2007) concluded that adult participants in a cardiac rehabilitation programme could discriminate between the Borg RPE values of 11 and 13 during a cycle based, estimation-production paradigm. A limitation of these evaluations is that they have generally been conducted at moderate intensities, making if difficult to generalise to intensities outside of this range.

Exercise prescription using the OMNI RPE walk/run scale.

OMNI RPE prescription in children.

Groslambert, Monner, Grange and Rouillon (2005) conducted a treadmill based estimation-production paradigm to determine the accuracy of exercise self-regulation in 32 young children (males, n =16 and females, n =16; aged 5 to 7 years). Using the child's version OMNI RPE walk/run scale, participants completed the estimation trial in a gymnasium-based, 20 m shuttle run test. During this trial, mean HR values were determined within the last 30 seconds of each stage, with OMNI RPE recorded at the end of the stage. Participants then produced three exercise intensities (equal to RPE 2, 6 and 10) of short duration during the outdoor production trial, in a randomly assigned order. The estimation-production trials were conducted five days apart.

Groslambert et al. (2005) concluded that participants had the ability to maintain a similar physiological workload (HR) for RPE values between trials ($p < .05$), which increased along with each RPE increment (RPE 2 to 6 and RPE 6 to 10, $p < .05$). Furthermore, the variability of HR averages was extremely low within and between trials, with a slight variability increase (not to a significant level) at each RPE

increment (4.1 to 8.3 beat•min^{-1}). Participant sex (girl or boy) did not have an effect on the results. Of importance are the significant correlations that were displayed for RPE and HR within the young population, and which were maintained within indoor and outdoor environments. The age and environment where exercise is conducted is known to influence an individual's ability to accurately regulate exercise, in turn these results demonstrate the successfulness of the OMNI RPE scale in regulation of exercise intensity within this population (Robertson & Noble, 1997).

OMNI RPE prescription in adults.

Employing the Adult OMNI RPE walk/run scale, Schafer (2007) investigated the effects of intensity and order production on the ability of adults to regulate treadmill exercise with perceived exertion. To complete the estimation-production paradigm, 31 recreationally active college students (males, *n* = 16; females, *n* = 15), aged 18 to 35 years old were recruited to conduct a 20-minute intermittent treadmill exercise task. The Bruce GXT protocol was employed for the estimation trial to allow participants to exert maximal effort. Throughout, $\dot{V}O_2$, $\dot{V}_E$, and RER were recorded in 15-second intervals, with HR measured every minute. During the estimation trial, RPE values matching 50% and 70% of their $\dot{V}O_2$ reserve ($\dot{V}O_2R$) were determined and then reproduced during the production trial 48 to 72 hours later. From here, participants were assigned to either counterbalance group one (70%, 50%, 70%, 50%) or counterbalance group two (50%, 70%, 50%, 70%), where intensities were produced in 5-minute intervals.

Schafer (2007) concluded that participants could regulate exercise intensity when ascending from a low to high intensity. However, if exercise descended from a high

to low intensity, then regulation became more difficult. Within the study, participants who exercised in a descending order, produced significantly greater HR (165.7 ± 19.9 beats•min^{-1}) and $\dot{V}O_2$ (32.5 ± 9.8 ml• kg•min^{-1}) for 50% $\dot{V}O_2$ R during the production trial in comparison to the estimation trial (HR: 139.3 ± 15.3 beats•min^{-1} and $\dot{V}O_2$: 25.9 ± 4.0 ml•kg•min^{-1}) ($p < .001$). Furthermore for the descending group, at 70% $\dot{V}O_2$ R, average HR was significantly greater during the production trial (176.8 ± 17.8 beats•min^{-1}) in comparison to the estimation trial (163.1 ± 13.3 beats•min^{-1}) ($p < .05$), whereas $\dot{V}O_2$ was not significantly different ($p > .05$). In contrast, with conduction of exercise in an ascending order there were no significant differences between the production and estimation trials at 50% $\dot{V}O_2$ R in HR ≈ 136 ± 16 beats•min^{-1} or $\dot{V}O_2$ ≈ 25 ± 6 ml•kg•min^{-1} and at 70% $\dot{V}O_2$ R in HR ≈ 162 ± 15 beats•min^{-1} (results for $\dot{V}O_2$ were not supplied at 70% $\dot{V}O_2$ R) ($p > .05$).

The large increase in HR and $\dot{V}O_2$ variability within Schafer's (2007) results demonstrates significant inaccuracy of intensity production in a descending order, in turn discrediting the prescription of exercise in this order. Furthermore, the research would have been complemented by recording the range of RPE values initially chosen for 50% and 70% $\dot{V}O_2$ R to determine if there was any correlation between participants. Schafer's results are supported by the research from Weiser et al. (2007) who concluded that participants could reliably predict RPE at 50% and 70% of $\dot{V}O_2$R on a cycle ergometer with ascending but not descending intensities.

Despite Utter, Robertson, Nieman, and Kang (2002) highlighting that future research should be conducted to determine the extent of inter-individual variability for the OMNI RPE walk/run scale, little focus has been placed on the identification of

physiological workload variability for given OMNI RPE values between individuals. Research conducted by Bolgar, Baker, Goss, Nagle and Robertson (2010) presented the variability of overall RPE (combined perceptual signals arising from RPE chest and legs) while performing cycle workloads corresponding to 40%, 60% and 80% $\dot{V}O_{2max}$, in 41 young (18 to 25 years) recreationally active and trained females. Within the last 40 to 60 seconds of each minute, differentiated (RPE-chest and RPE-legs) and undifferentiated RPE (RPE-overall) values were recorded, whilst HR was recorded in the last 15 seconds of each minute and $\dot{V}O_2$ every 15 seconds. The authors' results showed considerable variability in the reported RPE between participants for each $\%VO_{2max.}$ The results from the study of Bolgar et al. reveal that for recreationally active participants at 40% $\dot{V}O_{2max}$ participants reported mean (SD) OMNI-RPE corresponding to 1.59 (1.41), at 60% $\dot{V}O_{2max}$ 4.75 (1.68) and at 80% $\dot{V}O_{2max}$ 7.38 (2.06). For the aerobically trained, the reported RPE values demonstrated slightly less variability, whereby at 40% $\dot{V}O_{2max}$ participants reported OMNI-RPE corresponding to 1.53 (1.20), at 60% $\dot{V}O_{2max}$ 4.34 (1.42) and at 80% $\dot{V}O_{2max}$ 7.33(1.37).

In contrast, the findings reported by Bolgar et al. (2010) opposes research conducted by Groslambert et al. (2005) on children, which demonstrated low HR variability (mean [SD]) between participants during their production trial of RPE 2 (125.3 [4] beats•min^{-1}), 6 (166.2 [6] beats•min^{-1}) and 10 (203.1 [8] beats•min^{-1}). While these studies provide some initial insight to the variability between participants for RPE, the conflicting results between studied cohorts indicates that further research is required to ascertain the extent of variability between individuals of different age, gender, fitness level, health status and during a range of exercise modes. It is plausible that

RPE prescription is appropriate for some demographics but not others, however there is insufficient evidence to support recommendations in this regard.

Conclusion.

Considerable evidence establishes that RPE can be a successful measurement tool for regulating exercise prescription at multiple intensities and, to date, the majority of research has focused on the effectiveness of the 'gold standard' Borg 6 – 20 RPE scale. Research conducted into the OMNI RPE scale has highlighted its initial success within the adult population. A majority of this research has focused on determining OMNI-RPE validity in relation to physiological parameters, reliability, and the effect of intensity on RPE accuracy.

Uncertainty remains in three main areas, for which data is sparse, confirming the necessity for further research into the adult OMNI RPE scale and its role in exercise prescription. Firstly, more research is required to determine if the scale can be safely used as a primary regulator for a range of exercise intensities. This need is highlighted by the continued recommendation by the ASCM that, for exercise prescription, RPE should only be used in conjunction with an objective measurement tool such as HR (Garber et al., 2011). Secondly, there is a gap in the current literature as to the variability of physiological workload based on prescribed RPE values, during exercise. Thirdly, the effects of age, sex, fitness level and exercise mode on this variability during regulated treadmill exercise are still unclear. The study which follows aims to address these areas.

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Section 2: Manuscript

Note: This manuscript has been formatted according to author guidelines for the Medicine & Science in Sports & Exercise Journal (Appendix J). However, for examination purposes, graphs, tables and references to the appendices have been included inline, to improve readability.

Title page

Title: Prescribing Exercise using the Omnibus Ratings of Perceived Exertion Scale

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Abstract

Purpose: To establish variability for measures of absolute and relative intensity during treadmill exercise produced for each of three prescribed ratings of perceived exertion (RPE_P), and differences among RPE_P conditions. Secondarily, to evaluate how age, sex, fitness level and exercise mode affect produced intensities and reported ratings of perceived exertion (RPE_R). **Methods:** Healthy adults (n = 40; 18 – 58 years) exercised for three bouts of 5-min bouts at RPE_P 5, 7 and 8 (OMNI RPE walk/run scale), in randomised, counterbalanced sequence. A submaximal graded exercise test followed 24 h to one week later to estimate maximal oxygen uptake. **Results:** A wide range of relative heart-rates were reported, where the $\pm$1 SD range spanned from 66 – 89% maximum heart-rate (HR_{max}) for RPE_P of 5, 76 – 97% for RPE_P 7, and 80 – 100% for RPE_P 8. An effect of intensity was demonstrated for all outcome measures, $\%HR_{max}$, treadmill speed and RPE_R, ($P < 0.001$), with differences between each RPE_P level ($P < 0.05$). At RPE_P 5 males reported higher RPE_R values than females ($P < 0.05$), and age was inversely related to $\%HR_{max}$ and RPE_R (r = -0.5, $P < 0.01$). Participants' choices to walk or run (mode) for each RPE_P demonstrated association with $\%HR_{max}$ at all RPE_P values ($P < 0.05 – 0.001$). Regression analysis determined that mode accounted for the majority of variance demonstrated for $\%HR_{max}$, explaining 29 to 37% of its variability at different RPE_P levels. **Conclusion:** Participants demonstrated the ability to produce relative and absolute workloads that increased with each RPE_P increment, however there was large variability of $\%HR_{max}$ with the current sample. This indicates that perceptual-based prescription has limitations and may produce variable results.

Key Words: treadmill test, physical exertion, psychophysical production, exercise regulation

Introduction

Paragraph Number 1 Exercise is an essential component of daily life, as it has the ability to reduce mortality and improve overall quality of life (23). In turn, the facilitation of successful lifelong exercise habits is imperative, particularly given the rising levels of inactivity and related disease (58). Exercise prescription methods can be employed within the clinical environment to assist in making exercise participation as safe as possible, and effective in facilitating cardiorespiratory and strength fitness goals (17, 23, 32). The exercise prescription principles of intensity, duration, frequency, progression and activity mode are addressed and adapted for each individual, with exercise conducted within evidence-based guidelines, such as those from the American College of Sports Medicine (ACSM) (1, 36).

Paragraph Number 2 Within the clinical environment, exercise intensity is typically monitored by physiological variables such as heart rate (HR) or volumetric rate of oxygen uptake ($\dot{V}O_2$), to provide an objective measurement of an individual's physiological response to exercise (23). However, it has been well-established that physiological measurement via HR can be impractical, as the accuracy of HR measurement is susceptible to the effect of disorders such as anxiety, medications (e.g. beta blockers), abnormal hormone levels, temperature, humidity and caffeine (16, 22, 28, 31-33, 34, 57). Furthermore, HR measurement can be difficult and cumbersome to use during exercise, adversely affecting measurement accuracy, enjoyment of exercise and in turn, exercise compliance (6, 17, 32). Thus, ratings of perceived exertion (RPE) has been suggested as an appropriate alternative to HR measurement (17).

Paragraph Number 3 Perceived exertion, measured by RPE has demonstrated better accuracy, in comparison to HR, for the estimation of $\dot{V}O_2$ maximum ($\dot{V}O_{2max}$) and is simple and easily learnt for both practitioner and patient (17, 19, 45). Furthermore, Johnson and Phipps (27) and Wisniewski (57) highlight the popularity of perceptual exercise regulation, despite the rise in availability of physiological monitoring equipment. In their studies, 100 women exercisers (at least 3 months history recent exercise) (27) and, 60 obese adults (males, n = 22, age = 37.2 ± 9.7; females, n = 38, age = 34.5 ± 7.9) (57) were questioned, with around 88% of their participants choosing to regulate exercise through a method of perceived exertion, compared to 7 – 11% who chose HR methods.

Paragraph Number 4 The concept of perceived exertion is defined as the amount of effort, strain, discomfort and/or fatigue experienced by an individual during activity (45). Psychophysical scaling tools such as the traditional Borg 6 – 20 and Omnibus (OMNI) RPE category scales have been designed to subjectively determine the extent of perceived exertion during activity. The Borg 6 – 20 RPE scale works on the assumption that HR and $\dot{V}O_2$ increase linearly with RPE, with the scale beginning at a value of 6 (correlating to 60 beats•min^{-1}, average resting HR) and terminating at a value of 20 (correlating to 200 beats•min^{-1}, absolute maximum) (6, 7, 9, 45, 47, 57). Research has provided extensive validation and reliability for the scale, hence, as the 'gold standard' of psychophysical scaling tools it has been employed worldwide to regulate exercise (7, 10, 11, 14, 38).

Paragraph Number 5 Interest into the applicability of RPE scales in individuals of all cognitive abilities has lead to the development of the OMNI RPE scale. With a narrow 0 – 10 numerical range the OMNI RPE scale demonstrates better clinical applicability than the Borg 6 – 20 RPE scale, as it is similar to other numeric rating scales commonly used within

clinical practice and daily living. The OMNI RPE scale also contains verbal anchors (for example, from extremely easy to extremely hard for adults) and pictorial descriptors (exercise-mode specific) to assist with identification of the intensities required for the OMNI numerical values (37, 42, 51, 52). Scale development initially occurred for psychophysical measurement in children and adolescents (35, 37, 39, 46, 53) and because of its early success, research progressed to validation studies in adults. The OMNI RPE scale has shown to correlate highly with HR, $\dot{V}O_2$, ventilation, lactate and respiration rate $r = 0.67 – 0.88$, $P < 0.05 – 0.001$ (5, 25, 26, 47, 52, 57).

Paragraph Number 6 Prescription employing the OMNI RPE scale for exercise intensity regulation requires the scale to accurately represent physiological workloads. Accuracy of RPE has been demonstrated using the Borg 6 – 20 and OMNI RPE scales during a range of workload intensities (5, 8, 30, 33, 41, 47, 48, 55), although discrepancies are exhibited within the Borg 6 – 20 RPE scale literature, with production accuracy decreasing at low (4, 29, 49) and high (13, 18) ends of the intensity spectrum. A relative lack of research exists into the inter-individual differences (workload variability) for the walk/run, adult version of the OMNI RPE scale.

Paragraph Number 7 The only adult study using the OMNI RPE scale known to the authors that reports variability data is by Bolgar et al. (5), which investigates the signal dominance and integration of RPE in women of different training status for treadmill and cycle exercise. Variability of reported RPE by participants at 40, 60 and 80% $\dot{V}O_{2max}$ was only recorded for cycle exercise, where large variability of RPE_R was demonstrated for each $\dot{V}O_{2max}$ category. Importantly, Bolgar's (5) research opposed Groslambert's (24) on children, which

highlighted low HR variability between participants during their production trial of RPE 2, 6 and 10 whilst running.

Paragraph Number 8 The OMNI RPE walk/run scale was chosen for this study because of its simplicity, which allows for greater potential clinical utility, particularly when exercise is a secondary or adjunct treatment. Currently, the ACSM (2010) concludes that there is still insufficient research to endorse RPE as a primary method of prescription and intensity regulation and that if employed, either the OMNI or Borg RPE scales should be used in conjunction with physiological mediators whilst exercising (2). Furthermore, although validity of the OMNI RPE scale has been determined, research into the variability of workload production for prescribed RPE values is limited, and in turn little is understood about the clinical utility of the scale, indicating an area for future research. Hence, the primary purpose of the current research was to establish the variability for measures of absolute and relative intensity during treadmill exercise produced for each of three prescribed ratings of perceived exertion (RPE_P) (5, 7 and 8), and to establish the differences among RPE_P conditions. The secondary aim was to evaluate whether age, sex, fitness level and exercise mode are associated with the produced intensities and RPE_R, in healthy adults (18 to 58 years).

Methods

Recruitment and participants.

Paragraph Number 9 A convenience sample of clinically healthy adults voluntarily participated within this research (2). Participants were excluded if they were outside of the age range of 18 – 60 years, or if they were identified as "high risk" in accordance with the ACSM risk stratification criteria for exercise (2). Participants gave informed consent following an explanation of the research protocols (Information Sheet, Appendix C; Consent Form, Appendix D). Participant's height and weight measurements were then recorded, immediately prior to the production test. The Unitec Research Ethics Committee (UREC) approved this research (2011-1237) (Appendix A & B).

Pre-test instructions.

Paragraph Number 10 Participants were asked to avoid caffeine, cigarettes or alcohol the morning of the data collection; eating for at least 2 h prior to data collection; vigorous exercise for 24 h preceding data collection and encouraged to consume a typical intake of fluid over the 24 h prior to testing.

Production protocol.

Paragraph Number 11 Participants were familiarised with the Life Fitness (90 series model 97Ti Brunswick Corporation Illinois USA) treadmill that was used for both tests. A Polar T34 transmitter (Polar Electro Kemple Finland) was used for direct HR measurement for all exercise tasks. Participants were blinded to HR values at all times. The production test consisted of a 3-min casual warm-up, followed by three 5-min exercise bouts, completed with no intervening rest, between the randomly-ordered RPE_P values of 5, 7 and 8 (Appendix G).

Participants were able to alter treadmill speed but not incline in order to achieve the RPE_P and could choose to walk or run, according to the exercise mode they felt most appropriate for the assigned RPE_P. Participants were blinded to the control panel and were unaware of the speed at which they were exercising. At 2-min, for each bout, the researcher informed participants that they had 1-min left to make changes to their current speed, which they maintained for the final 2-min. During the last 15 s of each interval, average HR, treadmill speed and reported RPE (RPE_R) were recorded for each participant.

Graded exercise test for $\dot{V}O_{2max}$ estimation.

Paragraph Number 12 Participants returned 24 h to one week later to complete the submaximal graded exercise test (GXT), using the Balke-Ware ramp protocol to estimate maximal aerobic fitness (Appendix I) (3). During the last 15 s of each min, participants' HR and RPE_R were recorded. Termination of the test occurred once the participant reached 85% of their estimated maximum HR (HR_{max}), or if the participant scored an RPE_R value of 9 or higher. The Tanaka formula (Equation 1) for age-predicted HR_{max} was used to estimate HR_{max} (50). From here, $\%HR_{max}$ was calculated for direct measurements. Maximal aerobic fitness ($\dot{V}O_{2max}$) was calculated using the 'direct method' (ACSM), which estimates aerobic fitness by extrapolating estimated workload ($\dot{V}O_2$: Equation 2) to the intercept of estimated age-predicted HR_{max} (2). A correction equation was applied to correct for the non-steady state exercise associated with the ramp protocol. (Equation 3) (2).

Equation 1: Tanaka formula

Age-predicted HR_{max}= 208- 0.7 • age

Equation 2: Metabolic equation

$\dot{V}O_2$ (mL • kg^{-1} • min^{-1})= (0.2 • S) + (0.9 • S • G) + 3.5 mL.

S= Speed

G= Gradient (as a percentage)

Equation 3: Ramp correction

Corrected $\dot{V}O_{2max}$ = 0.72x + 3.67

x: Estimated $\dot{V}O_{2max}$

Ratings of perceived exertion (RPE).

Paragraph Number 13 The adult version of the OMNI RPE walk/run scale was used to prescribe exercise intensity (RPE_P) (Appendix E). RPE_R values were recorded to identify and correct for error in RPE production.

Paragraph Number 14 At the beginning of each trial participants read the script employed by Utter et al. (52), Robertson et al. (42) and Schafer (47) explaining the definition of RPE (Appendix F). For the production trial a set of instructions employed by Schafer (47) were adapted for the purpose of this research, to explain the OMNI RPE walk/run scale and how to use it (Appendix H & F). For the GXT the original set of instructions, which was employed by Schafer (47), was read by participants (Appendix F). The OMNI RPE walk/run scale was in participant view throughout both trials.

Data analysis.

Paragraph Number 15 Data analysis was conducted using SPSS version 19 (SPSS and IBM company, Chicago IL). Descriptive analysis determined the means and standard deviations of

relative ($\%HR_{max}$ and RPE_R) and absolute (treadmill speed) workloads for each RPE_P. Coefficients of variation (CVs) were calculated as indicators of the degree of variability of $\%HR_{max}$ at the RPE_P values. To determine the effects of intensity, sex, order sequence, exercise mode, age and fitness on participant's produced workloads ($\%HR_{max}$ and treadmill speed) parametric analyses (repeated measures ANOVA, independent t-tests and Pearson correlation coefficient) were conducted. All repeated measures ANOVAs were checked for violations of assumptions of sphericity (Mauchley's test), with Greenhouse-Geisser corrections made when these were violated. Pairwise differences were analysed using Bonferroni post-hoc tests. Non-parametric equivalents (Friedman's, Mann-Whitney U and Kendall Tau tests) were used to test the same effects on RPE_R. Effect sizes were determined using Cohen's effect sizes for the independent t-tests (p. 479 and 481) of Field (21). The level of statistical significance was set to $P < 0.05$, with 2-tailed tests applied throughout. Regression analysis was undertaken using exploratory stepwise (backward) regression ($P_{IN} = 0.049$; $P_{OUT} = 0.05$) and then a follow-up model with redundant variables removed for determination of r^2, as advised by Field (21) (pg. 213-214).

Results

Paragraph Number 16 Forty healthy adults, aged 18 – 58 years participated in this study (Table 1).

Table 1. Descriptive characteristics of participants

	Male (n= 20)	Female (n= 20)	Combined (N= 40)
Age (yr)	26.8 (6.1)	32.2 (13.1)	29.7 (10.6)
Height (cm)	180.2 (6.7)	164.4 (7.3)*	172.0 (10.5)
Weight (kg)	74.8 (9.2)	65.5 (13.6)*	70.0 (12.5)
Body Mass Index ($kg \bullet m^2$)	23.0 (2.4)	24.3 (5.4)	23.7 (4.3)
$\dot{V}O_{2max}$ ($mL \bullet kg^{-1} \bullet min^{-1}$)	45.3 (8.2)	38.7 (8.5)*	41.9 (8.9)

Note. Values are mean (standard deviation). $\dot{V}O_{2max}$= estimated maximal oxygen uptake.

* Indicates a statistically significant difference from males $P < 0.05$

Differences in relative and absolute intensity between RPE_P values.

Paragraph Number 17 RPE_P intensity had a significant effect on $\%HR_{max}$ ($F(2, 72)= 39.1$, $P < 0.001$), with pair-wise comparisons indicating differences between all prescribed RPE_P values ($P = 0.04$ for RPE_P between 7 and 8 and $P < 0.001$ for other comparisons) (Figure 1a). Similar differences between all RPE_P levels ($P < 0.001$ for post hoc tests) were observed for treadmill speed ($F(2, 78) = 109.6$, $P < 0.001$ for overall ANOVA, Figure 1b) and for RPE_R using nonparametric Friedman's ANOVA ($\chi^2 (2)= 68.9$, $P < 0.001$), with all pair-wise comparisons attaining statistical significance ($P < 0.001$, Figure 1c). The coefficients of variation for $\%HR_{max}$ for the RPE_P values of 5, 7 and 8 were 0.2, 0.1 and 0.1, respectively.

Relationship of sex with relative intensity.

Paragraph Number 18 Though males tended to show higher mean values of $\%HR_{max}$ compared to females, a 2-way ANOVA (Sex • RPE_P), did not show an effect of participant sex on $\%HR_{max}$ across RPE_P levels ($F(1.6, 62.2)= 2.3$, $P = 0.1$). Mann-Whitney non-parametric comparisons of male versus female RPE_R for each of the RPE_P levels showed that males, compared to females, produced a significantly greater RPE_R value at the RPE_P level of 5 ($P < 0.05$), although no sex differences at RPE_P levels of 7 or 8 were shown (Table 2).

Figure 4. Average $\%HR_{max}$, Treadmill Speed and RPE_R Produced by Participants for the RPE_P Values of 5, 7 and 8

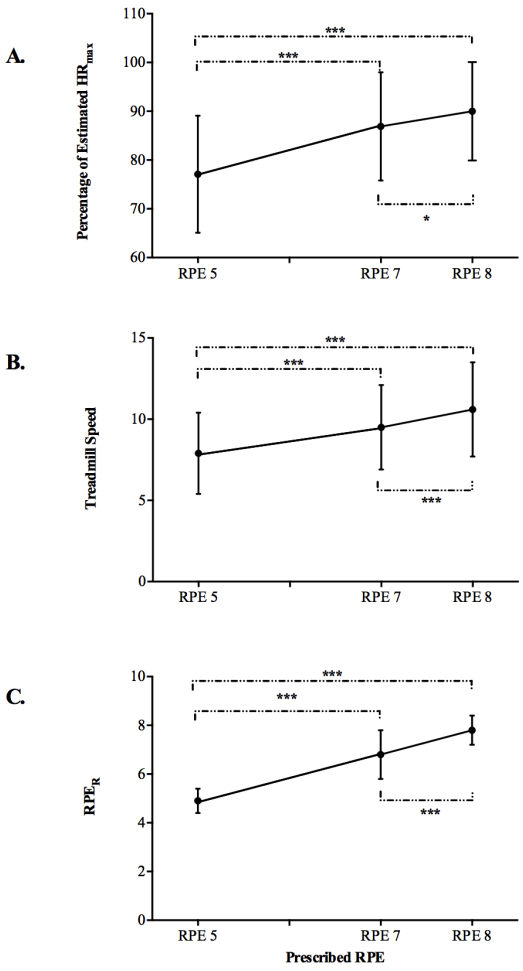

Figure 1. The mean values for $\%HR_{max}$ (relative maximal heart rate), treadmill speed and reported RPE (RPE_R) at each prescribed RPE (RPE_P) value is demonstrated. Error bars represent standard deviations.

A. $\%HR_{max}$ Produced by Participants for RPE_P Values
B. Treadmill Speed Produced by Participants for RPE_P Values
C. RPE_R Produced by Participants for RPE_P Values

Associated verbal cues for RPE values:
5: Situated between "somewhat easy" and "somewhat hard"
7: Situated between "somewhat hard" and "hard"
8: Situated at "hard"

*** Indicates statistically significant difference between RPE_P values at $P < 0.001$.

* Indicates statistically significant difference between RPE_P values at $P < 0.05$.

Table 2. Produced intensity (%HR_{max} and RPE_R) for male and female participants for each RPE_P value.

RPE	Sex	RPE_R	%HR_{max},	ES
5	M	5.1 *	79.4 (9.3)	0.3
	F	4.8	75.4 (13.2)	
7	M	6.7	86.3 (10.5)	0.1
	F	6.9	87.4 (10.6)	
8	M	7.8	92.1 (7.7)	0.1
	F	7.7	88.0 (11.7)	

Note. RPE_R= reported RPE; RPE_P= prescribed RPE; %HR_{max}= relative maximal heart-rate; ES= effect size. %HR_{max}= mean (standard deviation).

* Indicates a statistically significant sex difference at $P < 0.05$.

Relationship of age, fitness and order sequence with relative intensity.

Paragraph Number 19 At the RPE_P of 5, age was significantly inversely related to the %HR_{max} produced (Pearson's $r = -0.5$, $P < 0.01$). Similar trends not attaining statistical significance were demonstrated between %HR_{max} and age for RPE_P 7 ($P = 0.054$) and RPE_P 8 ($P = 0.06$). RPE_R demonstrated an inverse relationship to age (Kendall's statistic = 0.2; $P <$ 0.05) at RPE 5 only. No significant correlation was demonstrated between aerobic fitness ($\dot{V}O_{2max}$) (Pearson correlation coefficient) or RPE order sequence (two-way ANOVA) and %HR_{max} at any RPE_P value ($P = 0.2 – 0.8$).

Relationship of exercise mode with $\%HR_{max}$.

Paragraph Number 20 Univariate analysis of the association between exercise mode and $\%HR_{max}$ showed that participants who walked compared to those who ran had lower $\%HR_{max}$ at RPE_P 5 and 8 ($P < 0.001$) and RPE_P 7 ($P < 0.05$) (Table 3). Participants' RPE_R values were also significantly different between walkers and runners at an RPE_P level of 8 ($P < 0.01$), but not at levels 5 and 7 (Table 3).

Multivariate associations and predictors of $\%HR_{max}$.

Paragraph Number 21 The inter-relationships amongst exercise mode, sex, fitness and age are reported in Table 4. An exploratory regression analysis was conducted to determine which of them were independent predictors of $\%HR_{max}$. Regression analysis employed $\%HR_{max}$ as the dependent variable and included mode, sex, age and $\dot{V}O_{2max}$ as predictors. Exercise mode was retained (walking associated with lower $\%HR_{max}$) in the model at all RPE_P levels, along with sex at RPE_P of 5 (male sex associated with a lower $\%HR_{max}$), and $\dot{V}O_{2max}$ (inversely associated) at RPE_P of 7. The predictors in each model explained 37%, 29% and 34% of the variance in $\%HR_{max}$ for RPE_P of 5, 7, and 8, respectively.

Table 3. Average $\%HR_{max}$ and the RPE_R values produced by participants during the exercise modes of walking and running for the RPE_P values of 5, 7 and 8.

RPE_P	Walking				Running			
	n	>85%	$\%HR_{max}$	RPE_R	*n*	> 85%	$\%HR_{max}$	RPE_R
5.0	11	0	66.3 (6.7)	4.6 (0.5)	29	31.6	81.5 (10.1) ***	5.0 (0.5)*
7.0	7	0	76.8 (9.1)	6.0 (1.2)	33	52.0	89.0 (9.5) *	7.0 (0.8)
8.0	6	2.6	76.1 (6.0)	7.0 (0.9)	34	68.4	92.4 (8.6) ***	8.0 (0.4)**

Note. $\%HR_{max}$ = percentage of age-predicted maximum heart-rate; RPE_R= Reported RPE; *n*= participant number; >85%= percentage of participants exceeding 85% of their estimated HR_{max}; $\%HR_{max}$ and RPE_R values expressed as mean (SD).

* Indicates a statistically significant difference at $P < 0.05$.
** Indicates a statistically significant difference at $P < 0.01$.
*** Indicates a statistically significant difference at $P < 0.001$.

Table 4. The inter-relationships expressed between exercise mode, sex of participants, age and fitness for prescribed Ratings of Perceived Exertion (RPE_P) values.

	RPE_P								
	5			7			8		
	Walk	Run	*P* value	Walk	Run	*P* value	Walk	Run	*P* value
Gender (M/F)	1/10	18/11	0.003 **	1/6	18/15	0.053	0/6	19/15	0.011**
Age	41.5(13.7)	25.2(3.8)	0.003 **	45.4(12.4)	26.3(6.5)	0.000***	45.7(13.6)	26.8(7.1)	0.000 ***
$\dot{V}O_{2max}$	38.3(9.9)	43.4(8.2)	0.117	38.5(12.1)	42.7(8.0)	0.270	37.8(13.0)	42.7(7.9)	0.219

Note. Gender (M/F) = frequency of mode production for males and females (running or walking); Age = mean (SD); $\dot{V}O_{2max}$ (maximum volume of oxygen uptake) = mean (SD)

** Indicates a statistically significant difference at $P < 0.01$.
*** Indicates a statistically significant difference at $P < 0.001$.

Discussion

Paragraph Number 22 The intention of this study was to determine the clinical utility of the OMNI RPE walk/run scale for prescription of exercise intensity in healthy adults. The primary purpose was to establish the variability for measures of absolute (treadmill speed) and relative (percent maximal HR [$\%HR_{max}$] and reported ratings of perceived exertion [RPE_R]) intensity during treadmill exercise produced for each of three prescribed ratings of perceived exertion (RPE_P) (5, 7 and 8), and differences among RPE_P conditions in healthy adults (18 – 58 years). The results show large variability of $\%HR_{max}$ at each RPE_P 5, 7 and 8, which is likely to compromise the utility of the OMNI RPE walk/run scale during clinically prescribed exercise.

Paragraph Number 23 The large variability in $\%HR_{max}$ between participants supports the results of Bolgar et al. (5) who showed highly variable estimated RPE_R values in young female participants for 40, 60 and 80% $\dot{V}O_{2max}$. Compared to the estimation paradigm employed by Bolgar et al., whereby RPE was estimated for prescribed absolute workloads, the current study's RPE-production paradigm better represents the methods of prescribing exercise within everyday clinical practice. By employing this method, the present study established variability that could be expected if prescription was carried out in situations where physiological monitoring was unavailable. Because of the significant discrepancies in workload production between individuals, the usefulness of the OMNI RPE scale should be evaluated to determine if the simple construction and easy application outweighs the drawbacks of using more resource-intensive HR or other physiological or psychological monitoring.

Paragraph Number 24 High variability in the relative intensities produced for a specific RPE_P can be problematic. On the one hand, under-performance may not stimulate sufficient adaptive training responses. However on the other hand, over-performance may increase risk of a cardiac event for some individuals. This is especially true for individuals within the moderate to high-risk category under the ACSM exercise stratification guide (men≥ 45 years of age and women ≥ 55 years of age or those with two or more risk factors indicating disease), where it is not recommended intensity exceeds 85% HR_{max} (2). It is important to confidently prescribe exercise below this, yet at a level that will be beneficial for the individual, therefore it is recommended that prior exercise testing is conducted to determine the associations of RPE with $\%HR_{max}$ for each individual. In turn, the high variability limits the use of the OMNI RPE scale in some health care environments where the equipment (treadmill and monitoring equipment, i.e. HR monitors) necessary to conduct this preliminary testing is not available.

Paragraph Number 25 The most accurately produced workloads for RPE between individuals are equivocal within the current literature. Within this study relatively equal variability was demonstrated over all RPE_P intensities, however at the RPE_P 5 a slightly higher variability was observed in comparison to the RPE_P 7 and 8. These results are similar to research by Schafer (47), who demonstrated comparatively similar OMNI RPE / HR and $\dot{V}O_2$ correlations at both moderate and high treadmill exercise intensities. In contrast, data reported by Groslambert (24) for the OMNI RPE scale showed slighter large variability as intensity increased in children. Previous Borg 6 – 20 RPE scale research has demonstrated production accuracy decreasing at low (4, 29, 49) or high (13, 18) intensities.

Paragraph Number 26 Despite varied intensities produced by participants for each RPE_P value, both relative and absolute workload intensities increased with each RPE_P increment (RPE 5, 7 and 8) ($P < 0.05 – 0.001$, Figure 1), indicating that participants were able to differentiate between medium and high intensities. This ability of participants to self-select between low and high exercise intensity is consistent with previous research (5, 20, 42, 51, 55, 57).

Paragraph Number 27 The freedom to select the exercise mode of walking or running gave participants the ability to reach their desired physiological intensities within an environment aimed to accurately represent real-life exercise. It was observed that greater physiological intensities were performed by participants who chose to run, compared with those that chose to walk for RPE_P values (Table 3). These findings are consistent with literature from Borg (9) and Pandolf (34) who highlight that higher physiological workloads are commonly produced for running in comparison to walking for the same RPE_P value. Furthermore, the RPE_R chosen by participants who ran was much closer to target RPE_P, indicating that participants who chose to walk tended to under-regulate exercise, exercising at a lower level of RPE_R than what was prescribed (Table 3). These results suggest that running was well tolerated with greater physiological intensities produced. However, as regression analysis determined exercise mode as a main contributor to $\%HR_{max}$ variance, then controlling for this factor in future investigations has the potential to obtain a narrower range of workload intensities for RPE_P, and higher correlations with physiological workloads.

Paragraph Number 28 Interestingly, at the RPE_P value of 5 approximately one-third of participants who chose to run produced relative workloads ($\%HR_{max}$) over the submaximal intensity of 85% HR_{max} (Table 3). It is not expected that participants will self-select

physiological intensities over 85% HR_{max} for the RPE value of 5, which is considered to fall between 'somewhat easy' and 'somewhat hard' on the OMNI RPE scale (52). Whereas, all participants who chose to walk for the RPE_P value of 5 selected intensities equating to well under 85% of their HR_{max}, whilst only one participant who walked exercised over 85% HR_{max} for RPE_P values 7 and 8. In turn, it is recommended that walking could provide an appropriate alternative to running, when it is necessary for exercise to remain under 85% HR_{max}. However, as the study design allowed for a choice of walking or running the ability to draw this conclusion is limited, owing to other important factors that could influence a participant's decision (e.g. motivation, exercise history, physical ability or exercise goals). As these factors were not investigated, the intensity an individual would choose if they were required to walk or run could not be estimated, as some participants may simply over-perform regardless of the exercise mode.

Paragraph Number 29 This study examined the effects of demographic variables (age, sex, fitness) on exercise intensity selection. Importantly, this study recruited a broader age range of healthy adults, in comparison to previous OMNI RPE walk/run scale research that has investigated only healthy young adults (5, 25, 47, 52). Findings from the present study indicated that older adults produced lower relative workloads for modest prescribed exercise intensity (RPE_P 5) (%HR_{max}, $P < 0.01$ and RPE_R, $P < 0.05$). These findings could have been influenced by the participants' choices of exercise mode, as those over 40 were more likely to walk and walkers tended to under-regulate the intensity chosen for RPE_P values (Table 4). Another important factor is that even though the current research used an age-sensitive formula (50) to determine the physiological HR_{max} of participants, the physiological values determined are only estimates and are subsequently susceptible to error.

Paragraph Number 31 The differences in the psychological and physiological characteristics of males and females, has been thought to play an integral role in the workloads chosen for RPE values (44). In this study, the sex of participants did not appear to have an effect on resulting $\%HR_{max}$ (Table 2). However, it is apparent that males RPE_R values were closer to the target RPE_P value. It is possible that males were better able to select a treadmill speed that matched the prescribed RPE, whilst women under-estimated speed and thus reported producing lower RPE_R values. Another possibility is that male participants may have been trying to conform to tester expectations and simply tended to report exercising at an RPE that matched the instruction (prestige bias). The results demonstrate that the sex of an individual is less likely than their age or the exercise mode (walking or running) to affect $\%HR_{max}$ values (univariate analysis), although a greater proportion of females, also elderly adults, chose to walk for RPE_P values, probably explaining the resulting slightly increased $\%HR_{max}$ variability at the RPE_P 5.

Paragraph Number 32 Previous research conducted by Schafer (47) has displayed an effect of order sequence on physiological intensities chosen for a RPE value, demonstrating that participants could regulate treadmill exercise with OMNI- RPE values equal to 50% and 70% of an individuals' $\dot{V}O_2$ reserve ($\dot{V}O_2R$) (determined with an initial estimation trial), when intensity ascended (50 – 70 – 50 – 70% $\dot{V}O_2R$) but not when it descended (70 – 50 – 70 – 50 $\dot{V}O_2R$). However, in this study the RPE_P sequence order did not alter participants' $\%HR_{max}$. This finding is similar to research conducted by Robertson et al. (41) who reported that order sequence did not affect a child's ability to differentiate between the RPE of 2 and the RPE of 6. Likewise, the current study produced similar findings to that of previous research, demonstrating that self-selection of physiological intensities is perceived similarly amongst participants of differing fitness levels for RPE_P values (3, 10).

Paragraph Number 33 The results of the current study do not give the ability to determine the variability that would have been produced if the Borg 6 – 20 RPE scale was employed to perceptually regulate exercise. However, along with other OMNI research, data from this study show a positive linear relationship between HR and OMNI- RPE (Figure 1a), which concurs with the theoretical bases behind Borg's effort continua model (7, 9, 45). Response linearity for OMNI- RPE with the physiological variables has been confirmed for children, adolescents, adults and the elderly for the exercise modes of treadmill, cycle and resistance exercise (r = 0.60 – 0.95) (15, 25, 39, 40, 42-44, 52, 56, 57).

Paragraph Number 34 A limitation of this research involved relying on indirect estimation of $\dot{V}O_{2max}$ based on HR as the primary outcome measure of physiological intensity. With the use of HR as a measurement tool it meant that physiological measurements were more susceptible to exogenous factors such as medications, psychological disorders, caffeine, alcohol, food, dehydration and temperature (28, 32, 34). However, indirect measurement was conducted during submaximal exercise to allow for the inclusion of participants of low to medium risk, in accordance with the ACSM recommendations for individuals at moderate risk (2).

Paragraph Number 35 Future research is required as there is limited understanding of workload variability between individuals for the OMNI RPE scale. Future research should determine if relative workload variability decreases for RPE_P values after controlling or correcting for exercise mode and age. Research should continue to investigate the accuracy of intensity prediction for RPE_P at both ends of the intensity spectrum, to determine extent of variability and reliability between participants. Furthermore, future research should be conducted on the OMNI RPE walk/run scale employing participants in sampling groups

based on age and/or exercise mode to further examine the effects demonstrated within this study. It is recommended that future research employ a maximal GXT with direct measurement of HR and $\dot{V}O_2$ to determine if the current findings are reproducible.

Paragraph Number 36 This research highlighted that participants have the ability to differentiate between required intensities at RPE_P levels ranging from 'somewhat easy' to 'hard'. However, it confirmed that the perceptions of exercise intensity vary widely among individuals. This limits the use of the OMNI RPE walk/run scale for use in healthy adults during traditional exercise prescription, as it cannot be ensured that individuals will exercise within a precise range. Furthermore, a sizeable majority of participants exercised above the recommended intensity range for effective exercise, increasing the risk of acute cardiovascular events or musculoskeletal injuries. The results from this study might assist in determining the suitability of RPE prescription for submaximal exercise.

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Section three: Manuscript Appendices

Appendix A: Ethics Approval Letter

Cheri Quinton
286 Vipond Rd
Stanmore Bay
Auckland

8.12.2011

Dear Cheri,

Your file number for this application: 2011-1237
Title: A Production Trial of the OMNI RPE Scale in Treadmill Exercise.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 21.11.2011
Finish date: 21.11.2012

Please note that:

1. **The above dates must be referred to on the information AND consent forms given to all participants.**

2. **You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.**

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely,

Scott Wilson
Deputy Chair, UREC
cc: Jamie Mannion
Cynthia Almeida

Appendix B: Ethics Approval Letter, for Amendments to Participant Age and Submaximal Termination of GXT

Cheri Quinton
286 Vipond Rd
Stanmore Bay
Auckland

21.6.12

Dear Cheri,

Your file number for this application: **2011-1237**

Title: **A Production Trial of the OMNI RPE Scale in Treadmill Exercise.**

Your request for changes to the above application have been reviewed by the Unitec Research Ethics Committee (UREC) and have now been approved. Please note that all other conditions as specified in your original application approval letter apply.

You may now continue your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely,

Scott Wilson
Deputy Chair, UREC

cc: Jamie Mannion

Appendix C: Participant Information Sheet

RESEARCH INFORMATION FOR THE PARTICIPANTS

Title

A Production Trial of the Omnibus Ratings of Perceived Exertion Scale in Treadmill Exercise

You are invited to participate in our research investigation. Please read carefully through this information sheet before you make a decision about volunteering.

Principle Researcher

Cheri Quinton (Bachelor of Applied Science [Human Biology]). My name is Cheri and I am currently in my 2nd year of the Masters of Osteopathy program at Unitec New Zealand. The purpose of this project that I am undertaking is to determine the effectiveness of the OMNI- walk/run Ratings of Perceived Exertion (RPE) Scale in regulating exercise intensity for exercise prescription purposes in a clinically healthy sample of the adult population.

Why is this effectiveness important?

The effectiveness of the OMNI RPE scale to regulate treadmill exercise is important as traditional methods (heart rate and oxygen uptake) can be inappropriate within clinical situations (such as many osteopathic clinics) who do not have access to the expensive equipment. Further, heart rate measurement can be difficult to record accurately and can interupt exercise.

Ratings of perceived exertion (RPE) scales have been validated in their ability record exertion. As these scales are highly beneficial within the clinical setting, with easy measurement and an understandable procedure, the OMNI- walk/run RPE scale as an under researched scale is to be investigated.

Your voluntary participation

Your participation in this study is entirely voluntary, and you may withdraw at any time prior to data analysis.

Who may participate?

You are eligible to participate if you:

- Are aged between 18 and 60 years of age.
- If you have no musculoskeletal dysfunction and without any cardiovascular, respiratory, metabolic disease or psychological disorders.

Unfortunately you are unable to participate if you:

- Have acute or chronic musculoskeletal injury, cardiovascular, respiratory and metabolic conditions
- Current physician diagnosed psychological disorder
- Currently pregnant
- Smoker

Please feel free to contact the lead researcher if you are unsure about your eligibility.

What will happen in the study?

Should you agree to participate in the study, you will be required to attend two testing sessions which will initially include completing exericse questionnaires related to your past and current exercise and medical history. On the initial visit you will be ask to produce a walking/running intensity equal to three different intensities for five minutes each, at which point your heart rate will be measured. Twenty-four hours to one week following the initial visit you will be required to come in a second time to complete a submaximal graded exercise trial, whereby you will be required to

estimate the intensity level that you are exercising. This will occur at the end of each minute, in combination with measurement of you heart rate.

Prior to each visit you will be required not to partake in vigorous exercise the day prior and not to conduct your regular exercise routine the morning of data collection. You will need to ensure that you do not consume caffeine, smoke cigarettes or drink alcohol the morning of the treadmill tests. Furthermore, it is important that you wear loose fitting t-shirt with appropriate shorts and footwear and that you are in a normal state of hydration.

What we do with the data and results, and how we protect your privacy.
Personal information is collected and stored under the guidelines provided by the Privacy Act 1993 and the Health Information Privacy Code 1994. Should you be randomised to the osteopathic treatment group, your name will be recorded on a case history form as per usual clinical policy. However, in all other instances of information collection your identify will remain anonymous and you will simply have an identification number. If the information you provide is reported or published, this will be done in a way that does not identify you as its source. All the data recorded will be stored in a password-locked computer and archived in a locked file room in the Unitec Student Osteopathic Clinic and will be stored for a minimum of 5 years. Access to this data will be limited to the principle researcher (Cheri Quinton), the research supervisor, the osteopathic tutors at the Student Osteopathic Clinic, and yourself.

Discomforts/risks and benefits
There are minimal potential risks involved in this study. During the study if any pain or severe discomfort occurs then the exercise testing will be stopped to prevent any serious harm. Futhermore, participants recruitment excludes those who are within the “high risk” ACSM stratification criteria to assit in preventing adverse effects. Following the trials participants may experience mild stiffness,discomfort and muscular soreness immediately after or a couple of days following. All relvant information will be discussed prior to the trials being conducted and your consent will be sought.

Compensation may be available in the unlikely event of injury of negligence

Should you incur a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation and Compensation Act 2002. You may or may not be entitled to ACC compensation, depending on several factors such as whether or not you are an earner. ACC will usually cover a proportion of income lost due to a physical injury, this does not cover mental injury unless as a direct result from a physical injury. ACC cover may affect your right to sue. Please contact your nearest ACC office for further information (0800 735 566) or visit their website: www.acc.co.nz/claimscare/making-a-claim/medicalmisadventure/index.html.

Please contact us if you need further information about the study.

Contact Details

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UREC REGISTRATION NUMBER: (insert number here)

This study has been approved by the UNITEC Research Ethics Committee from (date) to (date). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix D: Participant Consent Form

Unitec
NEW ZEALAND
Te Whare Wānanga o Wairaka

Participant consent form

A Production Trial of the Omnibus Ratings of Perceived Exertion Scale in Treadmill Exercise

This form is to ensure that you understand the requirements of your participation and that you are aware of your rights. Please read carefully through the points below. If you are happy and agree with the points then please sign the bottom. If you have any questions at all please ask the researcher before signing this form.

- I have had the research project explained to me and I have read and understood the information sheet given to me.
- I understand that I don't have to be part of this if I don't want to and I may withdraw at any time prior to data analysis.
- I understand that everything I say and the information I provide will be collected in accordance with the Health Information Privacy Code 1994 and kept confidential and in accordance with the Privacy Act 1993. I understand that the only persons who will have access to my information will be the researchers and relevant clinical staff.
- I understand that all the information I give will be stored securely on a computer at Unitec for a period of 5 years.
- I understand that my discussion with the researcher will be recorded on a case history form as per usual clinical policy.
- I understand that I can see the finished research document.
- I have had time to consider the information provided, to ask questions, and to seek any guidance.

- I give my consent to be a part of this project.

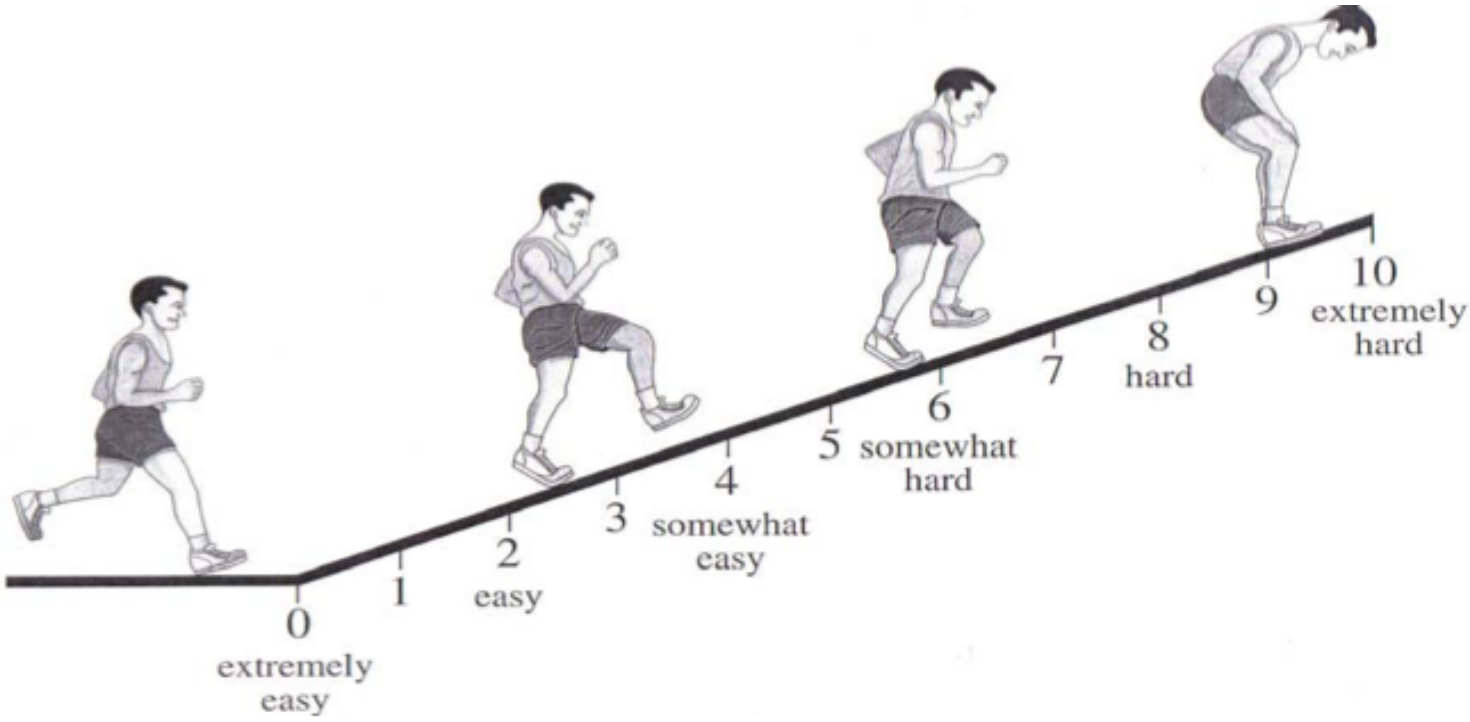
Participant Signature: …….. Date: ……

Principle Researcher: …….. Date: ……

UREC REGISTRATION NUMBER:

This study has been approved by the UNITEC Research Ethics Committee from (date) to (date). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix E: The OMNI RPE Scale



OMNI-walk/run scale of perceived exertion for adults. From “Validation of the adult OMNI scale of perceived exertion for walking/running exercise,” by Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McCanulty, S. R., & Nieman, D. C., 2004, *Medicine and Science in Sports and exercise, 36,*(10), p. 1777. Copyright 2004 by the American College of Sports Medicine.

Appendix F: Scripts Read to Participants for Both Treadmill Trials

At the beginning of each trial participants received a standard definition of RPE: "The perception of physical exertion is defined as the feeling of subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise"

At the beginning of the production trial participants read the following standard script, altered for the purposes of this research:

"We would like you to walk and then run on a treadmill. Please use the numbers on this scale to help regulate how your body is feeling when walking or running. Look at the person at the bottom of the hill who is just starting to walk. If you feel like this person when you are walking, the exertion will be Extremely Easy. In this case, your rating should be a number zero. Now look at the person who is exhausted at the top of the hill. If you feel like this person when walking/running, the exertion will be Extremely Hard. In this case, your rating should be a number 10. If you feel somewhere between Extremely Easy and Extremely Hard then give a number between 0 and 10. We will ask you to run at three different numbers throughout this trial. Please use the treadmill speed controls (not incline) to alter the exercise intensity until you feel your legs and chest/breathing at these levels. Use both the pictures and words to help you regulate your level of walking/running intensity."

At the beginning of the estimation trial participants read this standard script:

"We would like you to walk and then run on a treadmill. Please use the numbers on this scale to tell us how your body feels when walking or running. Look at the person at the bottom of the hill who is just starting to walk. If you feel like this person when

you are walking, the exertion will be Extremely Easy. In this case, your rating should be a number zero. Now look at the person who is exhausted at the top of the hill. If you feel like this person when walking/running, the exertion will be Extremely Hard. In this case, your rating should be a number 10. If you feel somewhere between Extremely Easy and Extremely Hard then give a number between 0 and 10. We will ask you to point to point to a number that tells you how your whole body feels including your legs and chest/breathing. Remember, there are no right or wrong numbers. Use both the pictures and words to help you select a number. Use any of the numbers to tell us how you feel when walking or running."

Participant instruction. From "*Intensity selection and regulation using the OMNI scale of perceived exertion during intermittent exercise*" (Unpublished doctoral thesis), by Schafer, M. A., 2007, University of Pittsburgh, p. 32-33.

Appendix G: Participant Randomisation Table

Participant	Order of RPE_P Production		
	First	Second	Third
1	5	7	8
2	8	7	5
3	7	5	8
4	5	8	7

Appendix H: Instruction read at the beginning of each five-minute interval to highlight to the participant the required RPE.

“Your target RPE is ____ make sure the effort/strain/discomfort and/or fatigue you are experiencing represents your target RPE of ____. If necessary, make adjustments in speed that will bring you to your target RPE”

Participant instruction. From “*Intensity selection and regulation using the OMNI scale of perceived exertion during intermittent exercise*” (Unpublished doctoral thesis), by Schafer, M. A., 2007, University of Pittsburgh, p. 36.

Appendix I: The Balke-Ware protocol used for the estimation trial GXT.

Table 3.4 Balke or Balke–Ware protocol*

Stage	Speed (mph)	Grade (%)
1	3.3	0
2	3.3	1
3	3.3	2
4	3.3	3
5	3.3	4
6	3.3	5
7	3.3	6
8	3.3	7
9	3.3	8
10–26	3.3	9–25
27	3.3	26

*Each stage is 1 min.

Balke-Ware Protocol. From “An experimental study of Air Force personnel,” by Balke, B. & Ware, R.W., 1959, *U.S. Armed Forces Med J*, *10*, p. 675.

Appendix J: Medicine & Science & Sports & Exercise Authors

Submission Information

Available at: http://edmgr.ovid.com/msse/accounts/ifauth.htm

General Information: *Medicine & Science in Sports & Exercise*® (MSSE®) is the official journal of the American College of Sports Medicine and is published monthly. Manuscripts dealing with original investigations, clinical studies, special communications, or brief reviews on topics relevant to the areas of interest of the College will be considered for publication.

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Significant manuscript writer
Significant manuscript reviewer/reviser
Concept and design
Data acquisition
Data analysis and interpretation
Statistical expertise

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For example: Conflicts of Interest and Source of Funding: A has received honoraria from Company Z. B is currently receiving a grant (#12345) from Organization Y, and is on the speaker's bureau for Organization X – the CME organizers for Company A. For the remaining authors none were declared.

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- Completed mandatory submission form
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- Manuscript submission fee (Non–ACSM member corresponding authors only)
- Letter of permission to reprint figures or tables (if applicable)

Manuscript Requirements The manuscript file must be in a document format, not PDF format. The manuscript shall be formatted so that it is set in Times Roman font with 12-point font size, has margins of 1" (all sides), and is double-spaced throughout. Typical manuscript length is approximately 20 pages including references, but excluding tables and figures. Paragraphs should be numbered; for example,

"***Paragraph Number 1*** The subjects of this study…" Paragraph numbers serve as an effective method for relaying reviewer comments to the author. Begin paragraph numbering with the first paragraph in the Introduction and end before the References section. Do not use an automatic paragraph numbering option, as titles, subtitles, abstracts, etc., should not be numbered. Submit all figure and table files separately from the manuscript text file. Do not use Microsoft Word for figure formatting. Figures shall be submitted in .tiff or .eps format. Figures and tables are limited to six (6) total (e.g., 2 figures, 4 tables; 0 figures, 6 tables).

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appropriate to the particular project:

- A general statement of the background of the project and the project objectives.
- A fair explanation of the procedures to be followed and their purposes, identification of any procedures that are experimental, and description of any and all risks attendant to the procedures.
- A description of any benefits to be reasonably expected and, in the case of treatment, disclosure of any appropriate alternative procedures that might be advantageous to the subject.
- An offer to answer any queries of the subject concerning procedures or other aspects of the project.
- An instruction that the subject is free to withdraw consent and to discontinue participation in the project or activity at any time without prejudice to the subject.
- An instruction that, in the case of questionnaires and interviews, the subject is free to deny answer to specific items or questions.
- An instruction that, if services or treatment are involved in the setting or context of the project, they will be neither enhanced nor diminished as a result of the subject's decision to volunteer or not to volunteer participation in the project.
- An explanation of the procedures to be taken to ensure the confidentiality of the data and information to be derived from the subject. If subjects are to be identified by name in the manuscript, permission for same should be obtained in the Informed Consent Form or obtained in writing at a later date.

If the subject is to be videotaped or photographed in any manner, this must be disclosed in the Informed Consent Form. The subject must be advised as to who will have custody of such videotapes or photographs, who will have access to the tapes or photographs, how the tapes or photographs are to be used, and what will be done with them when the study is completed.

The informed consent document, or process, shall not contain any exculpatory language or any other waiver of legal rights releasing, or appearing to release, an investigator, project director, or institution from liability. If a consent form is used, at the bottom of the form, provision shall be made for the signature of the subject

(and/or a legally authorized representative) and the date. It is generally advisable to precede this with a statement to the effect that the subject and/or representative have read the statement and understand it. In the case of minors, one or both parents should sign (as appropriate). For minors of sufficient maturity, signatures should be obtained from the subject and the parent(s).

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organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s).

- Abstract

1. Limit of 275 words, including numbers, abbreviations, and symbols
2. Structure states purpose, methods, results, and conclusion
3. Reference citations are not permitted

- Key Words

1. Four (4) to six (6) words following the abstract
2. Should not repeat terms or phrases from the title

- Introduction

1. State clearly the purpose and hypothesis of the study
2. Provide relevant references
3. Do not exhaustively review the subject

- Methods

1. Present subject information
2. Describe the experimental subjects and their controls
3. Insert “written informed consent” statement or animal-use statement and ethics committee approval statement (required) (see “Human & Animal Experimentation Policy Statements”)
4. Identify the methods, apparatus, and procedures employed with sufficient details to allow others to reproduce the results
5. Provide references for established methods and statistical procedures
6. Provide rationale for use and include a description of possible limitations for utilized methods not well known
7. Denote statistical significance when appropriate and include detailed statistical analyses, mathematical derivation, or computer programs in an appendix

- Results

1. Present findings of the study in the text, tables, or figures
2. Do not include the same data in tables and figures

- Discussion

1. Emphasize the original and important features of the study and avoid repeating all the data presented within the results section
2. Incorporate the significance of the findings and the relationship(s) and

relevance to published observations

3. Provide only those conclusions that are supported by the study

• Acknowledgments

1. Identify funding sources
2. Identify external reviewers, if any

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Authors are required to state in the acknowledgments all funding sources, and the names of companies, manufacturers, or outside organizations providing technical or equipment support. In particular, authors should:

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The reference list shall be in alphabetic order (rather than in the order of citation) and numbered. There shall not be more than 40 references for original investigations. Review articles are limited to 75 references. All references shall appear in the text. The format for references is that which has been adopted by the United States National Library of Medicine [Patrias K. *National Library of Medicine Recommended Formats for Bibliographic Citation*. Bethesda (MD): The Library; 1991. Available from: NTIS, Springfield, VA; PB91-182030.] and employed in *Index Medicus*. For those not included in *Index Medicus*, adhere to the form established by the American National Standard for Bibliographic References. Examples of the types of references are as follows:

1. **Book**

◦ Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. 567 p.

◦ Paffenbarger RS, Hyde RT, Wing AL. Physical activity and physical fitness as determinants of health and longevity. In: Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD, editors. *Exercise, Fitness, and Health*. Champaign: Human Kinetics; 1990. p. 33–48.

2. **Conference Proceedings**—Matthie JR, Withers PO, Van Loan MD, Mayclin PL. Development of a commercial complex bio-impedance spectroscopic (CBIS) system for determining intracellular water (ICW) and extracellular water (ECW) volumes. In: *Proceedings of the 8th International Conference on Electrical Bio-impedance*; 1992 Jul 28-31: Kuopio (Finland). University of Kuopio; 1992. p. 203–5.
3. **Doctoral Dissertation**—Crandall C. Alterations in human baroreceptor reflex regulation of blood pressure following 15 days of simulated microgravity exposure [dissertation]. Fort Worth (TX): University of North Texas; 1993. 100 p.
4. **Government Report**—U.S. Department of Health and Human Services. *Bone Health and Osteoporosis: A Report of the Surgeon General*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General; 2004. 436 p. Available from: U.S. GPO, Washington.
5. **Journal Article**—Blair SN, Ellsworth NM, Haskell WL, Stern MP, Farguhar JW, Wood PD. Comparison of nutrient intake in middle-aged men and women runners and controls. *Med Sci Sports Exerc*. 1981;13(5):310–5.
6. **E-Journal Article**—Vickers AJ. Time course of muscle soreness following different types of exercise. *BMC Musculoskeletal Disorders* [Internet]. 2001 [cited 2001 May 31];2(5). Available from: http://www.biomedcentral.com/1471-2474/2/5. doi:10.1186/1471-2474-2-5.
7. **Web site home page**—American Heart Association Web site [Internet]. Dallas (TX): American Heart Association; [cited 2006 Jan 1]. Available from: http://www.americanheart.org.
8. **Abstract**—An abstract can be cited when it is the only source of information.

Note: In-text reference citations shall be baseline in parentheses, not superscripts [e.g., (14,15), not ^{14,15}]. Personal Internet Web sites, Master of Science theses, personal communications, or other unpublished material are not acceptable as references. All book references require page numbers. Journal abbreviations should follow the abbreviations of *Index Medicus* published by the Library of Congress. Use of et al.—If fewer than seven (7) authors are listed, all should be mentioned. When seven or more authors are named, list only the first three.

- Appendices Appendices are considered supplemental material and will not be

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Terminology and Units of Measurement: To promote consistency and clarity of communication, authors should use standard terms generally acceptable to the field of exercise science and sports medicine.

The units of measurement shall be Système International d'Unités (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. When expressing compound units of measurement, authors must locate the raised dot midway between lines to avoid confusion with periods; for example, mL·min-1·kg-1.

The basic and derived units most commonly used in reporting research in this journal include the following:

mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (°C); energy, heat, work—joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N·m); frequency—hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol). Selected conversion factors: 1 N = 0.102 kg (force); 1 J = 1 N·m = 0.000239 kcal = 0.102 kg·m; 1 kJ = 1000 N·m = 0.239 kcal = 102 kg·m; 1 W = 1 J·s-1 = 6.118 kg·m·min-1.

Sample Size: Authors should justify the adequacy of their sample size by providing calculations regarding the power of their statistical tests. While there are different approaches that authors may take in performing these calculations, the book by Cohen is recommended as an appropriate starting point [Cohen J. *Statistical Power*

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Formulas and Equations: Simple in-text formulas and equations should be presented in a single line: $M = (a + b)/(x + y)$. More complex equations should be set displayed, and, if referenced in text, shall have an equation number:

$$\dot{V}O_{2(t)} = A_1(1 - e^{-(t-\delta_1)/\tau_1}) + A_2(1 - e^{-(t-\delta_2)/\tau_2})$$

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