EFFORT PERCEPTION

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Abstract

Research addressing children's perceptions of exercise effort (their ‘perceived exertion’) has appeared steadily in the scientific literature over the last 30 years. Accepting that the established Borg adult rating of perceived exertion (RPE) scale was not appropriate for children, investigators set about developing child-specific scales which employed numbers, words and/or images that were more familiar and understandable. Numerous studies have examined the validity and reliability of such scales as the CERT, PCERT and OMNI amongst children aged 5 to 16, across different modes of exercise (cycling, running, stepping, resistance exercise), protocols (intermittent vs. continuous, incremental vs. non-incremental) and paradigms (estimation vs. production). Such laboratory-based research has enabled the general conclusion that children can, especially with practice, use effort perception scales to differentiate between exercise intensity levels, and to self-regulate their exercise output to match various levels indicated on them. However, inconsistencies in the methodological approaches adopted diminish the certainty of some of the interpretations made by researchers. In addition, though often mentioned, the would-be application of effort perception in physical education and activity/health promotion contexts has been relatively ignored. Accordingly, the scope for research in this applied domain is now considerable.

Keywords: Perceived exertion**,** child-specific scales, CERT, OMNI, physical activity

Introduction

Individuals possess a well-developed system for sensing the strain involved in physical effort. Effort perception and perceived exertion are synonymous terms which can be defined as the act of detecting and interpreting the sensations arising from the body during physical exertion.[1]The ability to detect and interpret these sensations has been studied in a wide range of populations in a variety of sporting activities and exercise tasks. The plethora of research activity on perceived exertion in adults in the last 38 years has been the subject of several comprehensive reviews[2-4] and commentaries.[5,6] However, research on the efficacy of using perceived exertion in children is both less extensive and applied. This has been the subject of critical review papers[7,8] and editorials by the authors,[9] and others[10] and some of the information presented here utilises material from these manuscripts.

Although there have been over 90 studies incorporating measures of children's perceptions of exercise effort, our understanding of their value to exercise scientists and practitioners remains underdeveloped. For more than two decades researchers have realised that adult-derived methods and applications of the rating of perceived exertion (RPE) notion is not appropriate for use with children. When writing for the first edition of this text, we observed that prior to 2000, most investigators had conducted their research in the same vein as that performed in greater volume on adults, and we appealed for progress in this regard. Whilst we can report that significant progress has been made in the intervening years, and even since the second edition of this text in 2008, there remains, regrettably, a lack of consensus in terms of how data should be gathered (which tools and protocols are appropriate) and analysed statistically, making interpretations of validity and reliability quite difficult. Over the last 15 years existing scales have been refined and new ones have been constructed and promoted across a range of exercise modalities. Arguably, however, their potential for promoting physical activity and its associated health benefits has yet to be exploited. The following sections describe some controversies and advances, and present the current status of the application of effort perception research in the paediatric exercise domain.

Application and description of traditional adult RPE Scales

A description of the most common methods of assessing perceived exertion and how this information is used to assess and regulate the intensity of exercise follows. A variety of scales has been developed in an attempt to assess perceived exertion. The ubiquitous 15-point alpha-numeric RPE Category Scale, developed by Borg in 1970,[11] later revised in 1986,[12] and Borg's lesser used 12-point Category-Ratio 10 (CR 10) scale,[13] are the most commonly used rating of perceived exertion scales. These scales can be used to assess *overall* feelings of exertion or they can be used to differentiate between respiratory-metabolic ('central') and peripheral ('local') signals of exertion. For example, *differentiated* ratings of perceived exertion may be used to segregate the sensations arising from the upper body and the lower body during cycle ergometry exercise or during rowing, running or stepping.

In the traditional 15-point and CR 10 scales, numbers are anchored to verbal expressions. However, in the CR 10 scale the numbers have a fixed relationship to one another. For example, an intensity judgement of three would be gauged to be one-third that of nine. On this scale there is a point above 10 (extremely strong, almost maximal) which may be assigned any number in proportion to 10 which describes the proportionate increase in perceived exertion. For example, if the exercise intensity feels 30% harder than 10 on the CR 10 Scale, the RPE would be 13. This type of scale has been suggested to reflect the incremental pattern of effort perception in relation to ventilatory drive during exercise.

Estimation and production of exercise effort

It is generally observed that RPE measured during an exercise bout increases as exercise intensity increases. Reviews of studies have confirmed the existence of a strong positive association between RPE and indices of metabolic demand in adults[1-4,14] and children,[7,8] particularly when the exercise stimulus is presented in an incremental fashion. Such relationships have been most frequently observed using the so-called passive *estimation* paradigm. In this way, a rating of perceived exertion is given in response to a request from the exercise scientist or practitioner to indicate how 'hard' the exercise feels. The information is frequently used to compare responses between exercise conditions or after some form of intervention. It may also be used to assist a practitioner or coach to prescribe exercise intensities. For example, a specific exercise intensity [e.g., heart rate (HR), work rate or oxygen uptake (VO_2)], which is known to coincide with a given RPE, may be prescribed by the practitioner. Alternatively, an active *production* paradigm can be employed whereby the individual is requested to regulate his/her exercise intensity to match specified RPE values (such as 13 or 15 on the 15-point Borg scale). Measures of metabolic demand can then be compared at each RPE-derived exercise intensity. Several studies on adults[15-20] and children[21-32] show support for the use of the RPE scale in this way.

Evidence suggests that the accuracy of RPE in estimation and production procedures is improved with practice, although there are surprisingly few studies which have explored this fundamental concept in adults,[16] and only two[30,32] which have attempted to adequately address this issue in children. As this is deemed to be an important area of research by the authors, it is appropriate here to consider some of the issues relating to the process of learning. Consideration of the validity and reliability of an RPE scale for children should not ignore age, reading ability, experience and conceptual understanding. The latter is a developmental issue, which has been the subject of a review by Groslambert and Mahon.[10] Additionally, a confounding factor recognised by two of the original leading proponents of RPE, Borg[33] and Bar-Or,[34] 39 years ago is the extent to which children's direct experiences of exercise (their exposure to different exercise intensities) influence their perceptions of exertion.[9]

Surprisingly, however, few investigations on perceived exertion in children have incorporated all of these issues into their design. For a child to perceive effort accurately, and then reliably produce a given intensity at a given RPE, it is logical to assume that learning must occur. Implicit in the process of learning is practice (of the skill) and the cognitive ability of the child. According to Piaget's stages of development, children around the age of 7-10 years can understand categorization but find it easier to understand and interpret pictures and symbols rather than words and numbers. Since 2000, investigators have incorporated various symbols to emulate categories of effort and acute fatigue into paediatric versions of an RPE scale. These developments have also recognised the need for verbal descriptors and terminology which are more pertinent to a child's cognitive development, age and reading ability.

The study of perceived exertion in children: a historical perspective

The late Oded Bar-Or is credited with being the pioneer of research on perceived exertion in children.[34] In 1975, he presented RPE data on 589 children (aged 7-17 years) at the First International Symposium on Physical Work and Effort, recorded during continuous, incremental cycle ergometry. All six defined age-groups reported higher RPEs with increases in power output, though compared with adults, the children tended to report a lower RPE for a given relative exercise intensity.

This research acquired a near-definitive status for the next ten years. With a few exceptions, notably an abstract by Kahle *et al*.[35] which reported an increase in the reproducibility of RPE in healthy girls as they got older, a study by Davies *et al*.,[36] which observed that anorexic girls could use RPE to discriminate between differences in exercise intensity, and Eston's[37] somewhat prescient discussion paper on the potential for using RPE in the secondary-school physical education curriculum, there were no further reports in the academic literature until 1986. In that year, there were at least five simultaneous published reports from Canada, England, Japan and the United States.[38-42] With the exception of the paper by Eston,[37] researchers focused on the RPE-objective effort (HR, work rate) relationship in the laboratory setting and in the passive 'estimation' mode, described above. From 1990, however, research began to include an active 'production' mode whereby pre-specified RPEs were used to compare objective effort measures in children.[21]

The development of child-specific rating scales

Important advances in the study of effort perception in children have occurred in the last 25 years. Despite recognition that experience of exercise was an important determinant for accurate perception of exercise intensity,[33,34,43] little regard was given to the creation of a more developmentally-appropriate scale using meaningful terminology (semantics) and symbols until 1989. In that year, Nystad *et al*.[44] published an illustrated RPE Scale with all the written descriptors removed. Six stick figures depicted various stages of effort for use with a group of 10-12 year-old asthmatic children. Despite these attempts to improve the relatively incomprehensible nature of the 6-20 scale, children were still confused by it. The investigators concluded that the children lacked physical experience and awareness of different exercise intensities, and therefore could not understand the concept of perceived exertion.

Following earlier recommendations by Williams *et al.*[24] in 1991 for a more simple 1-10 perceived exertion scale, a significant development in the measurement of children's effort perception occurred in 1994 with the publication of two papers which proposed and validated an alternative child-specific rating[25,26] (Fig. 1). Compared to the Borg scale, the Children's Effort Rating Table (CERT) has five fewer possible responses, a range of numbers (1-10) more familiar to children (than 6-20) and verbal expressions chosen by children as descriptors of exercise effort. The CERT soon became recognised as a notable advancement in the study of paediatric effort perception[45]. Studies comparing the 6-20 RPE and CERT in children aged 5 to 9 years[46] during stepping and 8 to 11 years[26,27,47,48] during cycling exercise provided support for the CERT. The latter study on 69 Chinese children utilised Chinese-translated (Cantonese) versions of both the Borg 6-20 RPE and the CERT, and observed that the validity correlations for CERT, power output, HR and VO_2 were consistently higher than those for the 6-20 RPE scale. Leung *et al.*[48] also reported CERT ratings that were more reliable than RPE across two identical continuous, incremental cycling tests.

[Figure 1 about here]

Pictorial versions of the CERT

The CERT initiative for a simplified scale containing more 'developmentally-appropriate' numerical and verbal expressions, led to the development of scales which combined numerical and pictorial ratings of perceived exertion. All of these scales depict four to five animated figures, portraying increased states of physical exertion. Like the CERT, the scales have embraced a similar, condensed numerical range and words or expressions which are either identical to [Pictorial-CERT,[29] Fig. 3], abridged from [Cart and Load Effort Rating (CALER),[32] Fig. 2; Bug and Bag Effort (BABE);[49] Eston-Parfitt (E-P)[8], Fig. 4] or similar in context to the CERT

[OMNI,[45,50] Fig. 5] The rationale for the development of these scales and their application is described below.

The principle of presenting a scale that is readily assimilated by children on the basis of their own experiences and stages of development is very important. Accordingly, Fig. 2 presents a child pulling a cart that is loaded progressively with bricks [CALER scale]. The number of bricks in the cart is commensurate with numbers on the scale. The wording was selected from the CERT to accompany some of the categories of effort. In the study by Eston *et al.*,[32] 20 children aged 7-10 years performed four intermittent, incremental active production tests at CALER 2, 5 and 8 over a 4-week period. To reach the specific CALER level the child instructed the experimenter, in the first 2-3 min, to adjust the cycling resistance by adding or taking away weights (not visible to the child). Each bout was 3 min, separated by 2.5 min rest intervals. An increase in power output across trials (44, 65 and 79 W at CALER 2, 5 and 8, respectively), confirmed that the children understood the scale. Analysis between trials indicated that the reliability of the efforts produced improved with practice. This study was the first to apply more than two repeated effort production trials in young children and provides strong evidence that practice improves the reliability of effort perception in children of this age.

[Figure 2 about here]

A pictorial version of the CERT (PCERT), initially described by Eston & Lamb,[52] has been validated for both estimation and production tasks during stepping exercise in adolescents[29] (Fig. 3). The scale depicts a child running up a 45-degree stepped gradient at five stages of exertion, corresponding to CERT ratings of 2, 4, 6, 8 and 10. Yelling first proposed the PCERT at a perceived exertion symposium hosted by the authors and Gunnar Borg at the University of

Wales in 1999. The scale had immediate appeal and was considered to be a significant improvement on the CERT. To facilitate the development of the PCERT, Yelling *et al.*[29] engaged 48 boys and girls (aged 12-15 years) in a series of play and running activities. Throughout the lessons the children were asked to focus on the exercise sensations of breathlessness, body temperature and muscle aches. Immediately afterwards, the children were presented with a copy of the CERT in the form of a stepped gradient and five pictorial descriptors and asked to locate the positions which best reflected their own perceptions of effort. The frequency with which the children positioned the visual character at given points along the scale was recorded and the most commonly chosen format was selected, resulting in the pictorial scale.

[Figure 3 about here]

The validity of the PCERT was determined in a separate group of 48 similarly aged boys and girls in two exercise trials separated by 7-10 days.[29] In trial 1, the children completed 5 x 3 min incremental stepping exercise bouts interspersed with 2-min recovery periods. HR and RPE were recorded in the final 15 s of each bout. They observed that perceived exertion increased as exercise intensity increased. This was also reflected by simultaneous significant increases in HR. In trial 2, the children were asked to regulate their exercise intensity during four intermittent 4-min bouts of stepping to match randomly assigned ratings of perceived exertion at 3, 5, 7 and 9. Bouts were separated by a 2-min recovery period. The desired step heights and frequency were determined in the first 2 min of the 4-min exercise bout by verbal feedback from the child. HR and power output were recorded in the last 15 s of each bout. The HR and power output produced at each of the four prescribed effort levels were also significantly different. Yelling *et al.* [29] concluded that the children could discriminate between the four different exercise intensities and regulate their exercise intensity according to the four prescribed ratings from the PCERT.

The utility of the PCERT has been augmented by the findings of two rather different studies, one involving an innovative application of the scale in a U.K. physical education setting,[31] the other a comparison with the Borg Category-Ratio scale among Bulgarian children.[53] The latter study examined the concurrent validity of the PCERT and CR 10 scales during incremental (estimation) laboratory treadmill running in 50 boys and girls aged 10-17 years. The children completed identical trials separated by one month, reporting their effort perceptions with one scale in the first trial, and the other scale in the second. The analysis of the associations between effort ratings and physiologic measures (VO_2, HR and minute ventilation) revealed significantly higher correlations overall (r = 0.62–0.82) for the PCERT than the Borg CR 10 scale (r = 0.51–0.71). In the way that the original CERT scale had been shown to be more valid than the 6-20 Borg scale over 20 years ago,[47] these findings lead to the conclusion that the PCERT is more appropriate for estimating exercise effort among such children than the Borg scale.

In the field-based study of Preston and Lamb,[31] 21 boys (aged 13) were requested to regulate their exercise outputs during structured (intermittent) physical education activities to match PCERT levels 3, 9, 5 and 7 (in that order). The activity corresponding to PCERT 9 was repeated a week later to assess the children's ability to reproduce their exercise efforts. Analysis of HRs recorded during the exercise bouts revealed that the children could distinguish between level 3 ('easy') and level 9 ('very, very hard'), but not so between the other levels. Additionally, whilst the reliability of effort at PCERT 9 was at best modest overall, some of the children were able to reproduce efforts that were within a relatively narrow range of HRs. These data were encouraging and (still) represent one of the very few attempts there have been to apply effort perception in circumstances of practical, health- or fitness-related value.

A more recent variation on the PCERT addresses the notion that children's perceptions of exercise effort, particularly those of young children might not rise in a linear fashion with objective markers of effort, such as HR and VO_2, but that in the later stages of exercise they increase in a *curvilinear* manner. The Eston-Parfit (E-P) scale,[54] based on early empirical observations of Lamb[47] and more recently by Barkley & Roemmich,[55] depicts an ambulatory character (running) at various stages of exertion on a concave slope with a progressively increasing gradient at the higher intensities (Fig. 4). Accordingly, the distance between each numbered increment (0-10) on the horizontal axis is increasingly reduced in relation to its antecedent. The area under the curve is also shaded progressively from light to dark red from left to right. The validation of the E-P scale was confirmed initially (against HR and ventilation responses) among 7-8 year-olds using a discontinuous incremental cycling protocol to volitional exhaustion,[54] and more recently (against HR, VO_2, and ventilation) using a discontinuous graded treadmill protocol.[56] In both studies, strong relationships ($R^2 > 0.85$) were observed between the E-P scale ratings and physiological responses, reinforcing our view that such a visual representation of exercise effort might facilitate a young child's understanding of the perceptual framework and thereby his/her ability to provide accurate ratings. Moreover, further evidence of such comprehension can be gleaned from a study in which 7-8 year-olds engaged in submaximal production ('perceptually-regulated') paradigms up to E-P scale levels 5 and 7 generated exercise outputs (VO_2 values) that when extrapolated to the highest intensity (E-P 10), yielded predictions of maximal oxygen uptake (VO_2max) that were similar to measured values.[57] Similar (unpublished) results were reported recently by Bertelsen[58] during a treadmill estimation paradigm in 8-10 year-old children. Such an application of RPE reflects the research among adults (since 2004) which has used estimation and production paradigms successfully to predict this popular measure of cardiorespiratory fitness (see Coquart *et al*.[59] for a review).

[Figure 4 about here]

OMNI scales

In recognition of the advantages of using a comparatively narrow numerical range to assess perceived exertion, such as that used in the CERT, Robertson[45] proposed the idea of using pictorial descriptors along the scale for assessing perceived exertion in children. As part of a special symposium on effort perception at the European Paediatric Work Physiology Conference in 1997, he presented the idea for a 1-10 pictorial scale (now 0-10) which would be applicable to variations in race, gender and health status, hence the term OMNI scale. His original idea was to employ, 'pictorially interfaced cognitive anchoring procedures, eliminating the need for mode-specific maximal exercise tests to establish congruence between stimulus and response ranges" (p. 35). However, since then, numerous different pictorial OMNI scales have been validated for various modes of exercise in children – for example, cycling,[50] walking/running,[60] stepping,[61] and resistance exercise.[62]

In the original OMNI scale (see Fig. 5) validation study,[50] four equal groups of 20 healthy African-American and White boys and girls aged 8-12 years, performed a continuous, incremental exercise test on a cycle ergometer. Exercise intensities were increased by 25 W every 3 min and RPE, HR and VO_2 were monitored in the final minute of each test stage. The authors reported similarly high positive linear associations (r = 0.85 to 0.94) between HR, VO_2, and RPE for each gender/race cohort of children. Consequently, this study formed the basis for a succession of subsequent validation studies (see above) utilising various forms of the OMNI in estimation protocols. Fewer studies, however, have focused on the validity of the children's OMNI scales in production mode, although of note are two involving the cycling[28] and walking/running versions.[60] Robertson *et al.* [28] reported that 8-12 year-old boys and girls could use their perceptions of effort during an intermittent cycling protocol to adjust their exercise intensities (i.e. HR and VO_2) in line with two specified target OMNI values (2 and 6), whereas Groslambert *et al.*[63] observed that younger children (aged 5-7 years) were able to regulate indoor running intensity (HR) over intermittent 300 m distances across three randomly assigned OMNI values (3, 6 and 10). Given their ages and the task at hand, this impressive finding encouraged Groslambert *et al.*[63] to posit that such findings would be of value to physical education teachers and health practitioners who use perceived exertion to prescribe running exercise in children. However, as alluded to above, published accounts of such practice are scarce.

[Figure 5 about here]

Although they were developed independently, there are marked similarities between the PCERT and the OMNI scales. With the exception of the '0' starting point on the OMNI scale, there is the same limited range of numbers, a linear gradient and culturally familiar verbal cues derived from common verbal expressions used by the children in the two respective countries (United Kingdom and United States) to describe their feelings of exertion. With regard to the verbal anchors, it is noteworthy that the original derivation and validation of the CERT was based on children aged 5-9 years of age in the United Kingdom, whereas the OMNI was based on children aged 8-12 years of age in the United States. Accordingly, such differences in maturational status and cognitive development, in addition to cultural semantics and socioeconomic status, influenced the terminologies that were originally derived for the two scales. Moreover, the common cue throughout the children's OMNI Scale is 'tired', the degree of which is indicated by various adverbs: *0 – not tired at all, 2 – a little tired, 4 – getting more tired, 6 – tired, 8- really tired, 10 – very, very tired*. In the initial validation of the scale, this trunk word appeared 475 times out of a total of 1582 verbal expressions.[50] Conversely, the verbal cues derived for use in the CERT describe degrees of exertion according to various levels of being 'easy' or 'hard' to the extent that the exercise becomes so hard that the child will stop ('so hard I am going to stop'). The appropriateness of the latter term is supported by frequent observations by the authors that young children will often stop exercising when it becomes too uncomfortable. Sometimes, there is little pre-warning of this occurrence.

The connotations of the wording in the two scales are quite distinct. In this regard, the OMNI scale assumes a baseline level of 'tiredness' from the starting point of 0. From a purely semantic and literal perspective, feeling *tired* is a term used to describe a general condition or state of fatigue, weariness or sleepiness rather than effort. It is not an indication of exertion. Anchoring the scale around the central condition of varying states of 'feeling tired' could be perceived as portraying a negative (unpleasant) perspective on the feelings experienced during physical activity, such as that experienced in children's play. Indeed, feeling tired is a common psychological barrier to engaging in physical activity.[64]We, therefore, feel that the use of this term to describe states of physical exertion is somewhat inapt. It is notable that the more recent adult versions of the OMNI scale developed initially for resistance exercise and later to be re-illustrated for other forms of exercise, utilize the terms 'easy' and 'hard'. In our view, this change of the terminology is better suited for the purpose or rating perceived exertion, for both adults and children.

Independent validation of the pictorial versions of the CERT and OMNI scales

In recognition of the dearth of data for the OMNI walking/running scale[50] and the PCERT scale in young children,[29] Roemmich *et al.*[65] examined the two scales during sub-maximal exercise. In their study, 51 boys and girls aged 11-12 years performed a perceptual estimation paradigm, comprising a five-stage incremental treadmill test to elicit about 85% of the HR max. Increases in the PCERT and OMNI scales were correlated with increases in VO_2 (r = 0.90 and r = 0.92) and HR (r = 0.89 and r = 0.92), respectively. There was no difference in the slopes of the PCERT and OMNI scores when regressed against HR or VO_2. There was also no difference in the percentage of maximal PCERT and OMNI at each exercise stage. In effect, the results showed that the two scales could be used with equal validity. In a later study by the same research group,[55] the validity of the CALER and OMNI scales was confirmed (against HR and VO_2) among boys aged 9-10 years during an incremental cycle ergometer test to exhaustion. Increases in scores on both scales were associated with increases in VO_2 (r = 0.92 and 0.93) and HR (r = 0.88 and 0.89), respectively. These results are not that surprising since the scales utilise basically the same number range. This observation raises the question as to where the child's focus of attention is based. Is it mainly on the number scale, the figures, or equally combined between the two? If attention is focussed primarily on the limited number range, it perhaps questions the need for pictorial scales of perceived exertion for children of this age range.

All but one of the pictorial scales considered above have used either a horizontal line or one that has a linear slope. Following earlier suggestions by the authors in the first edition of this text,[52] the aforementioned (E-P) scale was constructed; its rationale founded on its inherent face validity. It is readily conceivable that a child will recognise from previous learning and experience that the steeper the hill, the harder it is to ascend. This may also be helpful in the process of 'anchoring' effort perceptions (see below). Further, as ventilation is a physiological mediator for respiratory-metabolic signals of exertion during endurance exercise, and given that this variable rises in a curvilinear fashion with equal increments in work rate, a curvilinear gradient seems appropriate. Indeed, the study by Barkley and Roemmich[55] showed that the proportions of maximal CALER (75%) and maximal OMNI (74%) were substantially less ($p < 0.001$) than the proportion of HR max (94.5%). In effect, the children's RPE ratings were disproportional to the physiological effort, leading to the authors' conclusion that the upper range of linear scales would benefit from modifications to the verbal descriptors or the slope of their lines.

Methodological issues in children's effort perception research

Anchoring effort perceptions

Whatever scale is used, it is important to provide the child with an understanding of the range of sensations that correspond to categories of effort within the scale. This is known as 'anchoring'. There are three ways by which perceptual anchoring may be accomplished – from memory, by definition or from actual physical experience. The 'memory' method requires the child to remember the easiest and hardest experiences of exercise and use these as the anchor values on the scale. The 'definition' method involves the experimenter defining the anchors with terms such as 'the lowest effort imaginable' for the low anchor or the 'greatest effort imaginable' as the high anchor. The third method (experience) allows the child to physically experience a range of perceptual anchors. In 2000, Eston and Lamb[52] stated that the experiential method is the preferred of the three methods and recommended that the child should be exposed to a range of intensities that can be used to set the perceptual anchor points at 'low' and 'high' levels. This can be achieved during habituation to the test or exercise procedures. In particular, it was suggested that following a warm-up, the child should be allowed to experience exercise that is perceived as being 'hard' or ‘very hard’. To avoid fatigue, a period of time should be allowed to regain full recovery. However, Lamb *et al.*[30] questioned this assertion. In their study, 41 boys and girls aged 11-13 years, randomly assigned to either an experiential anchor group or a non-anchor group, undertook two identical production-only trials (three 3-min cycle ergometer bouts at randomised CERT levels 3, 6 and 8). Before each trial, the anchor group received an experiential exercise trial to provide a frame of reference for their perceived exertions, at levels 2, 1 and 9, in that order. The authors reported slightly better test-retest reproducibility for HR and power output in the non-anchor group, with intraclass correlation (ICC) values ranging from 0.86-0.93 and 0.81-0.95, respectively. Importantly, limits of agreement analysis indicated no marked differences between the two groups in the amount of bias and within-subject error. The implementation of an experiential anchoring protocol therefore, had no positive effect on the reproducibility of the children’s ability to self-regulate exercise using prescribed CERT levels. Further research on this theme has not been forthcoming but would seem to be merited.

In her recent overview on the use of perceived exertion in physical education, Lagally[66] reinforced the necessity of anchoring exercise sensations, possibly over the course of several lessons, if it is to be an effective tool. In particular, it was suggested that exercise (experiential) anchoring was desirable given that children have less knowledge of maximal exercise. Although this view was not empirically supported, it was recommended that a means of providing such exercise was via an incremental running protocol conducted as part of their annual fitness testing, which, in principle, would expose them to a range of intensities from low to very high. Alternatively, lessons could be structured with specific activities designed to highlight the spectrum of physical exertion. In addition, teachers could compare their ratings of intensity for such activities with the students’ and explain any differences that occur.

Intermittent versus continuous exercise protocols

The majority of investigations have typically studied children's perceptions of effort during a passive estimation process (perceptual estimation paradigm) in which ratings recorded from either intermittent or continuous protocols have been correlated against objective measures of physiological strain, such as HR, power output, or VO_2. Most studies have used a continuous protocol, as with the development and validation of the CERT[25] and the OMNI[50] scales, for example. Fewer studies have applied procedures in which children are requested to regulate (produce) their exercise output to match experimenter-prescribed effort ratings. Of these, it has been most common to compare the objective indicators of effort with *expected* values derived from a previous estimation trial.[21-23,25,28] In this so-called estimation-production paradigm, the ability of children to use perceptions of effort to *actively* self-regulate exercise intensity levels using predetermined RPEs has, in our opinion, been inappropriately compared to their ability to *passively* appraise exercise intensity from a previous test. It is, therefore, difficult to appraise children's ability to reliably and accurately produce a given objective effort from these studies. For example, in the first full paper published on this theme,[21] it was concluded that overweight children (aged 9-15 years) could discriminate between four work rates based on pre-determined RPE values (7, 10, 13, and 16). However, it was reported that the children produced work rates that were significantly different to expected (or 'criterion') values. It is necessary to point out that these criterion values were derived from a different perceptual process. Similar findings were reported in later studies.[22,23] These observations lead us to recommend that validity studies should focus on either production data only, or estimation data only, and not confound the issue by comparing data derived from a passive perceptual process on one occasion to an active perceptual process on a subsequent occasion.[8] Noble's[67] argument that this involves two dissimilar psychophysical processes is highly pertinent. Furthermore, the disparity between the two psychophysical processes is most likely attenuated by the extent of children's limited perceptual experience. This mismatch has since been recognised as a lack of 'prescription congruence'.[28]

Lamb *et al.*[68] used a production-only paradigm to assess the influence of a continuous and intermittent exercise protocol on the relationship between CERT ratings objective effort in children aged 9-10 years. Common to both groups was the requirement to regulate exercise intensity to match four randomly presented 3 min effort rating levels (3, 5, 7 and 9). The provision of 3 min recovery periods between exercise bouts produced higher relationships between CERT and HR (r = 0.66 vs. r = 0.46, for the intermittent and continuous protocol, respectively). HRs tended to be lower in the discontinuous protocol. These results indicate that children may be more able to use effort ratings to control exercise intensity when the exercise is intermittent, rather than continuous in nature.

The assessment of perceived exertion using a repeat-production paradigm examines a child's ability to discern consistently between different target RPEs while self-regulating exercise intensity.[27,30-32,49,51,68] Studies by Eston and colleagues[32,49,51] are the only ones to apply three or more repeated-effort production trials in young children (7-11 years). The increase in the size of ICCs between paired comparisons of the successive production trials in both studies support the importance of practice. For example, in the 2000 study,[32] the ICCs improved from 0.76 to 0.97 and the overall bias and limits of agreement narrowed from -12 ± 19 W to 0 ± 10 W. These data provide the strongest evidence available to-date to demonstrate that practice improves the reliability of effort perception in children of this age.

Much of our understanding of children's effort perceptions has evolved from measuring responses to a situation in which they realise that the exercise is getting progressively harder. Studies which have allowed rest periods between exercise bouts,[32,35,41,69] and thereby reduced the influence of fatigue on effort perceptions, have all been incremental in nature. Few have randomised the order of presentation of workloads.[21,29,39,68] Logically, the 'accuracy' and reliability of effort perceptions and objective markers of effort produced at specified effort ratings will be influenced by test protocol (continuous or intermittent), the order of the load presentation (incremental or random) and the timing of the data collection. Furthermore, future investigations into children's effort perception should not disregard the manner in which the exercise is applied, the duration of the exercise bout, nor the number of practice periods, as these factors seem to have a bearing on the outcome measures.

Use of effort perception scales to promote and regulate physical activity levels

Throughout the evolution of child-specific effort perception scales it has been alluded to that they could be valuable as a practical tool for helping physical educators, coaches or health practitioners both in the prescription of children's physical activity and the development of their ability to interpret feelings of exercise and self-regulate their own health-promoting physical activity.[21,23,26,27,30,66,70,71,] However, there has been little evidence thus far of this becoming a reality. In the United Kingdom, the studies by Yelling and Penny[72] and Preston and Lamb[31] (referred to above) over 10 years ago seem to be the only ones reporting a concerted attempt to integrate a perceived exertion scale (PCERT) into the delivery of structured physical education lessons. Whilst both papers highlighted that the pupils (aged 9-18 years) appeared to grasp the concept of differentiating between physical activity of varying intensity, and were quite reliable at doing so,[31] their rating of activity levels was confounded by problems or complexities, such as their concern with a range of social issues that governed the ratings that they were prepared to give.[72] In effect, and perhaps unsurprising, individual feelings and sensations of physical exertion were not the only (or principal) factors determining their ratings.

More recently, two reports from the United States have employed the OMNI walking/running scale in a school setting for monitoring students' exertions during[73] and after[74] the cardiovascular endurance element (the PACER test) of a popular fitness assessment battery. One study involving 80 students (aged 11-12 years) demonstrated, as expected, that OMNI ratings increased as intensity (speed) increased during the incremental, 20 m shuttle-running,[73] whereas the other[74] was concerned with the overall effort exerted during the PACER by a large sample (n = 792) of high school boys and girls. In the latter, it was evident that most of the students provided OMNI ratings (< 5) immediately after the test that were lower than that equating to 'tired' (6) on the scale, which was a surprise given their task was to run until volitional exhaustion. The authors concluded that, for various reasons, many of the students did not provide a 'true', (maximal) effort during, and/or OMNI response after the field test of fitness. Notwithstanding these two attempts to use an effort perception scale in a physical education environment, they did not seek to assess its sensitivity to different physical education lessons, or utility as a means of self-regulating exercise within lessons.

Concluding Comments

As the importance of encouraging physical activity in children is recognised, it makes sense to study the accuracy and reliability of effort perception in this population. While the breadth of research into children's effort perception has expanded over the past eight years, in particular there has been little progress in examining its oft stated potential for enhancing their awareness of the range of their exercise capabilities, and the impact that this has on their willingness to engage in health-enhancing activities. In the United Kingdom, it has not emerged as a priority worthy of consideration in the National Curriculum for Physical Education, possibly owing to the inertia borne out of traditional teaching, or an insufficient lobby from professionals for its worth. In the United States, given the attempts to popularize perceived exertion scales by Bob Robertson and colleagues, perhaps there is optimism here.

Summary

- Effort perception research amongst paediatric populations has been in existence for 30 years, but only since 1994 have exercise scientists endeavoured to develop rating scales that are suited to children's cognitive abilities.
- It is universally recognised that Borg's 6-20 RPE scale is unsuitable for use with children of most ages.
- RPE scales constructed with children in mind have followed the example set by the 1-10 Children's Effort Rating Table (CERT) and typically include words and/or pictures to reflect varying degrees of exercise effort.
- Strong evidence exists to support the validity of paediatric scales against objective indicators of effort (HR, VO_2 and power output) when applied via a perceptual estimation paradigm, often involving continuous incremental protocols.
- Studies employing child-specific RPE scales via a production paradigm remain relatively scarce, though the evidence thus far suggests that children can use their understanding of perceived exertion to help them regulate their exercise outputs.
- Some recent evidence suggests that the associations between children's perceived and objective submaximal efforts could provide useful predictions of their cardiorespiratory fitness.
- Research has emerged showing that practice of using the RPE scale has a beneficial effect on the consistency of its application in both estimation and production paradigms.

- The effects of adopting preparatory anchoring techniques on scale application have been virtually overlooked.
- Very few studies have explored the efficacy of using a child scale in a practical (e.g. physical education) setting and the time to consider the external validity of such scales is overdue.

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8,456 words (incl. References, but excl. Abstract, Keywords & Figures).

1	**Very, very easy**
2	**Very easy**
3	**Easy**
4	**Just feeling a strain**
5	**Starting to get hard**
6	**Getting quite hard**
7	**Hard**
8	**Very hard**
9	**Very, very hard**
10	**So hard I'm going to stop**

Figure 1. Children's Effort Rating Table.[25]

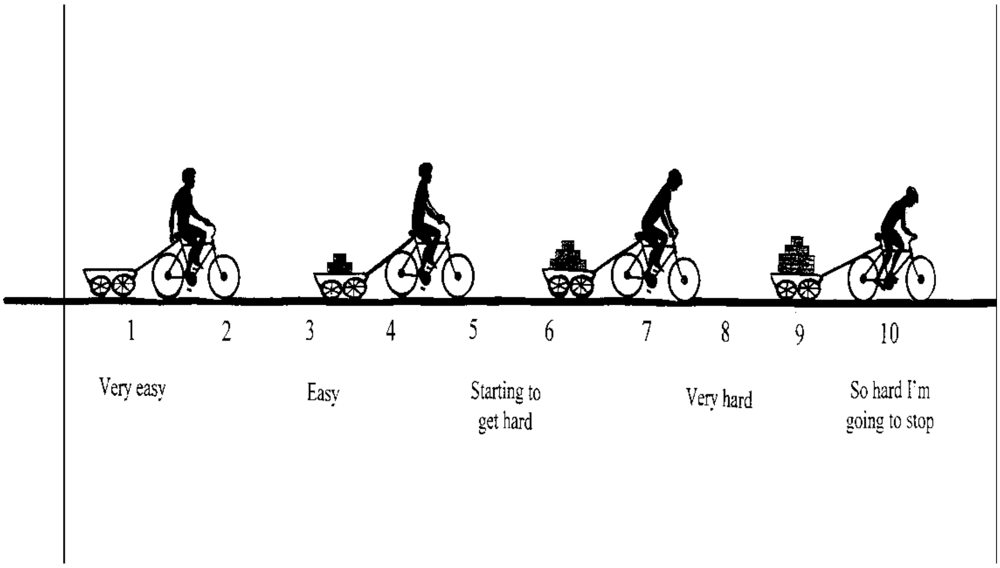

Figure 2. Cart and Load Effort Rating (CALER) scale.[32]

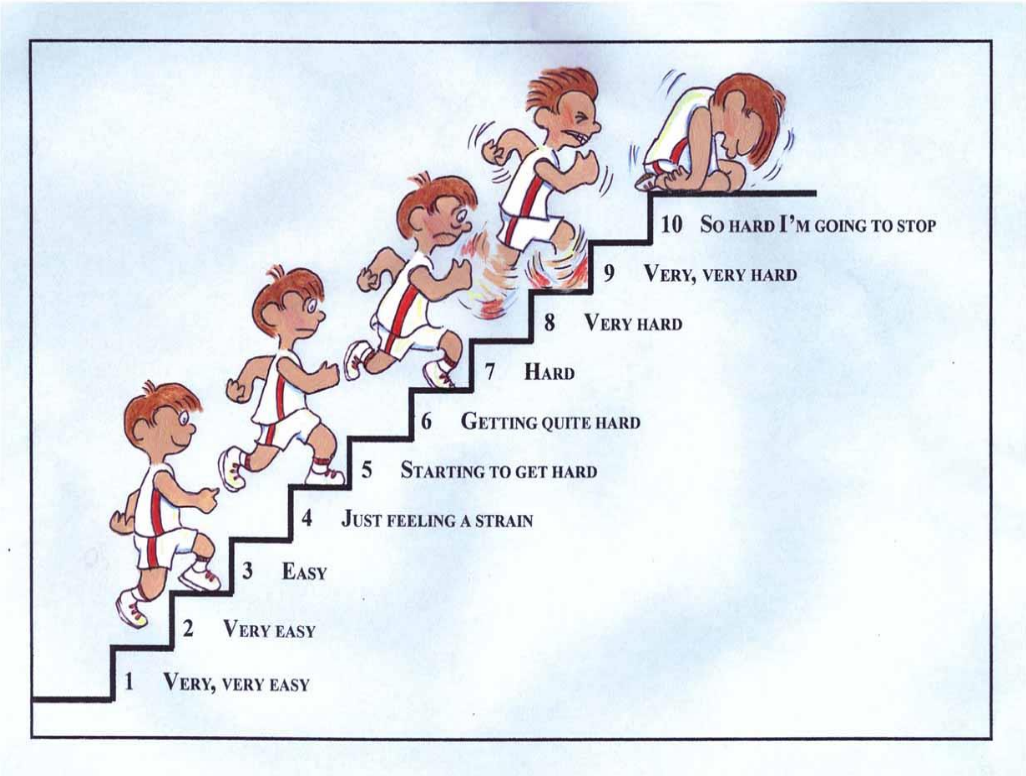

Figure 3. The Pictorial Children's Effort Rating Table (PCERT).[29]

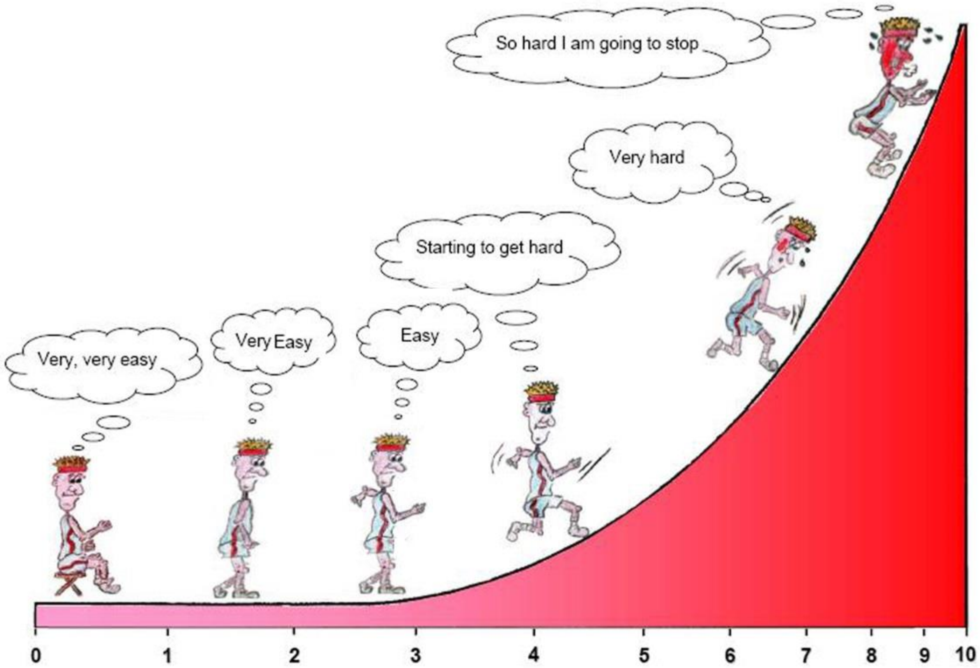

Figure 4. Eston-Parfitt (E-P) curvilinear rating of perceived exertion scale.[56]

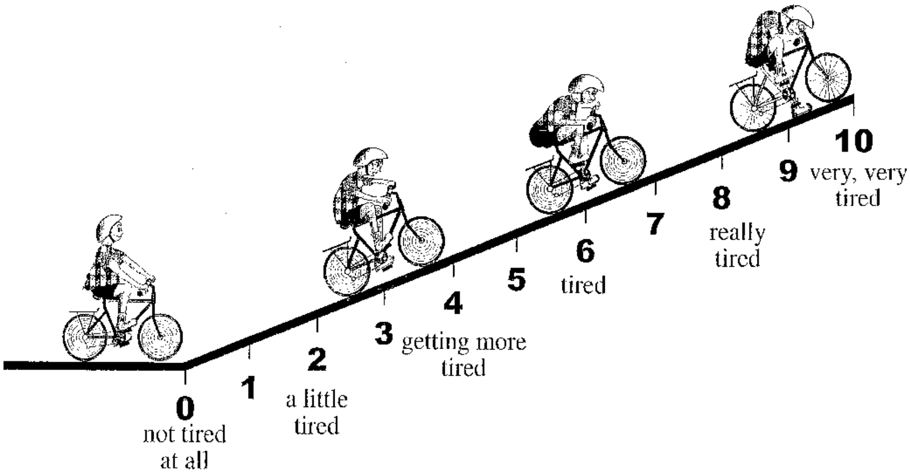

Figure 5. Original OMNI perceived exertion scale for children[50] (reprinted with permission R. Robertson, personal communication).