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The use of effort rating scales to control exercise intensity in children

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THE USE OF EFFORT RATING SCALES TO CONTROL EXERCISE INTENSITY IN CHILDREN

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SUMMARY

The literature suggests that children exhibit low levels of habitual physical activity and that many children rarely undertake the volume of physical activity believed to confer health benefits. Therefore, there is currently considerable scope for exploring the external validity and application of child-specific effort rating scales within a physical education environment. The introduction of such scales would help to determine if children can understand and apply effort sense, and use of such a concept could aid achievement of a range of attainment targets within the health-related physical education curriculum. Such attainment targets include awareness of what happens to the body during exercise, and for the child to be able to recognise and describe how the exercise makes them 'feel' (Harris, 2000).

This thesis incorporates four related studies which examine the ability of school children (aged 7 – 11 years) to utilise the psychophysical concept of perceived exertion (or effort perception) during stepping ergometry, cycle ergometry, and the real-world setting of a physical education class.

Since the emergence of child-specific effort rating scales, the scope for researching children's perception of exercise effort is now broader than ever before. Pictorial versions of paediatric effort rating scales have tended to depict youth cyclists; OMNI Scale of Perceived Exertion and the Cart and Load Effort Rating Scale (CALER). To address the issue of scale mode-specificity, the present studies set out to determine whether such scales could be used to assess the exertional perceptions of children engaged in other dynamic modes of exercise, such as stepping.

In addition, the performance of a recently developed mode-specific (stepping) paediatric exercise scale (Bug and Bag Effort (BABE) Scale) was explored across

exercise modalities. The design of the external validity study also considered the importance of children's personal scale preference.

The key outcomes of the current research were:

i. Children were able to adjust their exercise intensity (loading) to match three specific levels of perceived exertion using the Children's Effort Rating Table (CERT) and CALER Scales during an intermittent stepping protocol.

ii. Children were able to reproduce objective effort [Heart Rate (HR) and Power Output (PO)] using the pictorial versions of effort rating scales (CALER and BABE) with a higher degree of reliability compared to use of the CERT.

iii. Regardless of the type of paediatric effort rating scale employed, practice improved the reliability of results.

iv. The BABE Scale was found to be a valid and highly reliable tool for quantifying children's effort perception and for regulating exercise output.

v. Children preferred the BABE Scale to the CALER Scale in these exercise studies.

vi. Use of the CALER and BABE Scales produced similar results across exercise modalities (stepping and cycling), indicating that either effort rating scale may be employed during these exercise tasks. These pictorial versions of paediatric effort rating scales were found to be intermodal, both scales provided similar consistencies within exercise modes.

vii. For their normal Physical Education classes (circuit training), children were able to use the BABE Scale to regulate their exercise effort on specific activities.

viii. Children were more reliable in their production of exercise effort at a lower perceived exertion level (Effort Rating Level 3) during the circuit training, compared to the higher perceived exertion level (Effort Rating Level 8).

ix. Children felt more competent completing the exercise circuit with use of the BABE Scale compared to exercise circuits completed without use of the BABE Scale.

x. Recommendations for scale modifications include the addition of familiar verbal cues to all numbers, to further aid interpretation of exercise effort.

xi. Further research with the BABE Scale amongst children of various ages and across different Physical Education activities is recommended. The potential for using the BABE Scale as a resource for assisting with the delivery of Health-Related Exercise within the national curriculum should be explored.

CHAPTER 1
INTRODUCTION

Structure of the thesis

This thesis reports on a series of four empirical studies conducted between 1999 and 2001 into the ability of children to express their perception of exercise effort (perceived exertion) during randomised intermittent stepping ergometry, discontinuous cycle ergometry and the real-world setting of a physical education class.

The aim of these studies of effort perception in children is to provide a valid and reliable tool which children might use, and enjoy using, to be made aware of how they feel when they exercise and to provide an understanding of why they feel that way. Such scales could assist with the delivery of Health-Related Exercise (HRE) within the national curriculum in schools, to help children demonstrate that they understand what is happening to their bodies during exercise, an aim set out by the HRE Working Group (Harris, 2000). If children can learn to use and apply their effort sense in a variety of physical education activities this may help to regulate exercise intensity at a level which would be expected to confer physiological benefits.

To address many of the research questions relating to physical activity and health, it is essential to have a valid measure of physical activity. The rationale for this research was the introduction of new child-specific rating scales for assessing effort perception; the Children's Effort Rating Table (CERT) (Williams et al., 1994), OMNI Scale of Perceived Exertion (Robertson and Noble, 1997), and the Cart and Load Effort Rating Scale (CALER) (Eston and Lamb, 2000). In addition, to explore the efficacy of the newly developed Bug and Bag Effort (BABE) Scale designed for children participating in stepping protocols. These scales were developed specifically with children in mind, rather than the scale designed for adults, the Rating of Perceived Exertion (RPE) Scale.

The sequence of the four studies represents a developmental process. The first study was designed to collect preliminary information on the validity and reliability of the BABE and CALER Scales as tools for use with children during randomised intermittent stepping ergometry. This study also investigated whether pictorial representation (use of BABE and CALER) helped to improve reliability of effort perceptions over trials, as compared to the use of the CERT. In order to comprehensively address the issue of scale reliability, the Intraclass Correlation Coefficient and 95% Limits of Agreement methods of statistical analyses were applied. Data from this study were presented at the 10th World Congress of Sport Psychology in Greece, (Eston, Parfitt and Shepherd, 2001).

The second study was designed to address a potential criticism from the first study, and examined the effect of step height on stepping efficiency in children. In order to explore the relationship between hip angle and stepping efficiency, equations presented by Francis et al. (1998) were applied to the participants from the first study, in order to determine the range of hip angles that the children were working at during the intermittent stepping task. Results were presented to the School of Sport, Health and Exercise Sciences, The University of Wales, Bangor, and showed that the children were at optimal efficiency during the stepping protocol and had not been at a mechanical disadvantage. Alterations between subjects for relative leg length and hip angle did not result in significant changes in the physiological economy of the stepping task. Results were therefore shown to be valid.

The BABE Scale, depicting an ant stepping with a backpack of coloured rocks, had been specifically designed for use with children during stepping protocols. The CALER Scale, depicting a youth cyclist towing a cart loaded with bricks, has mainly been employed for children participating in cycling protocols. The third study was therefore designed to evaluate the validity and reliability of the BABE and CALER Scales for intra- and intermodal regulation of effort production using intermittent cycling and stepping ergometry. This study also examined the issue of scale preference in study design.

Building on this, the fourth study addressed an important and previously under-explored area of scale generalisability, by exploring the external validity of the BABE Scale in physical education classes (circuit training) for children.

The final section of this thesis (excluding appendices) concludes the current programme of research. Consequently it summarises the insight gained and offers guidance for future investigations in this area.

Summary of Review of Literature

The interest in adult's perception of exercise effort has been buoyant for over 30 years and remains the focus of considerable research activity amongst exercise and sport scientists. The application of perceived exertion is now established amongst clinicians, but was first recognised by Gunnar Borg in 1970, who acknowledged that self-reports of perceived exertion had a place in training and rehabilitation settings.

It is pertinent to review the literature relating to effort perception in adults since this 'sets the scene' for the ensuing programme of research on effort perception in children. The following review of literature will show that a body of research on children and effort perception has developed over the last twenty years. By accepting that a tool like the rating of perceived exertion (RPE) scale has face validity (with regard to the verbal expressions used) and criterion validity (with regard to its association with objective measures of effort), a platform is created from which alternative, subject-specific scales, such as those that feature in the studies of children that follow, can readily be devised and their utility assessed.

In general, more attention deserves to be given to assessing the efficacy of alternatives to the RPE Scale, in order that prospective consumers of this knowledge, such as physical educators and health promoters, can begin to contemplate their external validity in a variety of exercise settings.

There are a number of different perceived exertion scales that have been developed to assess subjective effort during exercise in children. These include the CERT (Williams et al., 1994), OMNI Scale (Robertson and Noble, 1997), and CALER Scale (Eston et al., 1999).

In paediatric exercise science over the last thirty years, the Borg (1970) 6-20 RPE scale has been the most widely used scale of perceived exertion. Until the 1980's, relatively little information was available on the way children and adolescents rated the intensity of their effort, although the possible use of the RPE in prescription of exercise for healthy or disabled children was suggested. Since the introduction of the CERT and development of the OMNI and CALER scales it is now accepted that the Borg RPE scale is unsuitable for use with children. The range of ratings (6-20) and verbal cues used to describe the ratings were designed for adults. The literature indicates that children have found the structure of the RPE scale awkward to conceptualise and thus comprehend, which questions the validity of using the RPE scale with children.

Regardless of the choice of scale, it is important that children are familiar with using the scale to maximize the likelihood of reliable and valid ratings of effort sense. This will include cognitively appropriate scale instructions, anchoring of the scale (i.e., assigning a low and high perceived exertion level so that during exercise children can be instructed to use the scale anchors to define the range of feelings within which to estimate or produce a level of effort on the scale), and adequate practice to improve reliability of exercise effort.

The new child-specific effort rating scales have a more familiar (1-10) numerical range of effort, and verbal cues which accompany all 10 numbers, representing words chosen and understood by children as descriptors of exercise effort (Williams et al., 1994). These scales offer an attractive and more valid alternative for use with children and have the potential application of encouraging / increasing physical activity and the delivery of optimal training intensities during school-based physical education lessons. Epstein et al. (1985) recommend the encouragement of lifestyle activities over regimented activities, since recreational and 'fun' activities will increase adherence. Simons-Morton et al. (1987) argued that increasing children's physical activity was a more important health goal than improving physical fitness. Health professionals and teachers should consider the special and important role school physical education has in encouraging children's physical activity. The hypothesis is improved physical education programmes for children could help prevent the next generation of adults from becoming so sedentary, thus reducing the incidence of hypokinetic disease. Health-related physical education programmes (Dwyer et al., 1983; Maynard et al., 1987) have been shown to improve children's levels of physical activity and decrease their coronary heart disease risk factors.

The literature suggests that physical activity in children is vital to health. Use of child-specific effort rating scales in a physical education environment may be desirable to; i. Encourage children to be more active, and ii. Enable children to self-regulate exercise. iii. Help achieve a range of Health-Related Exercise (HRE) attainment targets in the national curriculum for Physical Education and, iv. Could also be used as a tool to aid class discipline.

CHAPTER 2
REVIEW OF LITERATURE

Effort Perception

The Use of Effort Rating Scales to Control Exercise Intensity in Children

1. Physical Activity and Health in Adults

Prior to reviewing the literature on physical activity and health in children, it is pertinent to examine the relationships between physical activity and health in adults, since this provides a benchmark for paediatric studies.

Morris and colleagues (1953) were the first to compare the prevalence of coronary heart disease between active and sedentary adults. They compared 'sedentary' bus drivers with 'active' conductors who worked on double-decker buses for the London Transport Executive. It was reported that the more physically active conductors had 30% less occurrence of all manifestations of coronary heart disease and 50% fewer myocardial infarctions. Mortality from coronary heart disease was less than half as frequent in the conductors. In addition, when compared to less active government workers, postmen, like conductors, seemed to have protection against coronary heart disease. More difficult to explain was that the more active individuals in this study, i.e., the conductors and postmen, had approximately twice the frequency of angina pectoris. However, the study provided evidence that exercise protected against heart disease and helped to reduce premature mortality. To gain some protective effect, Morris et al. (1953) noted that considerable amounts, or high intensities of exercise, were not required.

In a follow-up study on the Physique of London Busmen, Morris et al. (1956) reported that on entry into the Transport Executive, for any given height, the bus drivers were fitted with trousers that had at least a 1-inch larger waist circumference than those of the conductors. In addition, the drivers had higher serum cholesterol and blood pressure levels (Morris et al., 1966). However, because the drivers and conductors were already different upon entry into the Transport Executive, it was difficult to determine if the higher physical activity levels of the conductors assisted in lowering their coronary heart disease risk, or if the conductors were different, even before entry into the Transport Executive.

In adults, physical fitness and activity are inversely related to mortality (Paffenbarger et al., 1986; Powell et al., 1987; Blair et al., 1989). Epidemiological studies on the physical activity and mortality rates of Harvard College alumni (Paffenbarger et al., 1994; Paffenbarger and Lee, 1997; Lee and Paffenbarger, 1998, 2000, 2000a) have shown that adopting and maintaining a physically active lifestyle, quitting cigarette smoking and remaining normotensive independently delayed all-cause mortality and extended longevity.

Being overweight, with a family history of hypertension, increased the risk of developing hypertension, which itself, was reported to be a strong predictor of premature death (Paffenbarger and Lee, 1997). The intensity of the physical activity is reported to be more important than the energy output levels in reducing risk of hypertension and preventing premature death (Paffenbarger and Lee, 1997). Participation in moderately vigorous sports led to a reduced risk of hypertension. Light sports, walking, and climbing stairs were reported not to alter that risk (Paffenbarger and Lee, 1997).

Physical activity is reported to be associated with decreased risk of stroke in men (Lee and Paffenbarger, 1998). Walking $\geq$ 20 -km/wk and expending 1000-2999 kcal/wk was reported to be associated with significantly lower risk, independent of other physical activity components (Lee and Paffenbarger, 1998). In addition, data from Lee and Paffenbarger (2000a) suggest that accumulation of short bouts of physical activity were associated with decreased coronary heart disease risk. This might be a more attractive exercise option to sedentary individuals who are trying to increase their activity levels, compared to undergoing longer, continuous, physical activity.

In conclusion, a sedentary lifestyle in adulthood is a major factor contributing to the increased prevalence of coronary heart disease and stroke (Boyd Eaton et al., 1988). By improving fitness in middle age, all-cause mortality can reduce by more than 50% (Erikssen et al., 1998). Public health professionals should emphasise and promote the need to reduce adult sedentary behaviour by increasing leisure-time activity levels, as well as incorporating physical activity into daily life (Lee et al., 1997). Activities that have been reported to significantly reduce risk of developing coronary heart disease include mowing the lawn (Leon et al., 1987), walking and climbing stairs (Paffenbarger et al., 1986) and gardening (Leon et al., 1987). Such activities may not be ideal for increasing activity levels in children. However, the data suggests that total energy expenditure might be the main dimension of activity for improvement of health in sedentary adults, rather than the mode, intensity, frequency or duration of physical activity (Boreham and Riddoch, 2001).

2. Examining Physical Activity in Children and Youth

2a. Evaluating Physical Activity and Energy Expenditure in Children

The apparent decline in children's physical fitness represents an important national concern (Ross and Pate, 1987; Cale and Almond, 1992; Armstrong, 1995, 1995a; Armstrong and Welsman, 1997). Researchers have attempted to gather information on children's perspectives on exercise and physical activity in order to increase knowledge about the role of attitudinal and belief characteristics to children's activity patterns. In order to do this, a variety of scales have been developed including a scale for assessing children's perceptions of physical competence (Harter, 1982), children's intrinsic / extrinsic motivational orientation in physical activity and sport (Weiss et al., 1985) and a scale to measure children's knowledge about exercise behaviour and exercise intentions (Ferguson et al., 1989).

Other scales have been developed in order to examine energy expenditure levels in young children. The five-level Children's Activity Rating Scale (CARS) designed by Puhl et al. (1990) was used to categorise the intensity of physical activities and discriminate between levels of energy expenditure. Energy expenditure for each level was assessed by measuring oxygen consumption and heart rate of 5-6 year old children (12 boys, 13 girls) whilst they performed 8 activities representing the CARS levels. Oxygen consumption levels and heart rates at each level were significantly different from all other levels. It was reported that the CARS encompassed a wide range of energy expenditures, distinguished between energy expenditure levels and could be used by researchers to reliably evaluate physical activity and estimate energy expenditure of young children (Puhl et al., 1990).

In 1991, Brustad reviewed the use of psychometric scales including the Children's Attitudes Towards Physical Activity (CATPA) developed by Simon and Smoll (1974). This scale was directly patterned after the adult scale by Kenyon (1968); Adult's Attitudes Towards Physical Activity (AATPA). It was reported that CATPA had questionable validity, the six factors on the scale were developed from adults not children, and the scale was found to have poor test-retest reliability (Smoll and Schutz, 1980). Measures employed must be appropriate for use with children, instruments from adult populations, which reflect adult ideas about how children should think, are not deemed suitable. Researchers must thoroughly assess the psychometric properties of measures they employ and future research should explore children's orientations towards health-promoting aspects of physical activity, not only attitudes towards participation in sport or physical education (Brustad, 1991). The validity and reliability of assessment scales must be established so that future investigators can use such measures with confidence.

Physical inactivity is becoming a major public health problem. Children's physical activity levels have declined in recent decades, with children today expending approximately 600 kCal /day less than their counterparts 50 years ago (Boreham and Riddoch, 2001). Physical inactivity during childhood is believed to be a significant risk factor for cardiovascular disease in adulthood (Sallis et al., 1992; Paffenbarger and Lee, 1996). Three main benefits from adequate physical activity in childhood have been highlighted by Boreham and Riddoch (2001); i. Active children generally display healthier cardiovascular profiles, ii. There is a biological carry-over effect from childhood into adulthood, whereby adequate childhood physical activity suggests improved adult health , and iii. There may be a behavioural carry-over into adulthood, whereby active children are more likely to become active (healthy) adults. However, measurement of activity in children is problematic (Riddoch and Boreham, 1995). A need, therefore, exists to find a valid and standardised method for assessing habitual physical activity levels in childhood.

The validity of methods used to evaluate physical activity and energy expenditure levels of children has been questioned. Saris (1985) and Rowlands (2001) reviewed a range of methods used to assess and evaluate daily physical activity and energy expenditure in children and discussed the problems associated with assessment. Amongst the methods reviewed were indirect calorimetry, doubly labelled water, observation, heart rate monitoring, activity questionnaires and diaries, and movement counters. It was reported that in most methods, conclusive validation studies had yet to be undertaken (Saris, 1985). Each of the methods presented had at least one negative aspect, such as a low degree of social acceptability, and questionable reliability. For example; for children completing activity questionnaires there were limitations associated with the recall of activities. It was therefore recommended that a combination of methods be used to measure daily physical activity and energy expenditure in children (Saris, 1985).

2b. Use of Pedometry

Studies that have used mechanical pedometers (Gayle et al., 1977; Washburn et al., 1980) have generally found that they are inaccurate at counting steps or measuring distance walked. However, a more recent study (Bassett et al., 1996), has reported that the newer electronic pedometers provide a reasonably accurate estimate of step counts and distance walked. Therefore, pedometers have potential use as tools for measurement of daily physical activity. Pedometer readings from children have been shown to correlate highly with observation. Saris and Binkhorst (1977) reported differentiated pedometer readings between the most and least active 4 - 6 year old children as predetermined by a supervisor's questionnaire ($p<0.0001$) and confirmed by observation ($p<0.01$). Running activity of kindergarten children as determined by observation (Nishikido et al., 1982), has also been shown to correlate with pedometer readings.

Use of the Yamax Digi-walker SW-200 pedometer was explored by Eston et al., (1998). This pedometer was found to be as valid as heart rate monitoring and uniaxial accelerometry when assessing the energy cost of a range of children's activities (Eston et al., 1998). Thirty 8–10 year old children from North Wales participated in the study. The children wore the pedometer on their hips while playing catch, playing hopscotch, walking (2 speeds), and running (2 speeds). Activities involving inclines or carrying loads were not included in the study. It was reported that additional pedometers (wrist and ankle) did not improve the estimation of energy cost (Eston et al., 1998). These results have been replicated with twenty-one 8-10 year old Hong Kong Chinese boys (Louie et al., 1999). Louie et al. (1999) recommend the use of pedometry in large population studies and report that triaxial accelerometry (which stores movement data including frequency, intensity, duration and also measures activity in three dimensions) provides the best assessment of energy expenditure in children.

Despite methodological problems associated with the estimation of physical activity in young people, the data are remarkably consistent. Many young people seldom experience the volume of physical activity associated with health-related outcomes (Armstrong and Welsman, 1997). Boys are reported to be more physically active than girls during childhood and girl's activity levels decline more rapidly than those of boys as they progress through adolescence (Sallis, 1993; Armstrong and Welsman, 1997). However, the difference between the activity levels of boys and girls is greatly reduced when moderate activity alone is compared, indicating that boys participate in more vigorous exercise than girls (Riddoch and Boreham, 1995).

2c. Active Children, Active Adults?

There is limited evidence for the tracking of physical activity from childhood into adulthood (Activity and Health Research, 1992). However, data from retrospective studies support the premise that inactive young people are unlikely to become physically active adults (Armstrong and Welsman, 1997).

Even if research suggested a weak association between physical activity and improved cardiovascular health of children, an active lifestyle in childhood should still be promoted (Gutin and Owens, 1996). An active lifestyle in childhood could delay or prevent chronic diseases, either directly or by increasing the likelihood of carrying-over activities into adulthood. Thus, health care costs could be reduced and quality of life improved (Rowlands, 2001). However, without valid and objective measures for assessing children's physical activity, future health benefits relating to children's physical activity cannot be determined. In addition, the degree of tracking of physical activity from childhood to adulthood can not be resolved without an objective method for the measurement of activity levels throughout childhood and adulthood. With children and adolescents the challenge lies with the encouragement and adoption of active lifestyles, which are likely to be sustained into adult life.

2d. Children's Adherence to Physical Activity

Researchers have explored children's adherence to physical activity. Ewing (1981) explored the reasons why "dropping out" of sport in general seemed to start at twelve years of age. It was reported that children whose main motive for sport was to demonstrate their ability, might drop out either because the sport they played gave them insufficient opportunity to show their ability or because they thought they lacked ability. It was suggested that children younger than twelve thought that effort was ability, and that they needed to try harder and show more effort in order to succeed (Ewing, 1981). Whereas, children older than twelve could distinguish between effort and ability, they realised that ability represented capacity, and that the effort alone was not enough.

In 1982, Dishman reported that other situational factors also influenced adherence behaviour. These included the exercise leader, convenience of the time and setting, initial selection of workloads, and the exercise mode and intensity. All structured exercise experiences were reported to be strongly influenced by the qualities of the exercise class leader (Dishman, 1982). Surprisingly, this is an understudied area in exercise psychology, despite the recognition of its potential importance. In a study on adherence to exercise in 179 obese children (at least 20% overweight for their height and age), Epstein et al. (1984) reported that the amount of exercise influenced adherence. The mechanism for this effect was not known but the greater the exercise expenditure, the greater the adherence problem. It was also suggested that incidence of injuries could also increase with the amount of exercise, which in turn would lead to reduced adherence (Epstein et al., 1984). Data on exercise adherence in obese and non-obese children is still limited.

2e. Physical Fitness in Children and Youth: What needs to be done?

In 1988, the ACSM published an opinion statement on Physical Fitness in Children and Youth, which highlighted three areas where action was required; i) Physical education classes ii) Influences by parents and the health care profession and iii) The role of physical activity in schools.

i) Physical Education Classes

It was reported that physical education classes devoted instructional time to physical fitness activities, but allocated class time was generally insufficient to develop and maintain optimal physical fitness. It was reported that a substantial amount of time was being lost by providing instructions, or waiting in line to play in sports (Public Health Service, 1991). It was suggested that classes should waste less time and include more physical activity (Public Health Service, 1991). In the United States, Faucette et al. (1990) observed 226 Physical Education classes and found that most classes consisted of game play in which only a few children were active while the remainder waited their turn. The main findings from this study were that; i. At least 50% of children do not have adequate time for physical activity in school physical education programmes. ii. During scheduled lesson time children are not very active and are not being prepared for lifetime physical activity and, iii. Teachers not trained in physical education deliver most classes. Indeed, over ten years later, informal discussion with the headmistress of a local Primary School in Wiltshire, England, supports this research. It seems that there has been little improvement in the quality and time allocated to children's physical education classes. With effect from September 1998, in line with government guidelines, three hours of Physical Education in the school were reduced to two hours in order to accommodate the introduction of a new literacy/ numeracy programme. In line with government guidelines, one of the physical education hours was required to be swimming.

By the time the children had travelled to the swimming pool and had changed, this non-weight bearing activity only lasted for 30-minutes. The other physical education hour on the timetable (15-minutes allocated for changing) was games. This session typically included a warm-up, stretching, and skills. The headmistress acknowledged that there were a small number of children who were always 'reluctant participants' in this activity. It was hypothesised that possible reasons for this included their dislike of the 'competitive' element, fear of being laughed at/ not very good at it, fear of injury on contact with other participants and general dislike of playing sports outside on the playing field. The headmistress acknowledged that these factors would most likely affect present and future adherence to exercise. The strongest drive to keep this hour of competitive games on the timetable as opposed to gymnastics, dance or other forms of activity had come from the parents of the school concerned.

The parents seemed to like their children participating in competitive team sports. In addition, from September 2000, the two hours allocated to Physical Education were under further threat due to the school having to follow new guidelines and offer extra lessons in areas such as 'Citizenship'. Already, literacy and numeracy have been introduced at the expense of Physical Education.

Government guidance must recognise the importance of Physical Education in the curriculum, and should help to promote health and fitness through a range of activities. It must be ensured that future government guidelines do not have the effect of diminishing the Physical Education programme within schools. Interventions to increase physical activity in young people must involve schools and centre on the important role that curriculum physical education can play (HEA, 1994). However, this may require a re-orientation of programme philosophy in some cases.

ii) Parental Influences

Home influences were also acknowledged by the ACSM (1988) as an important factor towards the adoption of lifelong physical activity in children and youth. It was suggested that parents should be encouraged to show concern for their child's health and well-being, and actively promote physical fitness (ACSM, 1988). It was also recommended that more continuing education programmes on childhood and youth physical activity should be offered to health care professionals in order for promoters to become more actively involved in physical fitness for children and youth.

iii) Physical Activity in School

The ACSM (1988) recommended that professional efforts were required in order to develop, pre-test, and publish educational materials suitable for use in schools. Such materials include the development and implementation of training programmes, in order to provide teachers with the knowledge and skills required to deliver a range of exercise experiences to young people. In addition, Bizley (1999) observed that teachers also required assistance in ways to integrate other aspects of health promotion (for example good nutrition) into instruction about exercise and physical fitness. If schools were to implement physical activity initiatives like those at Biddick School and Sports College, and Penryn College, children might improve their exercise experiences and enjoyment of Physical Education lessons.

2f. Opportunities to Participate in Physical Activity

In 1971, Hillman et al. surveyed children in five areas of England in order to explore their travel patterns and levels of personal freedom. The survey was repeated in 1990 in the same areas and results revealed a remarkable decline in children's freedom and choice to do things independently outside the home. Furthermore, results demonstrated that girls experienced substantially less independence than boys. This research is supported by Armstrong and Welsman (1997) who reported that girls had fewer opportunities to participate in community-organised physical activity and sport, and both school physical education curricular and extra-curricular activities appeared to be more appealing to boys than girls.

Children and young people (under 16 years) should be recognised as priority groups for the delivery of promotional messages and strategies (HEA, 1994). The year 2000 objectives for young people set out by the HEA were to increase regular exercise and to promote physical education. The Health Education Authority's (1994) recommendations focused specifically on school-age children, in order to provide education, skill development and specific experiences of the enjoyment and benefits of physical activity. Enjoyable, well-run physical activity programmes in schools were seen as the basis for lifelong habits and the capacity to make informed choices. Training programmes to enhance teachers' confidence and skills were regarded as a priority (HEA, 1994). Well-designed induction and training programmes for teachers were seen as essential, so that educators possessed the necessary skills and confidence to run interesting, stimulating lessons.

The HEA (1994) expressed concern that educational reforms potentially hindered the provision of quality health-related physical activity education to young people. It was acknowledged that health-related physical activity was being 'squeezed out' of the national curriculum in favour of traditional competitive team sports, most of which are not played by adults.

Methods for promoting the maintenance of physical activity through the transition from school to joining the workforce were highlighted as a key issue (HEA, 1994). It was suggested that physical education of sufficient quantity and quality would provide students with a chance to achieve some of the health benefits of physical activity. The educational process was regarded as critical in educating and providing opportunities for young people to become independently active for life.

3. Current Fitness Levels of Children

3a. Assessing Children's Exercise Habits and Fitness Levels

Researchers have employed a variety of methods to assess the current fitness levels and exercise habits of children and adolescents. Of these studies, only a limited number have reported that activity levels of children and adolescents were indeed adequate. In 1981, studies conducted in Canada (Canadian Fitness Survey) and America (Gilliam et al., 1981) reported conflicting results on the current physical activity levels of children. The Canadian Fitness Survey (1981) provided a detailed account of the physical recreation habits, physical fitness and health status of the Canadian population. More than 23,000 persons aged 7 years and upwards participated in the survey. The Canadian Home Fitness Test (step test) was used to determine recommended VO_2 max, based on the duration of stepping (Bailey et al., 1976).

It was reported that approximately 75% of young children were able to reach the desired fitness level of 49.9 ml/kg/min for males and 42.7 ml/kg/min for females. The survey found that approximately 75% of young children were sufficiently active (children were classed as active if they did an average of three or more hours of physical activity per week, for nine months of the year or more). However, this measure of activity did not determine the intensity of the children's activity, only the frequency and duration. It was therefore difficult to determine if the physical activity was sufficient to enhance their health status. These positive results regarding the activity levels of children were supported by an assessment in Finland of children's levels of leisure time activity (reported via a questionnaire), which concluded that a large proportion of Finnish children and adolescents were physically active (Telama et al., 1985).

Despite the positive results reported by the Canadian Fitness Survey (1981) and Telama et al. (1985), conflicting research exists that suggests that current fitness levels and activity habits of children and adolescents are poor. Gilliam et al. (1981) investigated the physical activity levels of primary school children aged 6 years in the United States. Heart rate was recorded over a 12-hour period (8am - 8pm). A heart rate of 160 bpm was chosen to indicate an intensity of activity appropriate for promoting health. Boys had heart rates of more than 160 beats/ minute for 7.8% of the time and girls for 4% of the time. Although this equates to approximately 56 minutes and 29 minutes of physical activity for boys and girls respectively, it was reported that these physical activity levels were insufficient to develop the cardiovascular system and promote cardiovascular health (Gilliam et al., 1981). A follow-up study conducted a year later with primary school children aged 7 years (Gilliam et al., 1982) corroborated these earlier findings.

Other international research conducted in Japan and Australia support these findings. The study in Japan (Atomi et al., 1986) investigated the physical activity levels in eleven 9-10 year old boys with reference to aerobic power or lactate threshold. Heart rate was monitored for 12 hours on three different days as a measure of physical activity. Boys were reported on average to spend only 4.7% of their time at heart rates equivalent to 60% of maximal aerobic power.

In Australia, a questionnaire survey (The Australian Health and Fitness Survey, 1987) revealed relatively low levels of activity in young children, especially activity of an intensity necessary to promote cardiovascular health. Children were asked, "In most weeks, do you get exercise or activity 3-4 times which makes you 'huff and puff' and lasts at least 30 minutes each time?" For the boys 50% said they did not, for the girls 61% said they did not.

In 1990, two studies (Armstrong et al., 1990; Simons-Morton et al., 1990) also concluded that physical activity levels amongst British and American school children were inadequate. Armstrong et al. (1990) examined patterns of physical activity among 266 British school children aged 11-16 years to assess whether they experienced sufficient intensity and duration of physical activity in order to stress the cardiopulmonary system. Continuous heart rate monitoring was used for 12-hour periods over three schooldays and one Saturday. Main outcome measures were the percentage of time and number of sustained periods in which heart rate was greater than 139 bpm.

It was reported that British children had surprisingly low levels of habitual physical activity and that many children were not experiencing the volume of physical activity believed to benefit the cardiopulmonary system (Armstrong et al., 1990). The study conducted in Texas (Simons-Morton et al., 1990) assessed the type and frequency of participation in moderate-to-vigorous physical activity lasting more than 10-minutes in children aged 8-9 years. Eight hundred and seventy pupils completed a self-report questionnaire form. The researchers considered children who reported less than one session of moderate-to-vigorous daily physical activity to be less active than recommended. The results revealed that only 33.1% of boys and 35.2% of girls achieved an adequate number of sessions. It was concluded that many children were not getting adequate amounts of physical activity (Simons-Morton et al., 1990).

However, results from these studies can be questioned. It is inappropriate to apply adult fitness training criteria (such as sustained periods of activity) to children, due to the different patterns of physical activity that children exhibit (Riddoch and Boreham, 1995). Children's activity patterns are sporadic in nature, rather than sustained (Riddoch, 1998). Bailey et al. (1995) observed the level and tempo of physical activity of 6 to 10 year olds over nine 4-hour periods. Results indicated that children's physical activity was characterised by very short bouts of intense physical activity interspersed with intervals of low to moderate-intensity physical activity. The researchers did not record any single bout of intense activity lasting 10 minutes.

Investigators (Gilliam et al., 1981; Armstrong et al., 1990) have also tended to select an arbitrary heart rate threshold (≥ 160bpm and ≥ 139 bpm, respectively), above which they consider activity to be beneficial to health, without reference to the fitness level of the children. Riddoch and Boreham (1995) highlighted that the arbitrary selection of different health-related thresholds can lead to inconsistencies between studies and possible errors in interpretation of what constitutes acceptable levels of physical activity. In addition, because children's activity is characterised by numerous short bouts of activity (which may be forgotten), activity recall such as that employed by Simons-Morton et al. (1990), is inappropriate. Studies based on self-reports tend to underestimate relationships between physical activity and health (Riddoch, 1998). Objective methods are therefore more valid for measuring children's activity patterns (Riddoch, 1998).

Pate et al. (1994) estimated that over 80% of adolescents (aged 11 to 21 years) met the NIH Consensus Development Panel's Physical Activity and Cardiovascular Health (1996) guidelines to accumulate at least 30 minutes or more of moderate-intensity physical activity each day. However, Pate et al. (1994) estimate that only 50% of adolescents meet the NIH guideline of participating in three or more sessions of 20-minute moderate to vigorous-intensity physical activity. This would suggest that most young people are not sufficiently active. However, as previously mentioned, sustained bouts of physical activity are not characteristic of young people's physical activity patterns. Thus, research results can be misleading.

3b. A Sedentary Lifestyle: What's the Problem?

Many youngsters have adopted sedentary habits, and promoting and fostering more active lifestyles should be a priority for all agencies interested in the current health and well-being of children and adolescents (Armstrong, 1995; 1995a). The implication of sedentary habits in childhood and youth is the development of Coronary Heart Disease risk factors, which research has shown track into adulthood (Clarke, 1978; Berenson, 1980; Freedman et al., 1985; Berenson et al., 1992; Boreham et al., 2002). Childhood overweight and obesity have increased in the U.K. In addition, many young people aged 5–18 years have at least one modifiable risk factor (Boreham et al., 1992; Biddle et al., 1998).

The Amsterdam Growth Study (Kemper, 1985) provided important information on children's habitual physical activity levels. The study was conducted in the Netherlands on 215 girls and 195 boys aged 13 to 14 years. Self-reporting of physical activity, three-day pedometer monitoring and two-day heart rate monitoring was used to estimate the children's habitual physical activity levels. In the first year of the study, boys were reported to spend 30 minutes per day and girls 37 minutes per day with heart rates above 150bpm (Verschuur et al., 1984). Activity scores from the pedometer monitoring showed that boys spent significantly more time on 'heavy' activities than girls. Girls spent more time than boys on 'light' activities. No gender differences for 'medium-heavy' activities were identified. Subsequent annual measurements showed that as age increased, children's habitual physical activity levels gradually decreased (Verschuur and Kemper, 1985). This was the case for both boys and girls.

From a health perspective, Biddle et al. (1998) have presented three main rationales for encouraging young people to take part in regular physical activity; i) to optimise physical fitness, current health, well-being and growth and development, ii) to develop active lifestyles that can be maintained throughout adult life and iii) to reduce the risk of chronic diseases in adulthood.

3c. Blood Pressure, Fitness and Obesity in Children and Youth

To learn more about these factors, the SCAN (Study Children's Activity and Nutrition) longitudinal study was initiated in the United States (Gutin et al., 1990). Two hundred and sixteen primarily Hispanic (91%) or non-Hispanic black (7%) children aged 5 to 6 years old were the focus of the study. Aerobic fitness was measured using a treadmill protocol. The children walked at a speed of 4 km/h starting at 0% grade for 2-minutes, after which the grade was increased by 5% every

2-minutes. Criteria for test termination were a heart rate above 170 bpm, or volitional exhaustion. Heart rate was plotted against work stage and extrapolated to the percent grade corresponding to a heart rate of 170 bpm. In addition, blood pressure, body mass index (BMI) and percent body fat by skinfolds were evaluated. The values of boys and girls were compared with unpaired t-tests. Univariate and multiple regression analyses were used to examine the separate and combined relations of fitness and fatness to blood pressures.

Results showed that boys had higher aerobic fitness than girls ($P<0.001$), while BMI did not differ between the sexes. Boys or girls who were aerobically fitter had lower diastolic BP, and fatter boys had higher diastolic BP. Systolic BP was higher in fatter boys and girls. It was reported that boys were generally fitter than girls and that for all children studied, fitness and fatness were inversely related (Gutin et al., 1990). Results from this study suggest that early intervention could be considered for children as young as five and six years old to help prevent cardiovascular disease.

Shea et al. (1994) also employed longitudinal analysis to explore whether changes in aerobic fitness and body mass index were related to the age-related rise in blood pressure in 196 healthy pre-school children over a mean follow-up period of 19.7 months. Results revealed that a greater increase in aerobic fitness, as measured by change in physical work capacity on a treadmill at a heart rate of 170 bpm, and a smaller increase in BMI were independently associated with a smaller increase in BP in children aged 5 years. Mean systolic BP was 95.3 mmHg ± 8.38 at baseline and increased by 4.46 mmHg per year ± 3.92. Mean diastolic BP was 53.9 mmHg ± 5.81 at baseline, and did not change significantly. It was reported that children who were aerobically more fit had a significantly smaller increase in systolic BP compared to children of lower aerobic fitness levels (2.92 vs. 5.10 mmHg / year; $P = .03$).

However, the results should be interpreted with caution since the study had several limitations. The longer-term implications of the effects of change in aerobic fitness and BMI on blood pressure are not known. Because of the lack of longer-term data, extrapolation of the differences observed over 19.7 months to adult populations at risk of cardiovascular disease are speculative. Longer-term studies need to be conducted to determine what levels of fitness and leanness are required to protect against development of higher ranges of normal blood pressure in children and hypertension in adulthood (Shea et al., 1994). Aerobic fitness increased over the period of the study. On a treadmill, taller children may have been more efficient because they used less energy per unit body weight, and therefore required a smaller increase in heart rate to achieve a given level of performance. In addition, as the children developed or started school, aerobic fitness may have increased due to increased physical activity levels. However, activity levels in this group of children were not monitored. Nevertheless, the observations from this study suggest that children aged 5 years who increase their aerobic fitness or decrease their body mass index have lower rates of increase in their blood pressure. These results may have important implications for development of interventions for the primary prevention of hypertension.

3d. Coronary Heart Disease Risk Factors in Children and Youth

Gutin et al. (1994) examined the relation of percentage body fat and maximal aerobic capacity to risk factors for atherosclerosis and diabetes in black and white children. Fifty-seven children aged 7 to 11 years (mean age 10.0 years ± 1.0) participated in the study. Percent body fat was measured using dual-energy x-ray absorptiometry (DEXA) and fat distribution expressed as the waist to hip ratio. Maximal aerobic capacity was measured on a treadmill, and blood pressure measured using an automated monitor. Measurements of several lipoproteins were combined into one atherogenic index.

Spearman rank correlations between fatness, fitness and risk factors revealed that percent body fat was related to the atherogenic index (p = 0.38; P<0.01) and insulin level (p = 0.78; P<0.001). Aerobic capacity was inversely related to the atherogenic index (p = -0.27; P<0.05) and insulin level (p = -0.72; P<0.001). The waist-to-hip ratio was reported not to be related to the risk factors and unlike the results from Shea et al. (1994), blood pressure was reported not to be related to fatness or aerobic capacity. The results suggest that fatness is related to certain risk factors for cardiovascular disease and diabetes in children aged 7 to 11 years.

Gortmaker et al. (1987) compared children's skinfold data from the National Health Examination Survey (NHES, 1965) to the second National Health and Nutrition Examination Survey (NHANES) conducted from 1976 to 1980. Their comparisons indicated a 54% increase in the prevalence of obesity among children aged 6-11 years, and a 98% increase in the prevalence of superobesity. They also compared skinfold data for 1966-1970 with the NHANES (1976-1980) skinfold data. Results indicated that the prevalence of obesity among children (aged 12-17 years) had increased by 39%, with a 64% increase in their prevalence of superobesity. Additionally, with regard to 6- to 11-year olds in 1976-1980, 31% of the white boys, 17% of the black boys, 26% of the white girls, and 27% of the black girls were obese. With regard to the 12-to 17-year olds, 19% of the white boys, 13% of the black boys, 26% of the white girls, and 25% of the black girls were obese. Overall, approximately 27% of all 6-to 11-year olds and 22% of the 12- to 17-year olds were obese, and 12% of the 6-to 11-year olds and 9% of the 12- to 17-year olds were superobese.

Data from Troiano et al. (1995) support these results. Their study compared data on body mass index (BMI) for 14,000 children aged 6 to 17 years taken from the National Health Examination Surveys and the National Health and Nutrition Examination surveys conducted between 1963 and 1991. They reported that 22% of children surveyed between 1988 and 1991 had a BMI above the 85th percentile, and 11% of children were in the upper 5% for surveys conducted in the 1960s. The major increase in the percentage of overweight children took place between a survey covering 1976 to 1980 and the one covering 1988 to 1991. Between these time periods, the percentage of black children of both sexes and all ages and the percentage of white male teenagers exceeding the 85th percentile increased by 9% or more. Increases ranged from 2% to 5.5% among other race, gender, and age groupings. However, Prentice and Jebb (2001) suggest that studies investigating obesity should directly measure body fat, instead of using the BMI, which can provide misleading information about body fat content. The body mass index fails as a measure of fatness due to reasons such as body muscularity and body shape (Eston, 2002). In general terms, the BMI can provide a useful and simple screening measure of obesity, but to evaluate individual body fat levels other anthropometric measures such as skinfolds and circumferences should be used (Eston, 2001).

Increasing prevalence of overweight among American youths highlights the need to focus on primary prevention. Increasing and encouraging physical activity in youth could be a suitable primary prevention strategy. However, the task is not an easy one. Updyke and Willett (1989) demonstrated that there has been an approximate 10% decline in the aerobic fitness levels of children as measured by distance runs (¼ mile for 6-to 7-year olds, ½ mile for 8- to 9-year olds, ¾ mile for 10- to 11-year olds, and 1 mile for children aged 12 to 17 years). Both boys and girls showed marked declines. So, in addition to the increasing prevalence of obesity in children, aerobic fitness levels are declining. There is a strong relationship between children's cardiovascular fitness and fatness (Boreham et al., 1997). Research has suggested that fatness is a major confounding variable in the relationship between fitness and other coronary heart disease risk factors (Sallis et al., 1988; Boreham et al., 2001). Therefore, any intervention to improve the health of children should involve methods to increase physical activity and control diet, in order to improve fitness and reduce body fat (Boreham and Riddoch, 2001).

Beunen et al. (1992) conducted a three-year longitudinal observation survey on 32 active and 32 inactive Belgian boys aged 12 to 19 years. Results revealed no relationship between separate skinfold thicknesses (subscapular, suprailiac, triceps and calf) or calf circumference and self-reported participation in sports (> 5 hr/wk vs. < 1.5 hr/wk). No significant differences were reported in body composition between active and inactive boys. However, limitations of this study included not measuring physical activity in school, in transit to and from school, or in activities other than sports. It is possible that summing the four skinfolds (thereby obtaining a more reliable index of total adiposity) could have yielded different results from those obtained from analysing each variable separately.

Physical inactivity is a major public health problem today. Physical inactivity during childhood is believed to be a significant risk factor for cardiovascular disease in adulthood (Bar-Or and Malina, 1995). Attempts to increase physical activity may provide a means to address this major health problem. Prospective epidemiologic studies indicate that aerobic fitness (Blair et al., 1989), degree of body fatness (Hubert et al., 1983) and fat patterning (Stern and Haffner, 1986) are important predictors of cardiovascular disease. There is evidence that cardiovascular disease originates in childhood (Section 11a). For example, it has been reported that blood pressure and lipids in youth are strongly associated with coronary artery fatty streaks measured during autopsy in young adults (Newman et al., 1986). Fat children tend to have elevated blood pressure and lower activity levels. Therefore, lowering children's blood pressure and increasing their habitual physical activity would be a way to prevent subsequent cardiovascular disease.

It is somewhat surprising to know that young children have been found to have risk factors for coronary heart disease, such as elevated blood pressure and cholesterol levels. According to a survey conducted in Northern Ireland as part of the 'Young Hearts' Project (Boreham et al., 1992), 14% of 12-year-old children and 20% of 15-year-old children exhibited three or more risk factors (despite the exclusion of family history from the analysis). In the United States, as many as 60% of 12-year-olds exhibited more than one modifiable adult risk factor for coronary heart disease (Berenson et al., 1980).

Boreham et al. (2001) examined fitness, fatness and coronary heart disease risk in adolescents as part of the Northern Ireland 'Young Hearts' Project. The project consisted of 1015 school children aged 12 and 15 years, randomly selected from 16 schools. Height, weight, sexual maturity (pubertal status), skinfold thicknesses (biceps, triceps, subscapular, suprailiac), blood pressure, non-fasting serum total, high density lipoprotein cholesterol, and cardiorespiratory fitness (20m multistage fitness test) were determined for each child.

Multiple regression analyses revealed that relationships between fatness and coronary heart disease risk factors were stronger than between fitness and the same risk factors. For example, partially adjusted standardised regression coefficients for 12-year-old boys revealed significant relationships between all five risk factors and fatness, compared with three of five for fitness. Data from the Northern Ireland 'Young Hearts Project' suggests that fatness is strongly and independently associated with coronary heart disease risk status in adolescents, and that aerobic fitness is not. Although the promotion of physical fitness during adolescence may reduce the prevalence of cardiovascular risk factors in adulthood (Boreham et al., 2002), the study recommends that the prevention or reduction of undue weight gain during childhood is important in the primary prevention of CHD (Boreham et al., 2001).

These statistics highlight the general concern about the level of potential coronary risk in school children. Other factors such as children's smoking and poor eating habits add to the concern, in that these factors may lead to degradation of health later in life (Boreham and Riddoch, 2001).

3e. The Relationship between Physical Activity, Fitness and Fatness in Children

A major constraint in assessing the association between adiposity and enhanced physical activity, or the effects of training, is the lack of standardised assessment of adiposity, physical activity and energy expenditure (Bar-Or and Baranowski, 1994; Louie et al., 1999). Rowlands et al. (1999) examined the relationship between activity levels, aerobic fitness and body fat in 8 to 10 year old children. Thirty-four children aged 9.5 ± 0.7 years participated in the study. The Tritrac-R3D and a pedometer were worn for up to 6 days, and heart rate was measured for 1 day. Endurance time on the Bruce maximal treadmill protocol was used to measure the children's aerobic fitness. Children ran until maximal volitional effort was attained, confirmed by attainment of maximal heart rate.

Results revealed that activity measured by Tritrac or pedometry counts correlated positively to fitness in the whole group (Tritrac, $r = 0.66$; Pedometer, $r = 0.59$, $P<0.01$) and in boys and girls separately ($P<0.05$), and correlated negatively to fatness in the whole group ($r = -0.42$, $P<0.05$). Heart rate did not correlate significantly with fitness and was reported to be a misleading measure of activity. The results suggest that low fitness levels and, to a lesser degree, increased fatness are related to inactivity in children aged 8 to 10 years.

In a follow-up study, Rowlands et al. (2000) examined the effect of type of physical activity measure on the relationship between body fatness and habitual physical activity in children. Fifty studies were used which satisfied certain criteria, (for example, that the subjects were under 18 years of age and a measure of body fat / relative weight was included), and meta-analytic procedures were employed to analyse the data. Results revealed a significant relationship between activity levels and body fat in children. The strength of the relationship was reported to be small to moderate and depended to some extent on the method used to assess activity levels. The mode of measuring activity was reported to have a strong influence on the strength of the activity-fat relationship (Rowlands et al., 2000). Observation was suggested as the best method for the assessment of activity.

It was recommended that inactivity in slightly or moderately overfat children be addressed as a matter of priority (Rowlands et al., 2000), since it is one of the most easily modifiable factors linked with body fatness. In order to improve quality of life and reduce health care costs, children and adults should be prevented from gaining high levels of body fat (Rowlands et al., 2000).

3f. The Prevention and Treatment of Obesity

In conclusion, obesity fits the definition of a widely prevalent disease which has suddenly increased in frequency in the U.K as well as many other affluent nations. Data summarised by the World Health Organisation (1998) demonstrates that epidemic obesity already afflicts most technologically advanced countries and is rapidly spreading to emerging regions such as the former eastern bloc countries, South and Central America, and Asia.

Obesity is the most important modifiable cause of type 2 diabetes. The combination of obesity with type 2 diabetes is associated with greatly increased cardiovascular risk and is also commonly associated with hypertension. As well as promoting weight loss to reduce risk factors, and prevent weight gain long-term, Barnett (1999) recommend the encouragement of an active lifestyle in the management of obesity.

The literature suggests that children are becoming fatter and that paediatric hypertension associated with obesity has increased. This suggests that the next generation may suffer from many preventable cardiovascular diseases. Gutin et al. (1990) describe three ways in which childhood eating and exercise habits may influence the risk of developing cardiovascular disease later in life; i. Habits formed early in life may become permanent, leading to reduced fitness, increased fatness, and higher cardiovascular risk later in life, ii. early behaviours may influence aerobic fitness and body composition when children are young. Reduced fitness and increased fatness are likely to affect intention to exercise, thereby forming a cycle that results in a fat and unfit adult at high risk of cardiovascular disease, and iii. eating and exercise behaviours may influence fitness, fatness, and cardiovascular risk factors when children are still young, which might contribute to the early formation of coronary lesions.

The management of obesity requires a three-pronged attack, involving primary, secondary and tertiary prevention (Stott, 1999). Primary prevention is aimed at removing causative factors from the environment or preventing the population being affected by them. Primary prevention can focus on specific populations, such as schools or the populations of individual health authorities. Prevention can include health promotion activities, educating people about physical fitness, diet and behaviour, all aimed at discouraging obesity-provoking lifestyles. Other prevention policies could include encouraging children to walk or cycle to school. Secondary prevention concentrates on those who are specifically at risk of a problem and offers strategies to reduce that risk. Screening programmes are an example of secondary prevention, for example blood pressure or cholesterol screening. Tertiary prevention involves identifying individuals who have already developed a medical problem as a result of obesity, and managing them effectively so as to reduce long-term risks due to progression. Management of established diabetes and hypertension are examples of tertiary prevention.

The cost of an effective three-level preventive strategy could be great. Prentice (1997) calculated that the direct and indirect health costs attributable to obesity are around 5% of the total health budgets of affluent countries, equivalent to over £2 billion annually in the U.K. Obesity is a modern epidemic that needs to be addressed at a variety of levels if the NHS is not to experience a major increase in workload caused by increases in obesity-related illnesses such as diabetes, hypertension, and hyperlipidaemia. In addition to diet and behavioural change, physical activity is recommended in the treatment of obese individuals, to increase net energy expenditure and fat loss and prevent weight gain. Often, all that is needed is more regular everyday activities, such as walking and cycling.

4. Increasing Activity in Daily Living

4a. Physical Activity Guidelines for Children

The literature suggests that physical activity and fitness levels in children and adults are inadequate for enhancing health status. Data from the Allied Dunbar National Fitness Survey (1992) (sponsored by the Sports Council, HEA and Department of Health) showed that physical activity levels in England are low and that many people do not take sufficient regular exercise during leisure time or at work in order to confer health benefits.

International data has revealed that many people in industrialised countries are essentially sedentary and that progress must be made to improve physical activity levels in order to confer health benefits (Caspersen et al., 1994). If our sedentary society is to improve physical activity levels, health organisations and educational establishments must communicate to the public the amounts and types of physical activity that are needed to promote health (Pate et al., 1995). These organisations and establishments must also implement effective strategies that promote the adoption of physically active lifestyles.

It was previously recommended that physical activity for children should involve large muscle groups, for a minimum of 20 minutes, 3 or more times per week at an intensity of >140 bpm (roughly 70% HRmax) (Shephard and Lavallee, 1977; Simons-Morton et al., 1988; Armstrong and Bray, 1991; Sallis and Patrick, 1994; Calfas and Taylor, 1994). This recommendation correlates with Sady (1986) and Morris et al. (1987) as being associated with a low incidence of CHD in adults. These recommendations have since been questioned.

In the mid 1990's new recommendations for adults and children regarding the benefits of accumulating exercise of low to moderate intensity during a day were published (USCDC and ACSM, 1993; 1995). These recommendations from the Centres for Disease Control and Prevention and the American College of Sports Medicine were that every U.S. adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, or preferably all, days of the week. This recommendation emphasised the benefits of accumulating moderate-intensity physical activity in relatively short bouts. With intermittent bouts, as short as 8 to 10 minutes, totalling 30 minutes or more each day reported to provide beneficial health and fitness effects (DeBusk, et al., 1990; Cureton, 1994; NIH Consensus Development Panel on Physical Activity and Cardiovascular Health, 1996). This approach of accumulating exercise during a day is attractive to those wishing to promote physical activity, and is now the accepted guideline in the U.K.

Physical activity patterns of young people (aged 5-18 years) are characterised by short, rather than sustained bouts of activity (Armstrong et al., 1990; Biddle et al., 1998), with most young people accumulating 30 minutes or more of moderate-intensity physical activity on most days of the week (Armstrong and Welsman, 1997). The HEA (1998) recommend that children should accumulate one hour of moderate-intensity physical activity per day, supplemented by regular activities that promote strength, flexibility and bone health (Biddle et al., 1998). Enjoyment is particularly important in young people's participation in physical activity (Wankel and Kreisel, 1985). The causes of enjoyment may vary between individuals and groups. If physical activities are enjoyable, some children may continue to be active, to their benefit, in their later years. Thus, physical education should be directed towards the enjoyment of the activity and the accompanying aspects of the class environment such as being outdoors, and socialising with friends (Saris, 1985). In encouraging young people to be physically active, schools play an important role, both in the Physical Education curriculum and at other times. Physical education programmes should be based on the needs of young people and should include health-related exercise curriculum activities (Biddle et al., 1998).

The literature suggests a conclusive link between heart disease and inactivity, and that even low doses of regular activity can confer significant health benefits and changes in coronary heart disease risk factors, for example blood pressure and cholesterol. The lifestyle activity intervention is a concept which aims to show people how to be more active during their normal daily routines. The simple message is that if a person uses their muscles, joints and circulation, as opposed to sitting or standing, then the body's metabolic rate will be raised to a state which may confer some beneficial adaptations (Buckley et al., 2000a).

Ideas and initiatives for increasing daily activity include going for a 10-minute walk three times a day and using stairs in shopping centres rather than escalators or lifts. The aim is to get children and adults to accumulate physical activity during a day rather than needing to perform two exercise sessions per week. Caspersen et al. (1985) describe physical activity as any bodily movement produced by skeletal muscles that results in energy expenditure. Recommendations to enhance physical activity in young adults include the adoption and promotion of health-related exercise in the national curriculum and to encourage young people to walk or cycle to school by developing safe routes.

In conclusion, the literature suggests that children's habitual physical activity levels are a cause for concern. Underlying reasons for low activity levels may be in part attributed to today's society and the environment in which children are raised.

For example, travelling by car to school instead of walking or cycling. Studies in Britain (Sleap and Warburton, 1990; Armstrong, 1995a) and the United States (Baranowski et al., 1987) have concluded that activity levels in young children are low, with many children not taking sufficient exercise to enhance their health status.

Future research should concentrate on the identification of the potential health benefits of different types, intensities, duration and frequencies of physical activity and their appropriateness for different stages of development (Biddle et al., 1998). In addition, further investigation is required into the contribution which physical education in schools makes to physical activity in young people.

5. Benefits of Controlled Exercise in Childhood

5a. Physiological Benefits

The development of an active lifestyle during childhood may be an important predictor of adult activity and fitness (Epstein et al., 1984). An epidemiological study by Blair et al. (1989) showed that low levels of habitual physical activity and low levels of physical fitness were associated with markedly increased mortality rates. This is supported by experimental studies which showed that exercise training in adults improved CHD risk factors, including blood lipid profiles (Haskell, 1986) and resting blood pressure in borderline hypertensives (Tipton, 1991). Other health-related factors that showed improvement were body composition (Pavlou, 1989) and psychological function (King et al., 1993).

There is extensive literature investigating the effects of physical activity on cardiorespiratory fitness in children. These studies have focused on physiological parameters including total haemoglobin (Koch and Rocker, 1977), myocardial mass and heart volume (Ekblom, 1969), stoke volume (Lind, 1970), heart rate and cardiac output (Eriksson and Koch, 1973), blood pressure (Alpert and Wilmore, 1994), and maximal oxygen uptake (Mirwald and Bailey, 1981; Krahenbuhl et al., 1985). Krahenbuhl et al. (1985) reported that the maximal oxygen uptake of children aged 8 to 14 years could be significantly increased following regular, intensive training. It was suggested that endurance exercise programs were more effective than intermittent exercise programs, despite intermittent exercise being more characteristic of children. Physical activity in children is inversely associated with CHD risk factors such as high blood pressure (Strazzullo et al., 1988), and obesity (Walberg and Ward, 1985). Armstrong et al. (1991) investigated the prevalence of obesity in young people. He reported that body fatness was related to both blood pressure and blood lipids, and that about 13% of young people could be classified as 'overweight'.

Epidemiological evidence for the cardiovascular benefits of physical activity has highlighted the importance of increasing habitual activity in childhood (Walberg and Ward 1985; Strazzullo et al., 1988). It has been suggested that cardiovascular disease has its roots in childhood (Berenson et al., 1992) and increasing research suggests that cardiovascular risk factors such as blood pressure, serum lipids and obesity track over time (Clarke, 1978; Berenson et al., 1980; Freedman et al., 1985) and that physical activity favourably alters these risk factors (Saris, 1985; Newman et al., 1986; Armstrong and Welsman, 1997; Boreham et al., 1997). Results of the Bogalusa Heart Study, (Berenson et al., 1980), showed that heart disease begins at a young age, with many children already possessing one or more cardiovascular risk factor, such as hypertension, obesity or adverse lipoproteins.

A key process in producing changes in central cardiovascular haemodynamics and aerobic fitness involves controlling the intensity of activity (ACSM, 1978). Too low an intensity is considered to be ineffective in bringing about improvements in cardiovascular health. Too high an intensity effort may have undesired effects which could cause children to report that the exercise is unenjoyable, giving rise to non-adherence. It could also result in musculoskeletal injury. In a review of paediatric literature concerned with physical activity and skeletal health, Bailey and Martin (1994) recommended that for optimal skeletal health, weight-bearing activities were better than weight-supported activities such as cycling or swimming. Short, intense daily activity was recommended rather than prolonged infrequent activity. Haskell (1994) suggested that health benefits of activity might be gained from repeated acute physiological responses to separate bouts of activity, rather than from true chronic adaptations to long-term activity. Therefore the frequency of activity might be more important to consider than the intensity or duration (Riddoch, 1998). Children might achieve healthy physical activity because of the sporadic, frequent nature of their activity patterns (Riddoch, 1998).

5b. Psychological Benefits

The physiological benefits of controlled exercise in childhood are well documented. In addition to physiological benefits, exercise in childhood is also reported to confer psychological improvements, for example in self-esteem. Gruber (1986) reported that children showed improvement in self-concept as a result of physical activity, and that emotionally disturbed, mentally retarded, or economically disadvantaged children showed the greatest improvement in self-concept. It was reported that those who participated in physical fitness and aerobic activities showed greater improvements in self-esteem (Gruber, 1986), than those who participated in programmes of creative movement (e.g.; dance, mime) or sports skills (e.g.; gymnastics or soccer), which is of particular importance to physical educators.

6. Physical Activity, Fitness and Physical Education in Children and Youth

6a. Physical Activity Programmes in Schools

In 1973, Bailey reported that school programmes of physical activity were inadequate and responsible for the poor prevailing fitness levels of most North American adolescents.

Shephard and Lavallee researched this further in 1977 using exercise training at the primary school level. The Trois Rivieres regional experiment was conducted in schools in Quebec. The exercise programme normally available to the Quebec primary school child (one forty-minute session of physical activity per week) was supplemented with five additional hours of physical education each week. The main requirements of the physical activity were i) the activity should be fun, ii) that the entire class should be active throughout a large part of the hour and iii) that adequate stress be imposed on the musculoskeletal and cardiorespiratory systems.

Six hundred children participated in the study over a long period (from age six to age twelve). Entire school classes were either allocated to experimental or control conditions. Regular measurements were made for growth, development, physical performance, intellectual attainment and clinical condition. Activity periods were supervised by teachers who were asked to concentrate on the development of cardiorespiratory and muscular endurance. Typical activities included indoor football, indoor hockey, ice hockey, basketball, dancing, jumping, cross-country running and the use of climbing apparatus and exercise mats. This varied the exercise programme and prevented the young children from becoming bored.

Results showed that the average primary school child could substantially improve their physical condition through participation in an additional daily hour of organised physical activity. Daily activity diaries showed that on weekdays the experimental group of children compensated for their vigorous school program by cutting out some light activity at home. However, on the weekend (when their physical activity was not controlled by the researchers), they chose to participate in more vigorous activities than the control subjects.

It was suggested that the introduction of an enhanced school physical education programme had created a positive attitude towards voluntary recreational activity (Shephard and Lavallee, 1977). Researchers should consider the effect children's exercise programmes might have on attitudes towards physical activity in adulthood (Shephard and Lavallee, 1977). A sport or exercise programme that causes chronic injuries in childhood or adolescence due to over-exertion cannot be regarded as satisfactory. It is suggested that emphasis is given to physical activities in childhood which are likely to have a substantial carry-over into adulthood (Shephard and Lavallee, 1977). Such activities could be pursued as a family and include swimming and cycling.

6b. Introducing a Theoretical Aspect of Exercise into Physical Education Classes

Physical Education in the United Kingdom is not seen as a curriculum priority. Most schools devote little more than 100 minutes a week to it in the curriculum, which is less than many other European countries (Revell, 1999). The problems for Physical Education are clear. Primary teachers lack the expertise needed to deliver it effectively.

In 1992, the National Association of Head Teachers and the Central Council for Physical Recreation reported that 56% of primary schools could not deliver the national curriculum for physical education due to lack of resources and that only 8% of primary school teachers delivering physical education had formal qualifications in the subject. The literature indicates that teenagers are not as fit as they used to be

(Armstrong, 1995a; Armstrong and Welsman, 1997) and that the current level and pattern of children's physical activity is a serious cause for concern (Armstrong, 1995). By the time children arrive at secondary school, their basic physical skills are lower than those of their peers from the past. To do something about this, two specialist sports colleges, Biddick School and Sports College in Washington, Tyne and Wear, and Penryn College in South Cornwall, tried to address the problems with a number of initiatives.

At Biddick, they introduced a full-time specialist Physical Education co-ordinator whose role was to work within all of the partner junior schools. The aim was not to provide Physical Education instruction, but to work with the teachers to enable them to teach the subject more effectively. Penryn sent coaches into neighbouring schools, and made an audit of each one to see what resources they had, with the main aim of giving children a greater variety of sporting experiences. Questionnaires administered to staff and students at these two specialist sports colleges provided quantitative feedback, which revealed that these initiatives had been extremely successful (Kirk, 1986).

One of the reasons children dislike Physical Education has reportedly been the physical demands of the activity itself (Dickenson and Sparkes, 1988). Physical education programmes represent an important gateway for encouraging young people to develop lifelong physical activity habits (Ferguson et al., 1989). A 45-question survey, which took about 15-minutes to complete, was administered to 603 students in two rural Iowa communities. Items on the survey included current exercise behaviour, exercise intent and knowledge about exercise developed from the health education curriculum used in one of the schools. It was reported that programmes that made attending physical education a pleasant experience and that explained the benefits of exercise could influence exercise intent and enhance students' sense of self-esteem, both of which could lead to increased future exercise behaviour (Ferguson et al., 1989).

The Department of Education and Science, DES (1989) and the Northern Ireland Curriculum Council (NICC) (1990) acknowledged the importance of interest in Physical Education. The DES (1989) stated that Physical Education programmes must emphasise the development of the capacity 'to maintain interest', and the NICC (1990) stated as one of its aims to promote 'in each pupil a love of, interest in, and knowledge of physical activity and its contribution to the maintenance of life-long personal health and fitness'. Physical education that does not prepare children for a life-long positive attitude towards physical activity, stands in the way of goals, which impacts on health and a meaningful use of leisure-time (Kirk, 1986). Organised programmes, which emphasise life-long physical activity, should be promoted in schools and community organisations. Activity experiences must be enjoyable in order to foster lifelong participation in physical activity (Dishman et al., 1985; Armstrong, 1993; Pate et al., 1995).

Schools are seen as the focal point for delivery of comprehensive health and physical education programmes that provide and promote physical activity at every opportunity. The physical education curriculum could also be used to acquaint youngsters with physical activity resources in their community. Health-related exercise within the physical education national curriculum is an important concept. Children should understand the principles underlying health-related physical activity and be taught how to become informed decision makers who can plan and implement their own activity programmes, which can be periodically re-appraised and modified, to suit their needs. The American Heart Association (Strong et al., 1992), suggest that children's health-related (cardiovascular) physical activity should focus on play rather than exercise. Therefore, the sporadic, spontaneous nature of children's activity may be a more important contributor to their cardiovascular health than exercise training or programming (Riddoch, 1998). For children to achieve healthy levels of physical activity, Corbin et al. (1994) have suggested that a minimum activity energy expenditure of 6-8 Kcal/kg/day is appropriate, and may be achieved through approximately 60 minutes of daily physical activity. If teachers are to develop successful courses, they need to understand current concepts in exercise and health science. Educators at all levels should be good models of physical activity behaviour.

In 1905, the Board of Education provided the first (National) British Syllabus for Physical Education and reported that the primary objective of any course of physical exercise in schools should be to maintain, and if possible, improve the health and physique of children. Over the years, the link between school physical education and health has remained, but has tended to be obscured by attempts by physical educators to stress the educational and recreational aspects of physical education. Besides actually participating in physical activities, a theoretical aspect of exercise could be introduced into physical education classes. This theoretical aspect could include introducing children to effort rating scales, to help them understand why they feel the way they do during physical education classes. No study to date has achieved this.

An active lifestyle does not require a regimented, vigorous exercise programme. An exercise prescription that is perceptually acceptable to the participant promotes programme adherence, and helps to establish a positive attitude towards physical activity (Dishman, 1982a). It has been reported that if inactive people select, or are prescribed an intensity that is perceived as very effortful relative to their physiological responses, they may experience problems with exercise adherence (Dishman, 1994). Instead, small changes that aim to increase daily physical activity in children would help to reduce their risk of chronic disease later in life, thus contributing to enhanced quality of life.

It is the relative intensity of physical effort that determines whether favourable physiological and biochemical changes take place (HEA, 1994). In order to determine this relative intensity of effort, a valid and reliable measuring tool is required. There is currently huge scope for exploring the external validity and application of child-specific effort rating scales within a physical education environment. This would give an added understanding of sport, physical activity and exercise, aiding delivery of health-related exercise in the physical education national curriculum. Such an understanding might contribute to the maintenance of life-long personal health and fitness, an aim set out by the DES (1989), NICC (1990), HEA (1994) and National Curriculum Guidelines (1999).

Physical education lessons must 'enable students to have enjoyable and meaningful experiences,' and 'develop positive attitudes towards health and fitness' (Kirk, 1986a). An ethnographic case study conducted by Kirk (1986a) explored teacher's attempts to introduce and develop a health-related fitness course as a part of the physical education curriculum at Forest School, a 14-18 years, co-educational Upper School and Community College in England. The teachers attempted to measure their effectiveness in achieving the aspiration of 'enabling students to have enjoyable and meaningful experiences' by relying on the cues and messages picked up from students during lessons. If students appeared to be interested and involved in the lesson, then teachers assumed that they were, more or less, enjoying themselves. Additional factors such as the extent to which students exercised during free time out of school, and were conscious of their diets were also deemed important indicators of the success or failure of teaching towards this aspiration.

To maintain participant confidentiality, the source of the 'aspirations' could not be published. In relation to the second aspiration of 'developing in students positive attitudes towards health and fitness', the idea was that through the development of such an attitude, students would take steps to become fit, or else stay fit, from schooling and on into adulthood. The problem arose of how to test the effectiveness of this aspiration, when the results were seen after the students had left school. Without direct evidence of what the students thought and did when they left school, the teachers had no way of knowing how effective their teaching had been. This difficulty could have been overcome by carrying out a longitudinal survey of students at intervals after they had left school. However, this would have involved a number of difficulties relating to finance, time, consistency of staff, locating students and access to relevant confidential information. Perhaps in anticipation of these difficulties, such a survey has never been carried out.

Without feedback on the effectiveness of their teaching, the best the teachers at Forest School could do was hope they had some influence. Without direct evidence of their success or failure at Forest School, the teachers had to argue the case for teaching the health-related aspects of the curriculum entirely on the basis of the vital role this knowledge played in students' lives. They had to argue that the knowledge was so important, that it was better that students were 'in the know,' and then allowed to make decisions for themselves concerning whether or not they wanted to use this knowledge, than to be left in ignorance.

The teachers at Forest School found new ways of publicising their classroom efforts in health-related fitness. They provided a fitness evaluation and exercise prescription service for other teachers in the school, and gave talks to professional groups. The teachers also staged some successful 'one-off' events in an attempt to attract attention. One of these events was 'Project 82' which was an exhibition and demonstration of fitness activities. The teaching of health-related fitness at Forest School has evolved and has continued to survive (Kirk, 1986a). The views of Forest School teachers were that the development of attitudes towards health and fitness had an essentially affective dimension. One teacher reported; "we hand-out information to all the kids, and if one takes it in and it has some effect then that's great. But we can't make them listen, we can't make them believe". The teachers at Forest School attempted to have some impact on students' values and attitudes towards health and fitness in the classroom environment, whilst also being judged publicly on their contribution to the pupils' school experience through extra-curricular sport and recreation.

If the promotion of individual health is to be anything more than rhetoric, then it has to be acknowledged by teachers and administrators. A health-related based physical education curriculum is a concept which should be supported with appropriate expertise and resources. Otherwise, the teaching of health and fitness in the Physical Education curriculum will continue to only be regarded as a by-product of participation in physical activity. Introduction of child-specific effort rating scales into a physical education environment would help to determine if children can understand and apply effort sense, providing a theoretical aspect of exercise to classes. Such a tool could also aid the delivery of concepts within health-related exercise in the physical education national curriculum.

7. The Historical Perspective of Effort Perception

7a. Rating of Perceived Exertion and Exercise Intensity

There are several ways of determining exercise intensity. These include proportion of maximal oxygen consumption (% VO_2 max), proportion of maximal power output (% PO max), proportion of maximal heart rate (% HR max), proportion of maximal heart rate reserve (% HRR max), blood lactate indices and the rating of perceived exertion (RPE). The Borg RPE Scale is a tool for estimating effort and exertion, breathlessness, and fatigue during physical work. The concept of perceived exertion originated in the 1950's from pilot studies investigating the problems related to fatigue and work capacity by Borg and Dahlstrom (1959). In the 1950's the development of reliable ergometers in exercise laboratories, hospitals and in clinical exercise testing, was an important advancement. The need to understand people's perceptions in clinical settings and to integrate information from subjective symptoms with physiological signs also became more apparent. This stimulated a development in the direction of ratings of perceived exertion. The concept of measuring subjective feelings of exertion by means of a category scale first appeared in the literature in 1961 (Borg, 1961), and since its development, the main use of the RPE scale has been in evaluating subjective 'strain' experienced during dynamic exercise (Borg and Linderholm, 1970). The modified 15-point Scale (Borg, 1971) is probably the most widely used RPE scale in sports and exercise science to date (Figure 1).

The heart rate at any given RPE can be approximated by multiplying the RPE by 10 (Borg, 1973; Morgan, 1981; Williams and Eston, 1989; Dunbar et al., 1992; Williams et al., 1994). The American College of Sports Medicine (ACSM, 1995) are more specific in their definition of approximate heart rate at any given RPE for normal individuals. The ACSM reported that HR will approximate (RPE x 10) ± 20 to 30 beats/ minute for RPE's of 11 to 16, (values in the typical intensity range for training). RPE levels of 12 to 16 closely approximate 50 to 85% of a person's VO_2 max (ACSM, 1986). It should be noted that the '6 to 20' scale was originally established for use with middle-aged men in order to predict exercise heart rate. For example, an RPE of 18 –20 (maximal exertion), when multiplied by 10 (180-200 bpm) equates to the average maximal heart rate of a middle-aged man (Buckley et al., 2000).

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

Figure 1: Borg's 15-point RPE Scale (Source: Borg, 1998)

7b. Mediators Influencing RPE

Experiences such as effort, breathlessness, fatigue, aches in the working muscles and feelings of warmness can be used to illustrate the concept of perceived exertion. Physical work or exercise always results in some degree of physical exertion (Borg, 1998). Exertion and fatigue are states with both physiological and psychological aspects (Borg, 1998). Other related concepts are subjective weight and heaviness, subjective force, arousal and exercise intensity. These sensations are filtered by the brain in order for a person to be able to perceive a single rating, expressed verbally using the RPE scale. Figure 2 shows the filtering of sensations that lead to the verbal expression of an RPE (Buckley et al., 2000a).

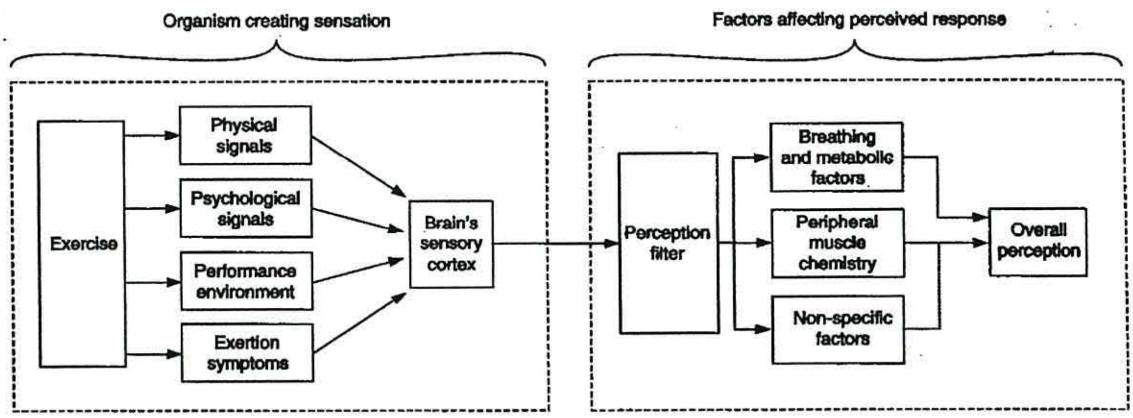


Figure 2: Mediators of RPE (Source: Buckley et al., 2000a)

Thus, when a person exercises, physical and psychological signals, together with information from the performance environment and exertional symptoms are processed by the brain's sensory cortex and perceptually filtered. The person therefore experiences a range of sensations including muscular and respiratory-metabolic factors, leading to the formation and expression of an overall rating of perceived exertion.

The study of perceived exertion may be considered to be a sub-discipline of psychophysiology, which by definition means the study of physiology as it relates to psychological or behavioural function (Watt and Grove, 1993). Identifying the physiological foundations of perceived exertion has not been an easy task. The perceptions are not neatly tied to any one specific cue (Mihevic, 1981), and the psychophysical judgements of perceived exertion involve more than cognition or perception alone (Morgan, 1981; Williams and Eston, 1989). The perception of exertion (and effort) at very high intensities is related to diminishing work capacity and fatigue, but at low or moderate intensities may be related to a state of activation or 'arousal' that can have a positive effect on performance (Borg, 1998).

Exertion and fatigue are states with both psychological and physiological components. Perceived exertion and pain are two concepts that may overlap at times. For example, during cardiac rehabilitation exercise testing, patients may experience pain in the legs or chest. The meaning of the pain in this situation has to be interpreted specifically for each person in terms of the suffering it causes. The intensity of pain may be used to compare changes within a person, or responses of the person pre- and post-therapeutic intervention.

Exercise intensity is a concept related to fatigue and exertion, and may be interpreted in different ways. Exercise intensity may be given a physical stimulus-based meaning, defined by physical measurements such as power or velocity, or it may be interpreted physiologically using measurements such as VO_2 or heart rate. The overall perceived exertion rating integrates information (Figure 2). Such information includes signals from the peripheral working muscles and joints, from the central cardiovascular and respiratory systems and from the central nervous system. These signals include muscle and blood lactate, muscle glycogen stores, blood glucose levels, ventilatory volumes, personality structure, pain tolerance, past experiences, catecholamine production and neurotransmitter levels in the brain (Borg, 1998). Thus, perception of effort can be described as involving multiple physiological sensory signals derived from *central* changes in the cardiopulmonary system and *local* feelings of strain in muscles and joints (Ekblom and Goldbarg, 1971; Robertson, 1982). All these signals, perceptions, and experiences are integrated into a configuration or 'Gestalt' of perceived exertion. Effort sense is therefore based upon the physiological cost, cognition (thinking), and perception (feeling).

There has been extensive research into the physiological factors correlated with the RPE scale. Ratings of perceived exertion are highly correlated with physical indicators of fatigue such as heart rate, oxygen consumption, blood lactate and ventilation (Pandolf, 1983; Borg et al., 1987; Williams and Eston, 1989). Because a close positive relationship has been observed between RPE and relative metabolic demand, it is accepted that the RPE scale may be used to regulate exercise intensity. If the HR:RPE relationship is known, exercise may continue without having to use heart rate monitors. Because ratings of perceived exertion for each individual provide a direct, subjective intensity level, other physiological measures such as % VO_2 max, may be predicted from intensity relationships (Table 2). Physiological measures, expressed as a proportion of the individual's maximum values, correlate better with perceived exertion (Borg, 1998). The percentage maximal heart rate reserve method can be employed to determine exercise training intensities using the equation; (% HRR max) x (HR max – HR rest) + HR rest (Karvonen and Vuorimaa, 1988). Therefore, for a 30 year old female with a resting heart rate of 72 bpm, a training intensity of 65% HRR max would equate to; (0.65 x 118) + 72 = 149 bpm. Borg (1977) reported that relative HR expressed as a proportion of the maximal heart rate reserve correlated better with RPE than raw HR values.

8. Nature of the Relationship

8a. The Category-Ratio (CR10) Scale

The RPE 6-20 scale was developed by Borg so that perceptual ratings of exercise effort increased linearly with power output, oxygen consumption and heart rate. However, certain physiological variables such as ventilation and blood lactate production are related to exercise intensity according to non-linear responses. A scale was therefore needed that would identify perceptual ratings of exercise effort associated with non-linear physiological responses, i.e. lactate metabolism. Therefore, Borg (1982) developed the 0 to 10 Category-Ratio (CR10) Scale so that perceptual ratings increased in an exponential fashion. Steven's (1946) classification of scales of measurement provided a fundamental basis for the CR10 scale construction. The ratio scale (Stevens, 1971), was accepted as the best choice for general descriptions of perceptual variations, so that verbal expressions and numbers could be used in a way that was suitable for non-linear characteristics of sensory perception and physical stimulation. The CR10 scale (Borg, 1982) has numbers anchored to verbal expressions (Figure 3) and contains some of the category properties of the 15-point RPE Scale. However, unlike the 6-20 RPE scale, the CR10 scale also contains ratio properties.

The numerical values in the Category-Ratio scale have a fixed relation to one another. For example, using the CR10 scale, an intensity judgement of 2 is gauged to be half that of 4. The dot above the 10 on the scale (Figure 3) means absolute maximum, numbers higher than 10 are therefore possible. If the subjective intensity increases above a rating of 10, the person may select any number in proportion to 10 that best describes the proportionate growth in the sensation of effort.

0	Nothing at all	No P'
0.3		
0.5	Extremely weak	Just Noticeable
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	**Extremely strong**	**'Max P'**
11		
↗		
•	Absolute maximum	Highest possible

Figure 3: Borg's CR10 Scale (Source: Borg, 1982)

To be able to compare RPE values obtained with the Borg 6-20 RPE scale and those obtained with the Borg CR10 scale, a transformation table (Table 1) can be employed (Borg and Ottoson, 1986). The transformation table can also be used for rough transformations in the other direction from the CR10 scale to the RPE scale. The CR10 scale is commonly used to estimate pain intensity, such as angina or musculoskeletal pain, or other subjective problems such as breathing difficulties. In contrast, the RPE 6-20 scale is preferable to use for tests of perceived exertion, exercise testing, and for prescribing exercise intensities in a variety of settings e.g.; cardiac rehabilitation.

Table 1: Scale Transformation

RPE Scale	CR10 Scale
6	0.0
7	0.0
8	0.5
9	1.0
10	1.5
11	2.0
12	3.0
13	3.5
14	4.5
15	5.5
16	6.5
17	7.5
18	9.0
19	10.0
20	12.0

An advantage of category scales when used for the assessment of clinical symptoms is that they provide certain 'absolute' or 'direct' estimates of intensity levels that ratio scales cannot (Borg, 1962; 1982). A disadvantage with category scales is that they don't reflect relations between subjective intensities as well as ratio scales.

8b. Power Functions

Blood lactate has been widely investigated as a local sensory cue that contributes to effort perception, as both lactate and CR10 increase exponentially with increases in exercise intensity (Borg et al., 1987; Hampson et al., 2001). Sensations of pain and discomfort in the muscles are often felt after the point at which lactate accumulates in the blood (Mihevic, 1981). Psychophysical relations may be described by power functions according to the psychophysical equation proposed by Borg (1961a); $R = a + CS^n$. This equation has been suggested to describe the growth of perceived effort (R) with increasing exercise intensity (S). The component 'a' represents perceptual noise, 'c' is the proportionality constant and 'n' is the exponent of the power function. Further simplified, the psychophysical characteristics of the relationship between perceived exertion (Response, R) and exercise intensity (Stimulus, S) can be described as $R = c \times S^n$, where n is the exponent which reflects the growth function (Eston and Williams, 2001).

Exponents of 1.6 have been obtained for perceived exertion in cycle ergometry exercise (Borg, 1982; Noble et al., 1983; Borg et al., 1985) (Figure 4), and exponents ranging between 2.2 – 2.5 for blood lactate (Noble et al., 1983; Borg et al., 1987) (Figure 5). Figure 6 shows that since lactate values rise in a positively accelerating manner with power output, the CR-10 Scale, devised to rise in a similar fashion, will show parallel responses.

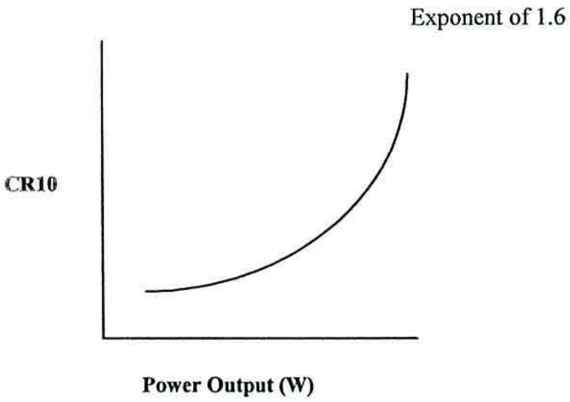


Figure 4: Hypothetical Relationship between CR10 and Power Output to show typical Curvilinear Response

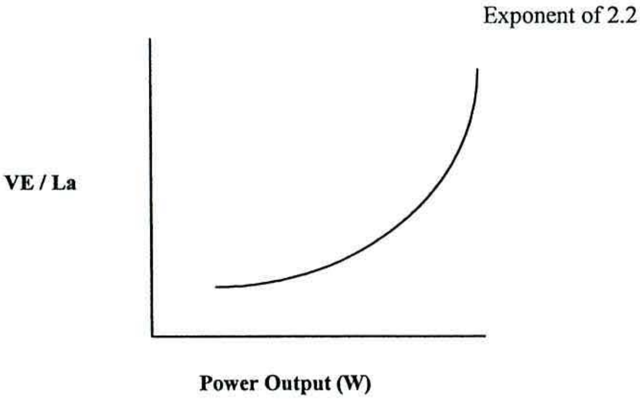


Figure 5: Hypothetical Relationship between Ventilation / Blood Lactate and Power Output to show typical Curvilinear Response

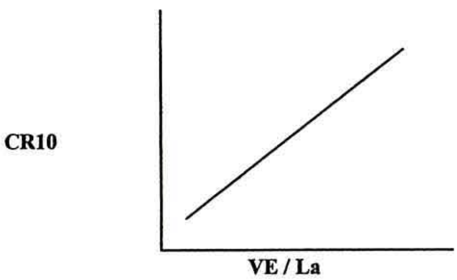


Figure 6: Hypothetical Relationship between CR10 and Ventilation/ Blood Lactate to show typical Linear Response

Borg and Borg (1998) regarded the CR10 scale as 'rather rough' for practical use, and suggested that a need existed for a more 'fine-graded' scale. Hence, Borg and Borg (1998) developed a new CR Scale: the CR 100 Scale, (Figure 7). The CR 100 Scale was developed using quantitative semantics, the science that deals with the meaning of words and the quantitative relationship between verbal expressions.

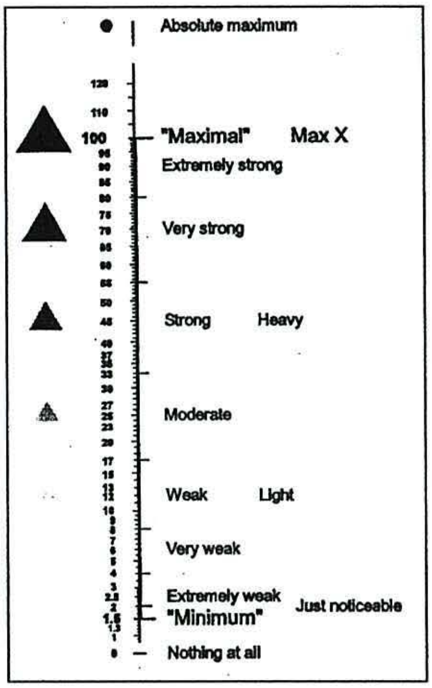


Figure 7: CR 100 Scale (Source: Borg & Borg, 1998)

In the CR 100 Scale, '100' anchored in 'Maximal – Max X', is the main point of reference. All other scale values are set in comparison to this point of reference. Therefore, responses are reported in centigrade of this 'Max' value as a 'unit'. The scale may also be referred to as the 'centi-Max' (cM) scale and the values cM values.

8c. Blood Lactate, RPE and the Exercise Mode

The lactate threshold (T_{lac}) was originally defined as the first increase in blood lactic acid above resting values during incremental exercise (Wasserman et al., 1973). The exercise intensity at the T_{lac} is associated with a non-linear increase in pulmonary ventilation (VE) (the ventilatory threshold, T_{vent}) due to the buffering of lactic acidosis. Hetzler et al. (1991) examined measures of heart rate, VO_2 and RPE (overall, peripheral and respiratory-metabolic) at exercise intensities corresponding to the lactate threshold, blood lactate levels of 2.0, 2.5 and 4.0 mmol/l, and maximal exercise. Peripheral RPE was defined as sensations of exertion in the active muscles and limbs, while respiratory-metabolic RPE was associated with sensations of exertion related to the cardiopulmonary system (ventilation and HR).

Twenty-nine untrained male participants (aged 31.5 ± 4.8 years) completed a VO_2 max / lactate threshold (T_{lac}) protocol on a cycle ergometer and treadmill. A repeated measures ANOVA indicated that despite significant differences ($P<0.05$) between the cycle ergometer and treadmill protocols in heart rate and VO_2 at the T_{lac}, each blood lactate level and maximal exercise, the RPE (overall, peripheral and respiratory-metabolic) were not significantly different. For example, mean (± S.D) overall RPE values at the lactate threshold, blood lactate concentrations of 2.0, 2.5, 4 mmol/l and maximal exercise were; 10.2 (2.2), 13.1 (2.1), 14.1 (2.3), 15.9 (2.3) and 18.8 (1.3) for cycling exercise and 10.8 (1.9), 13.8 (1.8), 14.6 (1.6), 16.2 (2.6) and 18.5 (1.5) for treadmill exercise. This is a somewhat surprising result since one would expect peripheral RPE to be significantly greater in cycling exercise (Shephard, 1987).

Significant differences were found to exist between differentiated RPE values for discrete workloads corresponding to the T_{lac}, blood lactate values of 2.0, 2.5 and 4 mmol/l and maximal exercise *within* exercise modalities. For example, peripheral

RPE values were significantly greater ($P<0.05$) at the T_{lac} and blood lactate concentrations of 2.5 mmol/l and 4 mmol/l for the treadmill protocol. It was also observed that in cycle exercise, peripheral RPE was greater than respiratory-metabolic RPE at each exercise intensity. These results suggest that localised sensations of exertion comprise a greater percentage of the overall perception of effort in cycling exercise. The lower respiratory-metabolic RPE compared with peripheral RPE in cycling exercise was consistent with the finding that VO_2 and HR values were less at each exercise intensity.

The results of this study found that perception of effort at the lactate threshold (T_{lac}) blood lactate concentrations of 2.0, 2.5 and 4.0 mmol/l and maximal exercise were stable across the protocols (cycle and treadmill), which may have implications for exercise prescription (Hetzler et al., 1991). Because blood lactate varied, as the RPE varied, it was suggested that blood lactate might act as a primary mediator for effort perception (Hetzler et al., 1991). However, because peak blood lactate concentration occurs some minutes after the performer has finished exercising (Winter and MacLaren, 2001), it may not serve as a primary mediator for effort perception. Although blood lactate is a useful indicator of metabolism that contributes to the physical signals leading to the verbal expression of an RPE (Buckley et al., 2000a), it is likely that other factors act as primary mediators of effort perception (Borg, 1998). Under many exercise conditions, the most intense perceptual signal arises from peripheral mediators such as exercise-induced changes in blood pH, plasma glucose levels and regional blood flow (Noble and Robertson, 1996). The respiratory-metabolic (minute ventilation, respiratory rate and relative oxygen consumption) and nonspecific physiological responses (increased catecholamine production and increased skin temperature) influence the 'fine tuning' of the verbal expression of an RPE (Noble and Robertson, 1996).

8d. Anaerobic and Ventilatory Thresholds in Adults and Children

In most individuals, lactate does not accumulate below an intensity of about 65% VO_2 max, and at lower intensities is unlikely to have much influence on RPE (Mihevic, 1981). As exercise intensity increases, VO_2 increases linearly, but blood lactate levels change only slightly until about 60-80% of VO_2 max is reached, depending on level of training. After this, blood lactate increases rapidly. Because blood acidity is a factor that increases ventilation (VE), the sharp increase in VE during exercise is often used to indicate the inflection point in the blood lactate curve (Eston, 2001). This is termed the Anaerobic Threshold, whereas the disproportionate rise in VE at this point is termed the Ventilatory Threshold (T_{vent}) (Eston, 2001). Although blood lactate levels relate to perceived exertion at high exercise intensities, the mechanism by which lactate mediates effort perception has not yet been identified (Hampson et al., 2001). Poulus et al. (1974) and Robertson et al. (1986) suggest that lactate does not affect perceived exertion *per se*, but indirectly contributes to effort sense through pH changes associated with lactic acid production. The lactate threshold (T_{lac}) therefore forms an important physiological anchor point for perception of effort. Research indicates that perceived exertion at the T_{lac} is not affected by gender or state of training (Purvis and Cureton, 1981).

In a study to examine ratings of perceived exertion at the T_{lac} using a discontinuous, progressive speed and grade-incremented treadmill protocol, Demello et al. (1987) observed that trained and untrained men and women aged 18-35 years perceived the exercise intensity at the T_{lac} as 'somewhat hard' (RPE = 13 to 14). They reported that regardless of state of training or gender, an exercise intensity equal to the

T_{lac} could be prescribed by having people exercise at an intensity that is perceived as 'somewhat hard', equivalent to an RPE of 13 to 14. It is reported that most adults rate the T_{vent} (60 - 75% VO_2 max) as 'somewhat hard' or 'hard' (RPE 13 to 16) (Borg and Linderholm, 1967; Purvis and Cureton, 1981, Hill et al., 1987), and reach the subjective limit of fatigue at an RPE of 18 to 19 'very very hard' (Borg and Linderholm, 1967). According to the above, an exercise intensity that equates with the lactate and ventilatory thresholds (RPE 13 to 16) could be prescribed by reference to this perceived level of relative effort production for improving cardiorespiratory fitness in adults (Purvis and Cureton, 1981; Pollock et al., 1986; ACSM, 1990).

The ventilatory threshold is related to endurance performance in both children and adults (Powers et al., 1983; Unnithan et al., 1995), and may serve as an optimal intensity for exercise prescription (Davis, 1985). Exercise above the T_{vent} is associated with increasing ventilatory responses, rising blood lactate and catecholamine concentrations, all of which may hinder optimal exercise duration (Davis, 1985). For these reasons the assessment of the RPE at the T_{vent} is justified.

In children, average RPE corresponding to the T_{vent} (approximately 71% VO_2 max) was reported to be 12.4 and 11.4 on successive graded exercise tests performed on a treadmill (Mahon and Marsh, 1992). Duncan et al. (1996) reported that RPE at the T_{vent} was 12.3 on a graded treadmill test and 11.6 on a graded cycle ergometer protocol in male children, and that the T_{vent} occurred at the same percentage of VO_2 max (63%) in each protocol. This may have occurred because the decline in VO_2 max from the treadmill test to the cycle test was similar to the decline in the VO_2 max at the T_{vent}. Therefore, the T_{vent} occurred at approximately 63% VO_2 max during both the treadmill and cycle tests. This observation has also been made in adults performing different modes of exercise (Davis et al., 1976; Robertson et al.,1990).

In conclusion, it appears that the RPE at the T_{vent} in children is slightly less than the values reported in adults. This supports the observation that children generally rate a given level of exercise as being less strenuous than adults (Bar-Or and Ward, 1989). Children's muscle is metabolically geared more towards aerobic energy metabolism than to anaerobic energy metabolism (Erikson, 1972). This results in children exhibiting a reduced ability to produce lactic acid during exercise, and therefore a need exists to alter the traditional concepts of the 'anaerobic threshold' (Boreham and Van Praagh, 2001).

The use of 4 mmol/l blood lactate as an indicator of the anaerobic threshold may coincide with approximately 77% VO_2 max in adults, compared with 90% VO_2 max in 13 to 14 year old children (Williams and Armstrong, 1991). Children are unable to generate or tolerate high levels of blood lactate. Williams and Armstrong (1991) therefore propose the use of a lower blood lactate concentration of 2.5 mmol/l in children as a guide to running capacity, rather than the marker of 4 mmol/l used for adults.

The T_{vent} can be assessed reliably and accurately in children during treadmill or cycle ergometry protocols. However, a number of considerations including the child's level of fitness, the influence of the walk-run transition, the increase in work rate and the exercise mode need to be considered when developing the optimal exercise testing protocol for determining the T_{vent} in paediatric subjects (Mahon and Cheatham, 2002).

Assessing differentiated RPE in children during exercise may provide a better insight into how children process sensory information during exercise to form an overall rating of perceived exertion. However, there is limited information regarding differentiated RPE in children.

In 1998, Mahon and colleagues examined overall, peripheral (leg) and central (chest) RPE at the ventilatory threshold in children and adults during the course of a graded exercise test. Although all three ratings in children were higher than in adults, the results suggest that children were able to distinguish sensory cues arising from different physiological responses during graded exercise.

A follow-up study (Mahon et al., 2001), was designed to examine overall, leg and chest RPE during constant work exercise performed at a submaximal intensity equivalent to the T_{vent} (64% VO_2 max for children and 61% VO_2 max for adult participants) in a group of subjects from the same cohort used in their 1998 investigation. Sixteen children (aged 10.7 ± 0.8 years) and 16 adults (aged 24.2 ± 1.8 years) completed a submaximal exercise bout on a cycle ergometer at a work rate corresponding to the VO_2 at the T_{vent}. The T_{vent} was determined during a graded exercise test on a cycle ergometer, and was defined as the point when the ventilatory equivalent for VO_2 began to increase without an accompanying change in the ventilatory equivalent for CO_2 (Caiozzo et al., 1982).

Each participant completed a 4-minute warm-up followed immediately by 16-minutes of constant submaximal exercise at the desired work rate. Pulmonary gas exchange, HR, blood lactate, and overall, peripheral (leg) and central (chest) RPE were measured at 8 and 16 minutes of the exercise bout.

ANOVA results revealed that between groups, RPE tended to be higher and increased more over time in the children compared to adults ($P<0.08$). Leg and Overall RPE were greater than Chest RPE ($P<0.05$). RPE in children ranged from 11.6 ± 2.3 (chest) to 12.6 ± 2.6 (leg) at 8-minutes, and from 13.3 ± 2.8 (chest) to 15.1

± 2.9 (leg) at 16-minutes. In adults, RPE ranged from 10.9 ± 1.9 (chest) to 12.0 ± 1.8 (leg) at 8-minutes, and from 11.8 ± 2.1 (chest) to 13.3 ± 1.6 (leg) at 16-minutes.

A two-way ANOVA (group x time) on the heart rate responses at 8 and 16-minutes of exercise revealed significant differences between the children and adult groups (children>adults) ($P<0.05$), and over time (16-minutes>8-minutes) ($P<0.05$). However, there was no interaction, indicating that HR increased by similar amounts between groups. Blood lactate concentration was significantly lower ($P<0.05$) in the children, and decreased ($P<0.05$) over time and similar to the HR data, there was no interaction effect. VE / VO_2 was significantly higher in the children ($P<0.05$), but there were no changes over time and no interaction effect.

Heart rate and VE / VO_2 were higher in the children than in the adults, and since signals from degree of cardiorespiratory strain may influence RPE, these responses may account for the tendency for RPE to be higher in children. Lower blood lactate concentrations observed in children may be attributed to reduced lactate production in the muscles and decreased muscle glycogen levels (Eriksson et al., 1971). In addition, lower blood lactate concentrations observed in children may be attributed to an increased oxidative capacity (Eriksson, 1972), and could also be influenced by factors associated with its clearance from the circulation (Mahon et al., 1997). The study by Mahon et al., (2001) confirms the ability of children to discriminate sensory cues of exertion. However, the authors recommend that the specific mediators involved in children's perception of effort warrant further study.

In conclusion, children display a different relationship between RPE and blood lactate compared to adults. Compared to adults, the literature indicates that children report a higher RPE for a given blood lactate level. Children exhibit a lower generation of blood lactate, but report a higher RPE. In addition, the blood lactate concentration of 2.5 mmol/l at the anaerobic threshold for children (Williams and Armstrong, 1991), is lower than the blood lactate concentration reported for adults of 4 mmol/l (Heck et al., 1985). In the reporting of an overall rating of perceived exertion, blood lactate is not the only determinant. The overall rating of effort perception integrates signals from the peripheral, central cardiovascular, respiratory and central nervous systems.

9. Use of RPE for Exercise Prescription

Rating of perceived exertion is often taken into account for exercise prescription. The concept may be applied to endurance training in various sports and also to improving general fitness and to rehabilitation. Perceived exertion is considered in exercise prescription because of its close relationship with physiological measures such as HR, and because it also integrates other important strain variables.

If a person can learn to use their effort sense and develop sufficient awareness for determining an appropriate exercise intensity for regulating and controlling their exertion, it would remove the need for using other devices e.g., heart rate monitors, and would ensure that exercise training is not interrupted for periodic heart rate measurements. Rating of perceived exertion is therefore a method of exercise prescription that is applicable over a wide range of clinical, recreational and athletic settings.

It has been recommended that during the initial phase of training, exercise intensity should be regulated by both HR and RPE (ACSM, 1991; Noble and Robertson, 1996). Additional use of perceptual monitoring helps to refine the exercise prescription by subjectively matching the performance with the training zone. As the training programme progresses and the participant develops a knowledge of the

HR:RPE relationship, heart rate monitoring can be reduced or eliminated, and RPE can be used as the main method for regulating intensity. Regulation of the prescribed exercise intensity can then be accomplished by producing a target RPE. In addition, changes in RPE can be used as a guideline in modifying the exercise prescription.

The ACSM (1990) recommend an intensity of 50 - 85% VO_2 max for enhancement of cardiorespiratory fitness in adults. In 1995 the guidelines for enhancement of health and cardiorespiratory fitness were 40 - 85% VO_2 max. The two sets of recommendations are not identical because the position stand (1990) focused primarily on fitness enhancement, whereas the recommendations (1995) were designed to encompass activity that may enhance health (at lower intensities). It has been reported that aerobic capacity improves if exercise is sufficiently intense to increase HR to about 70% of maximum, which is equivalent to 50 - 55% VO_2 max (Gaesser and Rich, 1984). Adapted from the ACSM (1991), Table 2 shows the approximate intensity relationships between percentage of maximum heart rate, maximum heart rate reserve, maximum oxygen consumption and the rating of perceived exertion.

Table 2: Intensity Relationships

% HR max	% HRR max	% VO_2 max	RPE (6-20)
60	45	38	10
70	55	50	12
80	65	60	13
85	80	70	13
90	85	85	16

10. RPE: Methodological Considerations

10a. Reliability of Effort Perception

In several studies examining the reliability of the RPE scale in adults (Skinner et al., 1973; Stamford, 1976; Wenos et al., 1996), reliability has typically been reported as test-retest correlation coefficients, which between the range of 0.70 – 0.90 have been regarded as sufficiently high to indicate 'consistency of results'. One could question these claims for reliability on statistical grounds. The lack of regard given to the appropriateness of the statistical techniques used to quantify reliability first appeared in the literature in 1986, when Bland and Altman highlighted that correlation coefficients do not actually assess the level of agreement between repeated measures (they quantify the degree of association). The intraclass correlation coefficient (ICC) for test-retest reliability analysis may be obtained from a repeated measures analysis of variance (Thomas and Nelson, 1990), and may be calculated as: $R = (MSs - MSw) / MSs$, where MSs represents between-subject variance, and MSw represents within-subject variance.

However, Bland and Altman (1986) argued that the intraclass correlation was too sensitive to the range of measurements in a sample (between-subjects variance), because any correlation coefficient depends not only on the level of agreement but also on the range of scores in the sample. Therefore, it is possible for the ICC to mask quite large disagreements for individual subjects. As an alternative, Bland and Altman (1986) presented their statistical technique of analysing the 95% limits of agreement (95% LoA) between repeated measurements. It is recommended that studies which research the validity and reliability of effort rating scales for children, conduct both the Intraclass Correlations (overall and individual level) and 95% Limits of Agreement analysis (Eston et al., 1999). Together they provide a comprehensive picture of a scale's reliability. This technique is now being increasingly used as the accepted method for examining the reliability of the RPE scale during standardised and replicated exercise conditions, and two research studies in the field of sports medicine and paediatric exercise science which have employed this analysis (Lamb et al., 1999; Buckley et al., 2000) are discussed in Section 12d.

10b. Mode of Exercise

The validity of the RPE has been demonstrated for different modes of exercise including cycling (Skinner et al., 1973), walking and running (Robertson, 1982), stepping (Walker et al., 1996) and rowing (Marriott and Lamb, 1996). In addition, variations in levels of physical activity (Eston and Williams, 1988; Parfitt et al., 1996), and conditions such as blindness (Buckley et al., 2000), asthma (Yorio et al., 1992) and cardiac disease (Dunbar et al., 1998) do not appear to affect the validity of the RPE scale to reflect metabolic demand.

Ratings of perceived exertion are now being increasingly applied to evaluate, monitor and prescribe the intensity of physical activity during clinical exercise testing, exercise programmes, occupational tasks and athletic performances. Ratings of perceived exertion are an important component in the clinical and laboratory practice for; (i) assessing exercise tolerance (Ekblom and Goldbarg, 1971; Noble, 1982; Pollock et al., 1986b; Eston and Thompson 1997), (ii) prescribing exercise intensity for training (Borg and Linderholm, 1967, 1970; Pollock et al., 1982; Eston et al., 1987; Eston and Williams, 1988; ACSM, 1986, 1991), (iii) assessing the effectiveness of a therapeutic exercise intervention (Gutmann et al., 1981), and (iv) guiding the duration of a graded exercise test (Noble, 1982).

10c. Exploring Preferred vs. Prescribed RPE

The differences in psychological affect and interest-enjoyment between a prescribed intensity (65% VO_2 max) and a preferred intensity exercise session were investigated by Parfitt et al. (2000). Twenty six (12 male and 14 female) aerobically fit individuals (aged 20.5 ± 2.6 years) exercised for 20 minutes at 65% of their predicted VO_2 max on a motorised treadmill. Heart rate, RPE (6-20) and Subjective Exercise Experiences Scale (SEES) (McAuley and Courneya, 1994) readings of psychological affect were measured in the last 45s of each 5-minute period.

On a subsequent occasion, participants were instructed to exercise continuously on a treadmill at their own preferred work rate for 20 minutes. They were informed that they could change the intensity after 5, 10 and 15 minutes if they wished to do so. As with the prescribed session, heart rate, RPE and SEES were measured in the last 45s of each 5-minute period.

At the end of a third session (either preferred or prescribed) participants were questioned about which exercise session they had preferred and why. Results revealed that during the preferred exercise condition participants chose to exercise significantly harder (average intensity of 71% VO_2 max) comp ared to their prescribed sessions of 65% VO_2 max, with no significant difference in RPE between the two exercise conditions. These results suggest that RPE in a preferred exercise protocol is lower. When left to select their own intensity, individual work rates increased over the duration of the exercise session. In addition, there were no significant differences in levels of positive well-being and psychological distress between a prescribed and preferred intensity exercise session, despite participants exercising at a significantly higher intensity in the preferred condition. In both conditions, participants showed high levels of interest-enjoyment. However, in the preferred condition they reported feeling more self-determined. Improved self-determination increases intrinsic motivation for exercise, which may lead to improved adherence to a preferred exercise regimen (Parfitt et al., 2000). These results are important from a health promotion perspective and have implications for the traditional method of prescribing exercise programmes.

10d. Mode in which the RPE is used:- Active or Passive?

Since the 1970's Ratings of Perceived Exertion have been examined by employing a variety of exercise methodologies; continuous, discontinuous, incremental and randomised. Unlike continuous methodologies, discontinuous methodologies have rest periods between exercise bouts, thus reducing the influence of fatigue on effort perception. Methods which measure responses to a situation where the exercise gets progressively harder are termed 'incremental', whereas 'randomised' methods randomise the order of presentation of workloads. In these methodologies the relationship between perceived exertion ratings and various measures of exercise intensity have been derived by the estimation and production methods. The estimation method is also termed the response method (Williams and Eston, 1996). For this method, a rating of perceived exertion is given in response to a request from the tester to indicate how 'hard' the exercise feels. The information may be used to compare responses between conditions or after some form of intervention. It may also be used to assist the tester in the prescription of exercise intensities (Eston and Lamb, 2000). In the production method the participant is requested to produce a specific RPE during the exercise bout (Eston and Lamb, 2000). Measures of metabolic demand may then be compared at each RPE-derived exercise intensity level.

The first study to apply the rating of perceived exertion in a production protocol was Smutok et al., (1980). Ten normal adult males aged 25.5 ± 2.7 years completed a discontinuous estimation treadmill protocol and reported their RPEs using the Borg 6-20 scale at treadmill speeds of 4.7, 6.5, 9.7, 11.3 and 12.9 km/hr (presented in a progressive order; Trial 1). Participants exercised at each treadmill speed for five minutes. Heart rate, VO_2, VE and RPE were measured during the last minute of each exercise bout. Participants were then requested to subjectively regulate their own treadmill speed during two separate discontinuous effort production protocols, to match the RPEs (randomised) reported for each speed during the estimation protocol (Trial 1). Speed and heart rate at equivalent RPEs were compared across Trial 1, Trial 2 and Trial 3. Trials were separated by approximately one week.

Regression analyses revealed that there was no difference in speed across all RPE between the three trials; however, heart rate was seen to become progressively higher during the production protocols (Trial 2 and 3) compared to the estimation protocol (Trial 1). Pearson's product moment correlation coefficient revealed that heart rate reliability was significant ($p<0.05$) during running speeds (above 9 km/hr, RPE 12), but not significant ($p>0.05$) during walking speeds. Regulation of walking exercise was shown to be inaccurate when considering heart rate as the measure of exercise intensity, even though speed was reliably regulated. For example, the mean speed at the lowest RPE was 4.7 km/hr during Trial 1 and 5.3 km/hr during Trial 2 and 3. The non-significant increase of 0.6 km/hr between the trials resulted in a significant increase in heart rate. Results revealed a general trend of improved accuracy with increasing RPE. Since 60% of the participants in this study preferred to change their mode of exercise (from walking to running) between the estimation and production trials, the mode change may have been responsible for the higher heart rates recorded in Trial 2 and 3, even though the RPE was the same. It was concluded that prescription of exercise by RPE could produce safe, effective and reliable conditioning heart rates above 150 bpm (80% HR max) and running speeds above 9 km/hr, but that caution ought to be used if strict adherence to target heart rates were required (Smutok et al., 1980).

A subsequent study to assess the usefulness of the Borg (1970) 6-20 RPE scale during estimation and production protocols was conducted by Eston et al., (1987). Sixteen relatively fit young men (aged 21 ± 2.5 years) and twelve women (aged 23.2 ± 4.8 years) attended the laboratory on three occasions. 'Relatively fit' males were described as having an average VO_2 max of 57.6 ± 4.5 ml/kg/min and females 42.3 ± 4.6 ml/kg/min. On the first visit participants were introduced to running on a treadmill. On the second visit they completed a graded exercise test to assess maximal oxygen uptake. Rating of perceived exertion was recorded in the last 15s of each incremental steady state VO_2. On a subsequent visit participants were requested to exercise on a treadmill at constant exercise intensities which they perceived corresponded to 9, 13 and 17 (presented in that order) on the RPE Scale. RPE was reported to be at least as good a predictor of exercise intensity as HR in both the estimation protocol (graded exercise test) and effort production test (Eston et al., 1987). A significant finding from this study was that all participants were within 59 to 84% VO_2 max (mean value 70% ± 7%) when their estimated effort RPE was 13, and an RPE of 16 to 17 correlated with approximately 90% VO_2 max. Rating of perceived exertion was reported to be a practically useful tool for quantifying exercise intensity when used by healthy and active individuals (Eston et al., 1987; Eston and Williams, 1988).

11. Effort Perception in Children

11a. Use of the Rating of Perceived Exertion Scale with Children

Although the RPE Scale has mainly been used with adults, it has been used with some success with children. Oded Bar-Or was the first to explore children's perceptions of exercise effort, and data was presented from six different projects involving a total of 589 children (aged 7-17 years) to the First International Symposium on Children and Exercise in Stockholm. Published in 1977, his research involved recording children's RPEs during continuous, incremental cycle ergometry, over an exercise range of 50 to 200W. Rating of perceived exertion was plotted against heart rate, and revealed that children in each of the six age groups (7 to 9, 8 to 10, 10 to 11, 11 to 12, 13 to 14 and 16 to 17 years) reported higher RPEs in line with increases in power output (cycling resistance). However, compared with adults, with one exception (the 7-to 9-year old group) the children reported lower ratings of perceived exertion than adults at the same relative intensity.

It was concluded that children younger than 16 years of age may experience problems with using the Borg RPE Scale compared with individuals aged 18 years or above. Although this research contained a number of methodological inconsistencies, i.e., variability of the children's exercise habits and some of the data collected as part of a heat-acclimatisation study, for the next ten years it was regarded as a benchmark for children's perception of effort.

With a few exceptions, including research reporting on the consistency of RPE ratings among 'active' girls (Kahle et al., 1977), and research by Davis et al. (1980) which explored RPE among anorexic female adolescents, no further studies relating to children's effort perception appeared in the literature until 1986. In this year, five studies were published; (Bar-Or and Reed, 1986; Eston and Williams, 1986; Miyashita et al., 1986; Van Huns, 1986; Ward et al., 1986).

Miyashita et al. (1986) examined the RPE:%HR max relationship during a continuous cycle ergometry estimation protocol in 120 boys aged 7 to 18 years, and reported correlation coefficients of $r > 0.90$ for the older age groups. The coefficient was lower ($r = 0.55$- 0.74) for the youngest age group (7 - 9 years). They concluded that 9 years of age might be the youngest age at which children could use the Borg RPE Scale in a valid manner.

Researchers continued to investigate the RPE:objective effort relationship, mainly in laboratory settings and in 'estimation' mode. Most studies used a cycle ergometer as the mode of exercise (Aleskeev, 1989; Gillach, 1989; Ward and Bar-Or, 1990; Ward et al., 1991; Lamb, 1995; Meyer et al., 1995). Ward and Bar-Or (1990) investigated the usefulness of the Borg 6 - 20 RPE scale as a means for exercise prescription in overweight (body fat 30-38%) children aged 9-15 years. Twenty children cycled at four intensities based on a pre-determined % peak power, reporting RPE ratings at each load. During two return visits participants were asked to alter the resistance on the cycle ergometer (cycle tasks) and to walk or run around an oval track (track tasks) at intensities they perceived to equate with RPE 7, 10, 13 and 16.

It was observed that children were able to discriminate between each of the RPE prescriptions on the cycle ergometer. However, the children over-estimated intensities on the track tasks. It was concluded that the overweight children needed additional instruction in using the Borg Scale for exercise prescription (Ward and Bar-Or, 1990). It is important to highlight that the above study contained fundamental methodological inconsistencies. Different tasks were compared (cycling vs. running) together with different psychophysical processes (estimation vs. production protocols). The implications of these methodological inconsistencies are considered further in Section 12c.

In a later study, Ward et al. (1991) also compared children aged 8 - 14 years (n = 17) to an adult group (n = 19), for their ability to use the Borg 6-20 RPE Scale in cycle and walk / run exercise tasks. From an initial estimation cycle ergometry protocol, peak mechanical power (PP) was predicted. Participants then completed an intermittent cycle ergometry protocol at a constant pace of 50-60 rpm. Participants were asked to instruct the tester to alter the amount of resistance (weight) needed to produce an RPE of 7, 10, 13 and 16 (randomised). A two-minute period was allowed for addition / removal of weights, and then once the intensity had been selected and confirmed, participants cycled for a further two minutes. Heart rate and RPE were recorded during the last 15s of the protocol. A minimum of two minutes rest was given between exercise bouts. For the intermittent running task, subjects were asked to complete one lap of an outdoor 400m track at a speed equalling an RPE of 7, 10, 13 and 16 (randomised). Speed was measured at 100m intervals around the track and heart rate was monitored via a Sport Tester PE3000. Following each task RPE ratings were obtained.

Results indicated that for the cycle ergometry task, both children and adults chose work levels that were incrementally higher at each of the four RPE levels (RPE 16> RPE 13> RPE 10> RPE7) as shown by progressive increases in %PP and % HRmax with increasing RPE number ($p<0.001$). As expected, adults ran faster than children but the children were unable to discriminate between the four RPE levels. Only RPE 7 was significantly different ($p<0.05$) from the other RPE levels. Velocities at RPE 13 and 16 were nearly identical (3.31 vs. 3.33 m/s). Whereas the adults employed a wider range of speeds, with significant increases ($p<0.05$) recorded at each RPE level. The adults were also closer to the laboratory-determined criterion than the children were. It was recommended that children needed adequate practice in order to understand the concept of the RPE scale (Ward et al. 1991).

A variety of exercise modes have been employed to investigate the validity of using the RPE scale with children. For example; a treadmill (Eakin et al., 1992; Mahon and Marsh, 1992; Mahon and Ray, 1995; Tolfrey and Mitchell, 1996), an arm ergometer (Ward et al., 1995) and a swimming pool (Ueda and Kurokawa, 1991).

Despite Eston's (1984) discussion paper on the potential for using RPE in the secondary school physical education curriculum, only two studies to date (Nystad et al., 1989; Stratton and Armstrong, 1994) have attempted to use the RPE Scale in the field setting of a school physical education lesson in order to explore whether children's ratings of perceived exertion were related to their objective measures of exercise effort. A potential application of this would be in the delivery of optimal (cardiorespiratory) training intensities during school-based physical education lessons. In 1989, Nystad et al. published an illustrated RPE Scale with all of the written descriptors removed (Figure 8). Instead, six figures depicted various stages of effort and the scale was employed with a group of 10-12 year old asthmatic children in the real-world setting of a 60-minute physical education lesson.

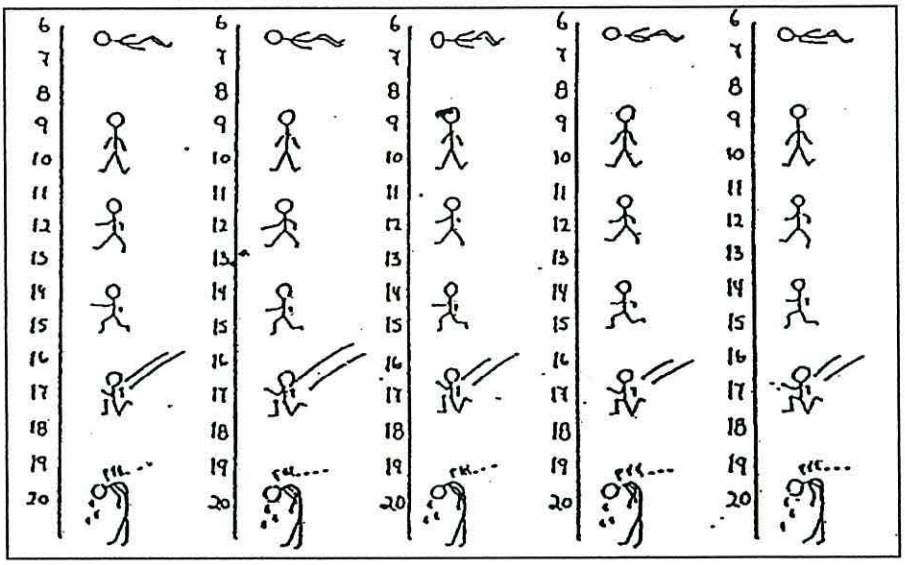


Figure 8: Illustrated RPE Scale (Source: Nystad et al., 1989)

The lack of a RPE:HR association was explained in terms of the small sample size (n=10), relatively low intensity level of the physical education lesson (most heart rates below 150 bpm), and the fact that because the children were asthmatic they reported disproportionately higher RPEs than their heart rates. It was also reported that the children might have been physically inexperienced (lacking an awareness of different exercise intensities) (Nystad et al., 1989). In spite of Nystad's attempt to improve the children's interpretation of the RPE 6-20 Scale and to try to enhance their understanding of exercise effort it was observed that children were still confused by the scale.

11b. External Validity of RPE

In the early 1990's, although two investigations had ventured out of the laboratory onto a running track (Ward and Bar-Or, 1990; Ward et al., 1991) it was not until 1994 that the external validity of the RPE scale was further explored in a field / game setting by Stratton and Armstrong. Their study was the first to explore whether children were able to use the RPE Scale during a games session (indoor handball lessons). Forty-two boys and girls aged 12.7 ± 0.3 years participated in the study. Heart rates were recorded once every 15s during the lessons, as were the percentages of lesson time spent at the 140 bpm, 160 bpm and maximum heart rate levels. Post-lesson, the children provided an RPE score for when they perceived they were working their hardest during the physical education lesson, and how they perceived the overall intensity of the lesson. Pearson product-moment correlations were employed to assess three heart rate and RPE relationships. Results of the correlation analyses indicated non-significant differences at all levels. It was observed that the children had poor perceptions of the intensity of exercise during indoor handball lessons and grossly underestimated their level of exertion on Borg's CR10 Scale. It was concluded that the results had implications for coaches and teachers of young children, who should be aware that during games lessons, children's perceptions of the exercise intensity might well be confused with the difficulty experienced with the game activity itself (Stratton and Armstrong, 1994).

Their choice of employing the CR10 scale in this study is interesting in light of the overwhelming research providing evidence that adult-specific RPE scales may be invalid when used with paediatric populations. Due to this methodological discrepancy, it may have been that the children were confused by the use of the CR10 scale itself and not with the difficulty experienced during the handball lessons. It is highly likely that comprehension difficulties confounded the results. Another methodological flaw arising from this study is the fact that the children had to remember back to how they felt during the lesson, because they were asked to report their RPE scores after the lesson had finished. In light of this, one could question the validity of the children's RPE scores recorded in this study.

11c. Reported Difficulties of Using RPE

Three years earlier, Williams et al. (1991) suggested that young children (aged 8-14 years) were capable of interpreting and using the RPE scale to control (or produce) exercise intensity levels. However, they observed that children younger than 11 years of age had difficulty in cognitively assigning numbers to words or phrases that described exercise-related feelings. Many young children seemed to experience difficulty interpreting certain verbal cues that were semantically more advanced than their level of reading comprehension.

Estimates based on discussions at American College of Sports Medicine (ACSM) meetings have highlighted the fact that even though the RPE scale was designed specifically for use with adults, a small percentage (5-10%) of adults experienced difficulty in understanding the instruction and the requests to respond (Borg, 1998). The ACSM (1995) reported that 5 - 10% of persons unfamiliar with the RPE scale tended to over or under-estimate RPE during the early and middle stages of exercise testing, and suggest that three learning trials might help to reduce most errors of rating and permit RPE to be used as an adjunct to HR for monitoring exercise intensity. Already confirmed earlier by Williams and Eston (1988) and later by Buckley et al., (2000), practice with the RPE scale appeared to improve the reliability from trial to trial, even at lower RPEs.

In 1998, Borg reported that adults of average or above intelligence, with a good understanding of their own language and ability to count and use numbers should not have any difficulties using the RPE scale. This clearly highlights the implications for using the RPE scale with younger populations!

To ensure validity and reliability of using a scale with children, their age, their reading ability, and their ability to understand the chosen scale must be considered (Lamb and Eston, 1997). It was recognised at the first international symposium on physical work and effort in 1975 that perception of exercise effort was a developmental process, which might be greatly influenced by the extent of children's experiences of exercise (Borg, 1977). However, the RPE scale has continued to be routinely applied without question in many studies and nearly ten years later Bar-Or (1986) was still recommending that further research be conducted in order to determine the youngest age at which a child could use the RPE scale as an intensity measure. Since then, there has been extensive research which suggests that the RPE scale might not be the most appropriate for use with children (Miyashita et al., 1986; Eston and Williams, 1989; Williams et al., 1994; Lamb and Eston, 1997; Eston et al., 2000). Younger children might have problems regulating intensity of effort due to a limited experience of the range of sensations that accompany various exercise intensities. Children's ratings of perceived exertion become more realistically related to the metabolic cost of the activity as they grow older. This may be due to the increased experience of the range of sensations that accompany different types of physical effort (Eston and Williams, 1989).

Effective use of the RPE scale demands comprehension and translation of verbal expressions of exertion into the corresponding numerical form. Continued use of the RPE scale with young people has shown that they are puzzled by both the wording of the verbal expressions and the unusual range of numbers on the scale (Williams et al., 1993; 1994). The RPE scale was developed with adults in mind, not children. The accompanying instructions were employed for adults not children, reminding participants not to focus on any one 'cue', but rather on general fatigue. Comprehension difficulties for children may therefore exist.

Following continued research into the use of the RPE scale with children it was highlighted in the late 1980's that derivation of an alternative means of assessing exercise intensity was needed when rating effort perception in children (Williams and Eston, 1989). Irrespective of the type of scale employed, it is absolutely imperative that the exercising participant understands exactly what is expected in terms of perceived effort ratings. Many cognitive difficulties exist with the use of the RPE scale with children, therefore the employment and research of other scales is justified.

11d. Child-Specific Effort Rating Scales

The literature suggests that the validity of using the rating of perceived exertion scale with children is questionable. The scale was designed for adults, and children may have difficulties in understanding the verbal cues on the RPE scale and the accompanying instruction. The numbers (6 - 20) are also unfamiliar, with not all numbers having verbal cues, which may lead to further confusion. By accepting that the RPE scale has face validity with regards to the verbal expressions used, and criterion validity with regards to the relationship between RPE and objective measures of physiological strain, a basis is formed from which alternative scales for children can be devised and their use assessed.

Despite Nystad's (1989) attempt to improve the relatively incomprehensible nature of the 6-20 Scale, children were still confused by the scale. It was reported that the children lacked physical experience and awareness of a range of different exercise intensities, and therefore could not understand the concept of perceived exertion (Nystad et al., 1989). A suitable effort-rating system for children could act as a regulatory catalyst in learning to interpret the feelings associated with vigorous exercise of all types. Mutrie and colleagues at the University of Glasgow (Eston and Lamb, 2000), adopted a similar idea to Nystad's earlier attempt in order to try and enhance children's comprehension of the RPE scale (Figure 9). Original verbal cues used by Borg (1970) were retained, and phrases indigenous to the Glasgow area were also adopted! At present there are no validity and reliability data on this scale.

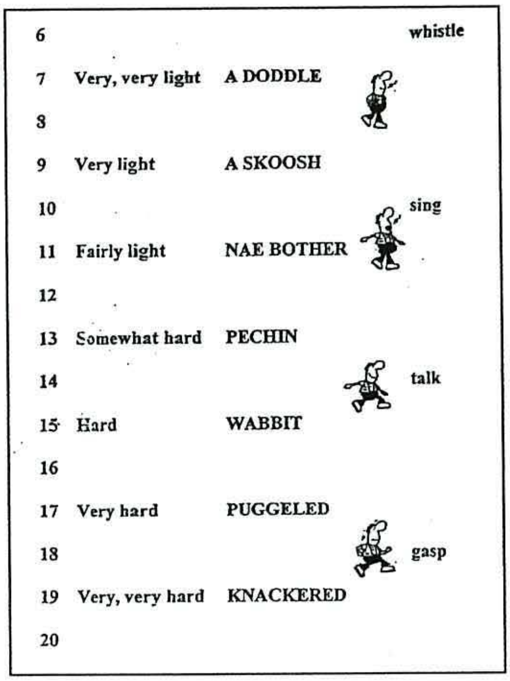


Figure 9: University of Glasgow vernacular RPE Scale (Source: Eston & Lamb, 2000)

A significant development in the study of children's perceptions of exercise effort occurred in 1993 when, as a result of these concerns, Williams et al. devised an exercise intensity scale specifically with children in mind. A project entitled 'Exercise: How it makes you feel' was introduced to 257 children in two schools in the Merseyside area of England through classroom teachers working with a small team of researchers. The children exercised in the playground mainly by running, walking and skipping (jumping rope) at different speeds and time periods. Shortly after participating in these activities, they wrote about the exercise and were encouraged to draw pictures depicting their efforts. They also discussed how the activity felt with their teachers and members of the research team. On the basis of the information provided by the children, the Children's Effort Rating Table (CERT) was devised as a conceptual model, adopting words and expressions that the children had used.

The Children's Effort Rating Table has familiar numbers (1 - 10), with familiar language to children accompanying each number (Figure 10). In this respect, it has 5 fewer possible responses and a range of numbers which are more familiar to children than '6 to 20'. The verbal expressions not only accompany all 10 numbers but also represent words chosen and understood by children as descriptors of exercise effort. The numerical range of the CERT (1 to 10) reflects a conceptual model in which perceived effort and HR in the range 100 to 200 beats/ minute are assumed to be linearly related as; HR = 110 + 12X, where X is the CERT value reported at any one time (Williams et al., 1994).

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 10: The Children's Effort Rating Table (CERT) (Source: Williams et al., 1994)

The first data involving the CERT emerged from an exploratory study with children aged 4 to 9 years (Williams et al., 1993). Four groups (n = 28 each) of children (Kindergarten: aged 4-5 years; Grade 1: 6-7 years; Grade 2: 7-8 years; and Grade 3: 8-9 years) completed an incremental stepping exercise protocol with increased backpack loadings corresponding to 0, 5, 10 and 20% of individual body mass.

Perceived exertion was rated using the CERT and heart rate recorded via HR monitors during the final 15s of each exercise bout. The correlation of the CERT exertion level: heart rate relationship by grade was reported as Kindergarten, $r = 0.73$; Grade 1, $r = 0.95$; Grade 2, $r = 0.99$; and Grade 3, $r = 0.99$ (all values $p<0.01$). Predicted individual heart rate values were calculated for CERT level 5 (*starting to get hard*) and 7 (*hard*), and then children aged 6-9 years (Grades 1-3) attempted to produce these exertion levels by adjustment of backpack loadings whilst stepping. The authors reported no significant association between predicted and observed heart rate. It was reported that when providing ratings, most of these children used only three levels of the table, namely, *'easy'* (3), *'hard'* (7), *and 'very hard'* (8). Apparently, the behaviour of these younger participants was linked to their phase of cognitive development. It was concluded that from around age 6 years, children were able to translate bodily sensations in a meaningful manner relative to the developmentally appropriate CERT, thus confirming the criterion validity of the scale. However, the children were generally unable to regulate their efforts accurately during the incremental stepping task. It was suggested that this might have been because the children had limited experience of working at varied exercise intensities.

The Kindergarten age group were more variable in their ratings of exercise effort. It would appear that very young children might be unable to match the full perceptual response range with a corresponding exercise stimulus during incremental stepping ergometry (Williams et al., 1993). Further research into how experiences of various types of exercise affect the nature of this cognitive development was recommended (Williams et al., 1993).

A year later, Eston et al. (1994) explored the validity of the CERT using a psychophysiological estimation / production paradigm. Sixteen children (aged 9.9 years ± 1.2) completed a continuous incremental exercise test on a mechanically braked cycle ergometer. The test commenced at 25W for 4-minutes and increased thereafter by 25W (or 10W for the youngest children) after every 4-minutes. At the end of each successive exercise stage the children estimated their exercise effort using the CERT, and heart rate was recorded. A CERT value of 9 or 10 indicated test termination. Linear regression analyses yielded the predictive ability of CERT as; HR = 127.7 + 6.6 (CERT); SE = 18.3 bpm, and PO = 26.7 + 6.8 (CERT); SE = 19.7 W.

In a subsequent cycle ergometer test, power output was self-selected to produce exercise effort equivalent to CERT levels 5, 7 and 9 (randomly ordered for each child). This production protocol was repeated in order to estimate test-retest reliability. Scale validation criteria were heart rate and power output responses during the production trial. Intraclass correlations of R = 0.91-0.95 for power output and R = 0.65-0.86 for heart rate between production protocol test-retest suggested that the CERT provided a reliable estimate of exercise intensity in children. During the cycle production protocol, the power output equivalent to CERT values of 5, 7 and 9 correlated significantly with the power output determined at the same CERT categories during the estimation protocol i.e., r = 0.84, 0.87 and 0.91 respectively, ($p<0.01$). Heart rate correlations between the estimation and production protocols yielded validity coefficients of r = 0.65, 0.78 and 0.79 ($p<0.01$) for CERT categories 5, 7 and 9, respectively. Although an explanation was not readily available, both power output and heart rate at CERT categories 5, 7 and 9 were 13-18% ($p<0.01$)

lower in the production protocol than in the estimation protocol. Nevertheless, the results provided preliminary evidence that the CERT was a useful indicator of physiological effort during cycle ergometry (Eston et al., 1994). They concluded that children aged 8 to 11 years were not only successful in perceiving tester-applied changes in their exercise efforts, but could also reliably regulate such effort by applying their comprehension of the CERT.

In a further follow-up validation study, Lamb (1995) examined the use of the CERT with 70 primary school children (aged 9.6 years ± 0.28). In this validation study, CERT category responses during a continuous incremental estimation cycle ergometry protocol correlated strongly ($p<0.001$) with both heart rate ($r = 0.96$) and power output ($r = 0.97$) for the mixed gender sample. In addition, correlations for CERT were consistently higher than for RPE. The results highlight that the traditional RPE Scale is not the best option for monitoring perceived exertion during controlled exercise with children (Lamb, 1995), and that the CERT is a useful alternative.

In 1997, Lamb and Eston highlighted the importance of employing consistent methodologies. Their concerns over the practice of comparing exercise intensities produced at particular perceived effort levels during discontinuous, randomised protocols with those estimated from continuous, incremental protocols are justified. It has since been recommended that ratings of perceived exertion studies involving children should only focus on examining how subjects perform during production trials (Lamb and Eston, 1997). The responses obtained during estimation trials are considered less important.

There has been continuing research into the development of children's perceived exertion. This research has lead to further refinement and development of existing effort rating scales such as the CERT, to facilitate children's understanding and interpretation of exercise effort. This was the case when Yelling and Swaine (2000) developed a pictorial version; the Pictorial Children's Effort Rating Table (PCERT) (Figure 11).

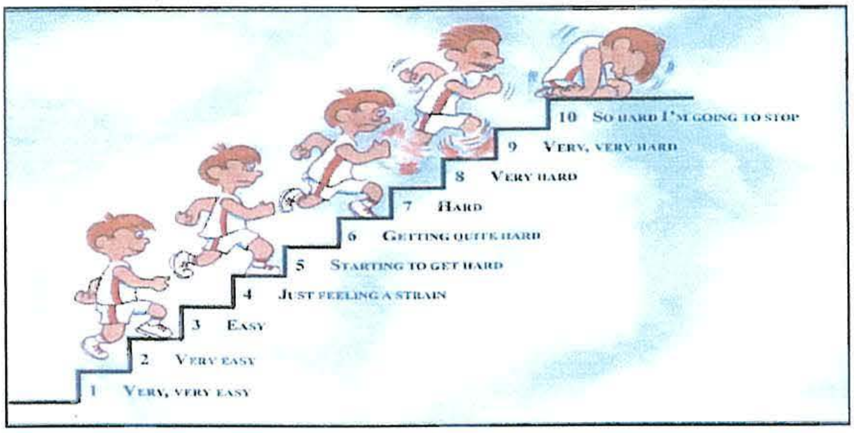


Figure 11: The Pictorial Children's Effort Rating Table (PCERT)
(Source: Yelling & Swaine, 2000)

Yelling, Swaine and colleagues (In Press) conducted an initial validation study using a stepping ergometry protocol. A mixed sample of 104 children (2 age cohorts of boys / girls, aged 11-12 and 14-15 years) completed a 5 x 3-minute single estimation trial (incremental and discontinuous) at 5 levels of the PCERT. Heart rate and ratings of perceived exertion were recorded during the final 15s of each exercise bout. Seven to ten days later the children completed a single 4 x 4-minute production trial (random and discontinuous) at PCERT 3, 5, 7 and 9. For the estimation trial HR vs. PCERT rating was; $r = 0.72$ (11-12 year olds) and 0.78 (14-15 year olds), respectively. The main effects of exercise intensity on perceived exertion and heart rate were significant ($p<0.01$). Perceived exertion increased as exercise intensity increased and this was reflected in simultaneous increases in heart rate. For the production protocol, heart rate and power output produced at each of the four prescribed effort levels were significantly different ($p<0.01$). These findings suggest that children's perceptions of effort using the PCERT represent valid reflections of the changing physiological demands of the exercise tasks presented. In addition, the children experienced some success in using the PCERT to regulate their exercise efforts to match four prescribed effort levels. Further research is required in order to determine whether this pictorial version of the CERT is indeed superior to the non-pictorial version developed in 1993 by Williams and colleagues.

Development of the child-specific Children's Effort Rating Table (CERT) has advanced research in children's effort perception, and the concept has received positive comment and interest (Robertson and Noble, 1997; Borg 1998). Prior to the appearance of the CERT, the RPE Scale, despite constant criticism with regards to its cognitive limitations, had still been employed with paediatric populations. Since the emergence of the CERT the scope for further research is now broader than ever before. Whilst further research will reveal whether the CERT is actually superior to the RPE Scale, it was at least devised with children in mind (Lamb and Eston, 1997). If research shows the CERT to be superior to the traditional RPE scale for use with children (perhaps above a minimum age) the challenge of incorporating it into physical education classes may be possible (Eston et al., 1994).

The CERT requires the child to interpret words and numbers alone, and prior to the development of the PCERT, researchers were already exploring how pictures could be incorporated into paediatric versions of effort perception scales in order to depict categories of exercise effort. Lowry (1995) developed a pictorial scale to assess perceived exertion in school children (Figure 12).

This four-point scale (below) used images of a heart exercising on a cycle in progressively increasing stages of exertion. The hearts were also coloured varying shades of red, as appropriate for each exertion level.

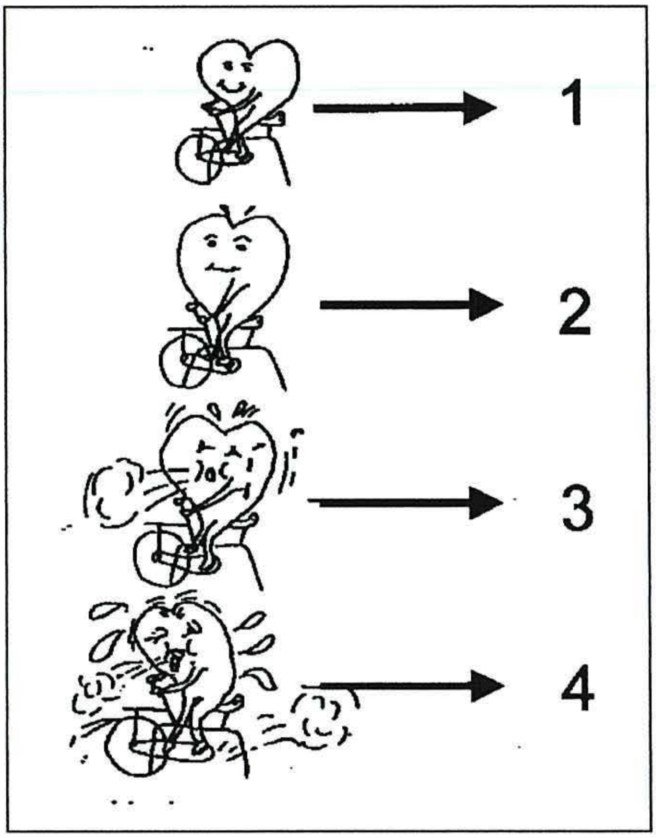


Figure 12: Exercising Heart RPE Scale (Source: Lowry, 1995)

In a pilot study to investigate the validity of the Exercising Heart RPE Scale, 20 boys and girls (aged 9 to 11 years) completed a discontinuous cycling protocol. The correlation coefficients (Spearman) between effort ratings and heart rates (0.62; $p<0.01$) and power output (0.67; $p<0.01$) suggest that this scale, with its limited selection of exertion categories might be worthy of future investigation.

Two years later, Robertson and Noble (1997) developed the OMNI Scale of Perceived Exertion for children (Figure 13). The scale was developed with the children's definition of perceived exertion in mind:- How *tired* does my body feel during exercise? The advantages of the OMNI Scale of Perceived Exertion were described by Robertson (1997); i) OMNI requires minimum scaling expertise on the part of either the tester or participant. ii) its responses are generalisable to developmentally, clinically and culturally different groups of children or adolescents. iii) it is simple to administer in diagnostic, competitive, recreational and structured learning settings. iv) it employs pictorially interfaced cognitive anchoring procedures, eliminating the need for mode-specific maximal exercise tests to establish agreement between stimulus and response ranges.

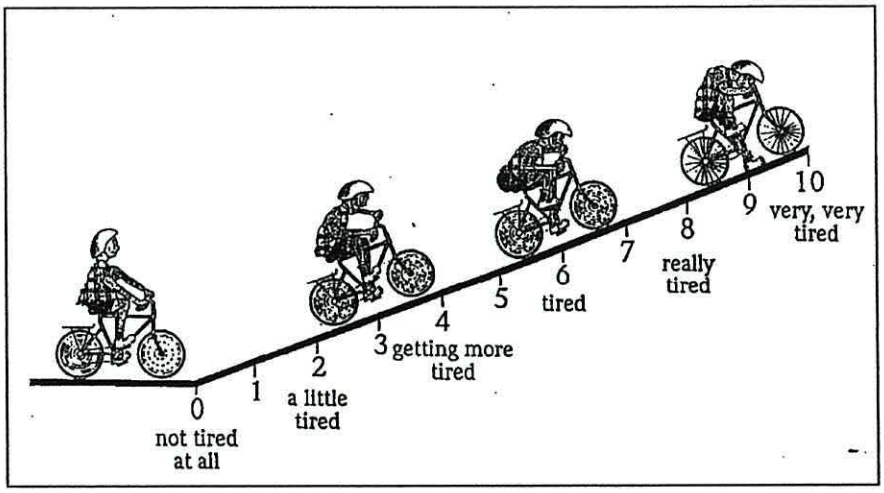


Figure 13: OMNI Scale of Perceived Exertion (Source: Robertson & Noble, 1997)

In 1999, Robertson and colleagues conducted an initial validation study of the OMNI Scale. A mixed sample of eighty 8-12 year olds (4 cohorts of clinically normal, boys/girls, white/African-American), completed a single estimation trial (incremental and continuous) on a cycle ergometer at 25, 50, 75 and 100W. Pedalling rate was maintained at 50 rpm. An undifferentiated OMNI rating was estimated for the overall body and differentiated ratings were estimated for the chest and the legs. Oxygen uptake, heart rate and OMNI ratings were determined at the end of each 3-minute stage.

For undifferentiated OMNI ratings, correlation coefficients revealed that for all 4 cohorts $r > 0.92$ (VO_2 *vs.* OMNI ratings) and $r > 0.92$ (HR *vs.* OMNI ratings). For differentiated OMNI ratings correlation coefficients revealed that for all 4 cohorts $r > 0.85$ (VO_2 *vs.* OMNI ratings) and $r > 0.97$ (HR *vs.* OMNI ratings). Regression analyses indicated that within each of the four gender / race sample cohorts, undifferentiated and differentiated OMNI ratings distributed as a positive linear function of both VO_2 and HR. Validity evidence for perceived exertion responses were also obtained using a two-factor (RPE x PO) ANOVA to determine differences between undifferentiated and differentiated OMNI ratings. Significant main and interaction effects were probed with a Tukey post hoc analysis. Results revealed that OMNI ratings for the legs were higher ($p<0.01$) than OMNI ratings for the chest and overall at the 25, 50, 75 and 100W power output levels. OMNI ratings for the chest did not differ from overall OMNI ratings at 25W and 50W, but were lower ($p<0.01$) than the overall OMNI ratings at 75W and 100W.

The data provided preliminary evidence that the OMNI scale was a useful indicator of physiological effort during cycle ergometry with children aged 8-12 years. Nevertheless, since the pictorial format of the OMNI scale shows a young person cycling, it is not yet known whether it can be used to assess children's effort perception in other dynamic modes of exercise such as running, swimming, stepping or climbing. The question of scale generalisability could be explored in future validation experiments (Robertson et al., 1999). In 2000, Robertson and colleagues further developed the OMNI Scale for use by children during walking / treadmill exercise (Figure 14). The pictorial descriptors on the OMNI–walk / run Scale were modified to represent a child at various levels of exertion, walking / running up an incline.

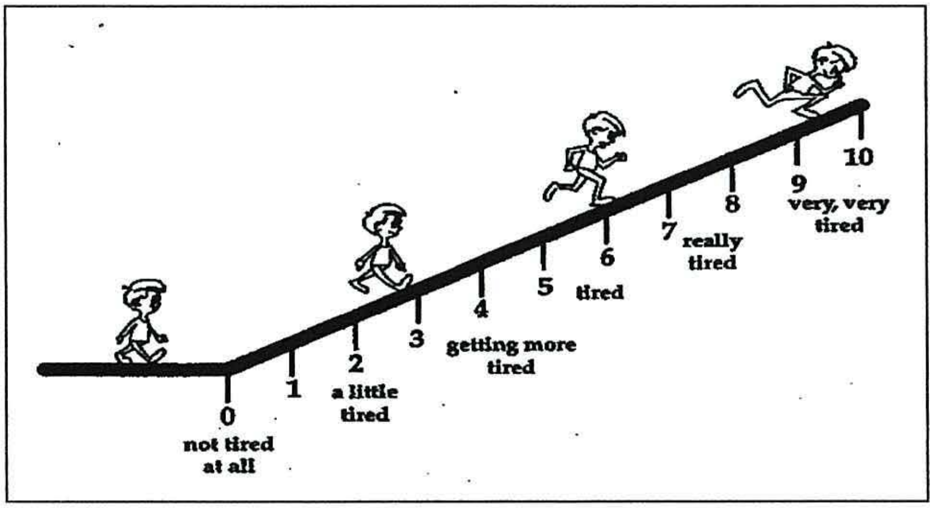


Figure 14: Children's OMNI Scale of Perceived Exertion for Walking/ Running
(Source: Robertson et al., 2000)

The validity of the above scale was examined during incremental treadmill exercise using a single estimation protocol (Utter et al., 2002). Sixty-three healthy male and female children aged 6-13 years completed a walking / running graded exercise test until VO_2 max had been achieved. RPE and heart rate measurements were recorded every minute throughout the test. Children were required to provide an undifferentiated RPE rating for the overall body. Significant pearson correlations were reported between OMNI-walk/ run Scale responses and VO_2, $\%VO_2max$, HR, VE/VO_2 ratio and respiratory rate throughout the maximal treadmill exercise test. The strongest correlations were reported between OMNI ratings and $\%VO_2max$ ($r = 0.41-0.60$, $p<0.001$) and HR ($r = 0.26-0.52$, $p<0.01$). These results provide preliminary evidence that the children's OMNI-walk/ run Scale is a useful indicator of children's physiological responses during walking and running tasks. Further research would need to be conducted in order to assess the reliability of such a scale and to determine if there is significant benefit of using the OMNI-walk /run Scale in exercise tasks as opposed to Robertson and Noble's (1997) original OMNI Scale.

The overall psychophysical structure of the OMNI Scale has been debated by Eston and Lamb (1999, 2000) who suggest that it would perhaps be more ecologically valid if a pictorial version of a perceived exertion scale for children contained a gradient that was curvilinear in nature and not linear, given that ventilation rises in a curvilinear fashion with equal increments in work rate. A child could recognise from previous learning and experience that the steeper the 'hill', the harder it is to ascend, which may also be useful in the process of 'anchoring'. In 2000, Eston and Lamb presented a perceived exertion scale that was readily assimilated by children on the basis of their own experiences and stages of cognitive development. The Cart and Load Effort Rating Scale (CALER) for regulating exercise intensity in children depicted a child cycling at various stages of exertion, towing a cart whose load progressively increased (Figure 15). Words were selected from the CERT to accompany some of the categories of exercise effort.

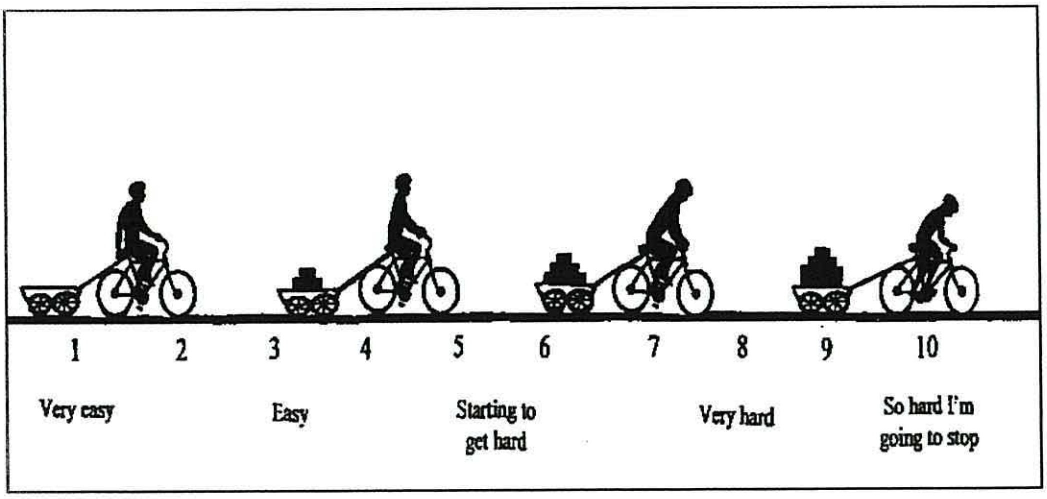


Figure 15: Cart and Load Effort Rating Scale (CALER)
(Source: Eston and Lamb, 2000)

An initial pilot study conducted in 1999 assessed the reliability of the CALER Scale to regulate exercise intensity production with practice, without reference to objective feedback measures (Eston et al., 1999). After warm-up and perceptual anchoring of the scale, 10 boys and 10 girls aged 7 – 10 years (8.15 years ± 0.87) performed a 3 x 3-minute intermittent, incremental, effort production protocol at CALER 2, 5 and 8 on a Monark 814E cycle ergometer. Power output was measured in the last 15s and each exercise bout was separated by a 2.5-minute rest period. This protocol was repeated on three occasions with at least one week between trials.

An increase in power output across trials (43, 65 and 80W) at CALER 2, 5 and 8, respectively, confirmed that the children understood the scale and provided concurrent validity for it. A Bland and Altman limits of agreement (LoA) analysis and an Intraclass Correlation Coefficient (ICC) between trials indicated that reliability improved with practice for both groups, particularly for boys. This demonstrated that children had learned how to self-regulate exercise intensity. Inter-trial comparisons of overall reliability from trial 1 to trial 2 and from trial 3 to trial 4 ranged from 0.76 to 0.97 and overall bias ± 95% LoA improved from –12 ± 19W to 0 ± 10W. This data provided preliminary evidence that the CALER scale is potentially a valid and reliable tool for regulating exercise intensity during intermittent, incremental cycle ergometry with young children aged 7 – 10 years (Eston et al., 1999). This study was the first to apply more than two repeated effort production trials in young children and provided strong evidence that practice improved the reliability of children's ratings of exercise effort.

There is extensive literature on exercise-related effort perception with adults. However, further exploration on exercise-related effort perception with children may now be conducted due to the development of child-specific effort rating scales. Of particular interest, is the application and use of such scales within a physical education environment. A child may associate the terms 'physical activity' or 'exercise' with personal experiences that encompass exertion, competition, play, and social interaction or skill development. Children's perspectives will undergo change and refinement as a result of personal experiences and maturation.

12. Child-Specific Effort Rating Scales: Methodological Considerations

12a. Anchoring Effort Perception

Whatever scale is used, it is important to provide children with an understanding of the range of sensations that correspond with categories of exercise effort on the scale. This is known as 'anchoring' (Eston and Lamb, 2000). This may be partially achieved by reference to previous experience (memory), but it can also be achieved through directed experience. In this way, the child is asked to produce a range of intensities, which can be used to set the perceptual anchor points at 'low' and 'high' levels. This can be achieved during test habituation. After an appropriate warm-up at an 'easy' level, the child should be allowed to experience exercise which is perceived as being 'hard' or 'very hard'. To avoid fatigue, a rest period should be given so the child can make a full recovery between anchoring points.

It is also important to standardise the instructions before using a perceived exertion scale. It is good practice prior to commencement of data collection with paediatric subjects, to issue copies of the scale to be used to participants, together with the scale instructions. For example, in studies by Eston et al., (1994); Lamb, (1995; 1996); and Lamb et al., (1997), copies were issued several days before data collection commenced.

Anchoring effort perception is now accepted as an important and integral part of test design and methodology. It should be recognised that the way in which the anchoring process is administered is also important. Researchers, for ease of administration, have typically anchored scales with children in a group situation. This may give rise to potential problems that could occur with peer assessment. In addition, when designing test methodology, researchers should consider the convincing evidence provided by Eston et al. (1999; 2000) that the reliability of rating of perceived exertion to gauge exercise intensity is enhanced by the number of practice periods. The way in which a subject practices is important. Research suggests this could be influenced by role, for example self-presentation (Hardy et al., 1986; Boutcher et al., 1988).

12b. Estimation and Production of Effort

Estimation and production protocols have been previously described by Williams and Eston (1996), see Section 10d. An 'estimation protocol' uses the RPE as the dependent variable, whereby the individual gives a subjective estimation of intensity of effort. In this way the rating of perceived exertion is provided in response to a given work rate or exercise intensity and may be considered as a 'passive' process. It may also be in response to a given heart rate, lactate concentration or speed. The subjective estimates may then be compared against measures of exercise intensity on a subsequent occasion. In a 'production protocol' ratings of perceived exertion may be manipulated as the independent variable to regulate exercise intensity (Eston and Thompson, 1997). In this way, the individual produces an objective measure of exercise intensity according to a pre-determined exertion level. This may be considered an 'active process' (Eston and Lamb, 2000).

The majority of research has focused on children's perceptions of effort during a passive estimation process. The effort perceptions have then been compared against objective measures of physiological strain, such as heart rate, power output or oxygen uptake. Most studies of rating of perceived exertion have employed a continuous testing protocol (Table 3) in preference to an intermittent testing protocol (Table 4). Fewer studies have applied effort production procedures in which children have been asked to regulate their exercise output to match experimenter-prescribed effort ratings. Such studies have included continuous and intermittent exercise protocols and are summarised in Table 5.

TABLE 3

Exercise intensity estimation using ratings of perceived exertion: Continuous exercise protocols and validation analyses with children

STUDY	AGE (y)	PROTOCOL	VALIDITY
Bar-Or (1977)	7-17	Cycle, incremental; 3 min. bouts: 50-200W (depending on age)	RPE vs. HR; r = 0.76-0.88
Davies et al. (1980)	12-18	Cycle, constant load; 60 min at 62% VO_2 max (RPE reported every 10 min).	Not addressed
Bar-Or & Reed (1986)	9-19	Cycle or arm cranking, incremental; 3 to 6 x 2 min. bouts until cadence <50 rpm.	RPE vs. HR (arms); r = 0.58-0.81 RPE vs. HR (legs); r = 0.69-0.82 RPE vs. %PP (arms);r = 0.74-0.92 RPE vs. %PP[1](legs); r = 0.72-0.86
Eston & Williams (1986)	15-17	Cycle, random, 3 to 4 min bouts; 30, 60 and 90% of predicted PO max.	RPE vs. HR; r = 0.74, p<0.01 RPE vs. PO; r = 0.78, p<0.01
Miyashita et al. (1986)	7-18	Cycle, 3 to 5 x 4 min. bouts (further details not specified).	RPE vs. % HR max; r = 0.55-0.94, p<0.01
Ward et al. (1986)	14-17	Cycle, incremental (unspecified) to VE.[2]	RPE vs. %PP; r = 0.84-0.86 (boys) r = 0.79-0.83 (girls)
Nystad et al. (1989)	10-12	Physical education lesson, 10 x 1 hour lessons.	RPE vs. HR; r = 0.05
Gillach et al. (1989)	10-14	Cycle, incremental; 25W / 2 min. to 85% predicted HR max.	RPE vs. HR; r = 0.64-0.65, p<0.01
Alekseev (1989)	10-14	Cycle, incremental (unspecified) to VE.	RPE vs. HR; r = 0.84, p<0.01 RPE vs. HR max; r = 0.87, p<0.01
Ward & Bar-Or (1990)	9-15	Cycle, incremental & random; bouts of 20, 40, 60 & 80% peak aerobic power every 2 min.	Not addressed.
Ward et al. (1991)	8-14	Cycle, incremental; 25W / 2 min. to VE.	Not addressed.
Eakin et al. (1992)	10-17	Treadmill, incremental; variable speed, 3-min. stages, 2% slope increase / min. (from 10%) to VE.	RPE vs. HR; r = 0.83-0.87, p<0.01 RPE vs. VO_2; r = 0.84-0.85, p<0.01
Mahon & Marsh (1992)	8-12	Treadmill, incremental; fixed speed, 2% slope increase/min. to VO_2 max.	Not addressed.
Stratton & Armstrong (1994)	12-13	Physical education lesson (handball)	[3]RPEM vs. HR; r = 0.23, p>0.05 [4]RPEH vs. HR; r = 0.10, p>0.05 [5]RPEH vs. HR max; r = 0.11, p>0.05

TABLE 3 (continued).

Exercise intensity estimation using ratings of perceived exertion: Continuous exercise protocols and validation analyses with children

STUDY	AGE (y)	PROTOCOL	VALIDITY
Williams et al. (1994)	4-9	Stepping ergometry,[6] incremental; 4 x 2-min. bouts with loadings of 0, 5, 10 & 20% body mass.	CERT vs. HR; r = 0.73-0.99, p<0.01
Eston et al. (1994)	8-11	Cycle, incremental, 25W / 4 min. to CERT rating 9 or 10.	CERT vs. HR; r = 0.76, p<0.01 CERT vs. PO; r = 0.75, p<0.01
Mahon & Ray (1995)	9-11	Treadmill, incremental; fixed speed, 2% slope increase/min. to VE.	Not addressed.
Ward et al. (1995)	11-30	Arm ergometry, incremental; 3 to 6 x 2 min loadings (unspecified) to VE	Not addressed.
Lamb (1995)	9-10	Cycle, incremental; 25W / 4 min. to CERT $\geq$ 9, or RPE $\geq$ 18.	CERT vs. HR; r = 0.69-0.79, p<0.01. RPE vs. HR; r = 0.45-0.79, p<0.01 CERT vs. PO ; r = 0.75-0.84, p<0.01 RPE vs. PO ; r = 0.53-0.83, p<0.01
Duncan et al. (1996)	9-11	Cycle, incremental; 10W/min. to VE. Treadmill, incremental; 3mph, 2.5% slope increase/min. to VE.	RPE vs. HR; mean r = 0.98 RPE vs. HR; mean r = 0.98
Robertson et al. (1999)	8-12	Cycle, incremental; 3 min. at 25, 50, 75 and 100W. Pedal rate of 50 rpm.	RPE-Overall body, RPE-Legs and RPE-Chest distributed as a positive linear function of both VO_2 and HR; r = 0.85 to 0.94; p<0.01.
Utter et al. (2002)	6-13	Treadmill, incremental; 13.4 m/min increase every 2 min until speed of 147.4 m/min attained. Then 3.0% slope increase / min to VO_2max.	OMNI[7] vs. % VO_2 max (r = 0.41-0.60, p<0.001) OMNI vs. HR (r = 0.26-0.52, p<0.01)

Key:

1 PP = Peak Power (W).

2 VE = Volitional exhaustion.

3 Relationship between lesson time spent at 140 bpm and RPEM (how the overall intensity of the lesson was perceived).

4 Relationship between lesson time spent at 160 bpm and RPEH (RPE score for when they perceived they were working their hardest during the P.E. lesson).

5 Relationship between the RPEH and maximum heart rates of individual children.

6 Protocol unclear, assumed continuous.

7 OMNI-walk / run Scale

TABLE 4

Exercise intensity estimation using ratings of perceived exertion: Intermittent exercise protocols and validation analyses with children

STUDY	AGE (y)	PROTOCOL	VALIDITY
Kahle et al. (1977)	7-11	Cycle, incremental; 5 x 1 min bouts at 25, 50, 75, 100 and 125% of PWC_{170} , interspersed with 1.5-min rests	Not addressed
Van Huss et al. (1986)	8-15	Treadmill, incremental; 3 min bouts separated by 3-min rest: 6mph at 0% & 5% grade, then increasing 1mph and 1% grade until VE	RPE vs. HR; linear (girls) RPE vs. VO_2; linear (boys and girls)
Ueda & Kurokawa (1991)	10-12	Swim, tethered, incremental; 1kg / 5 min (separated by 10-20 min rest)	RPE vs. % VO_2max ; r = 0.816 – 0.997 (for individual subjects)
Meyer et al. (1995)	9-12	Cycle, incremental; 3 x 15 min at 50% VO_2 max, then at 90% to VE (separated by 10 min rest)	Not addressed
Tolfrey & Mitchell (1996)	11-14	Treadmill, incremental; 3 min stages (unspecified) to VE	Not addressed
Yelling & Swaine (In Press)	11-15	Stepping ergometry, incremental; 5 x 3-minute at 5 levels of PCERT (separated by 2- minute rest period)	HR vs. PCERT rating; r = 0.72 (11-12y olds) and r = 0.78 (14-15y olds)

TABLE 5

Exercise intensity production using ratings of perceived exertion: Exercise protocols and validation analyses with children

STUDY	AGE (y)	PROTOCOL	VALIDITY
		Continuous Protocols	
Williams et al. (1991)	11-14	Cycle, incremental; 4 min. at RPE 9, 13 and 17.	Significant effect of RPE level on HR (p<0.01)
Williams et al. (1994)	4-9	Stepping ergometry, random; 1 min. at CERT 5 and 7	Non-significant correlation between HR pred. and HR obs. (p>0.05)
Eston et al. (1994)	8-11	Cycle, random; 4 min. at CERT 5, 7 and 9	HR pred. vs. HR obs; r = 0.65-0.79, p<0.01. PO pred. vs. PO obs; r = 0.84-0.91, p<0.01.
Lamb et al. (1997)	9-11	Cycle, random; 3 min. at CERT 3, 5, 7 and 9	HR vs. CERT; r = 0.36-0.50 (p<0.01). PO vs. CERT; r = 0.74-0.76 (p<0.01).
		Intermittent Protocols	
Ward & Bar-Or (1990)	9-15	Cycle, random; 4 min. at RPE 7, 10, 13 and 16, separated by >3-min. rest.	HR significantly higher (p<0.05) at each RPE level; (RPE16>RPE13>RPE10>RPE7).
		Track walk / run, random; 1 x 400m lap at RPE 7, 10, 13 and 16, separated by >3-min rest.	HR at RPE 7 lower (p<0.05) than at other RPE levels.
Ward et al. (1991)	8-14	Protocol as above.	Cycle: %PP higher (p<0.05) at each RPE level; (RPE16>RPE13>RPE10>RPE7). Track: %PP at RPE7 lower (p<0.05) than at other RPE levels.
Ward et al. (1995)	11-30	Track (subjects were wheelchair bound), random; 1 x 400m lap at RPE 10, 13, and 16, separated by rest until HR < 100 bpm.	HR higher (p<0.01) at each RPE level; (RPE16>RPE13>RPE10>RPE7). Wheeling speeds higher (p<0.05) at each RPE level; (RPE16>RPE13>RPE10>RPE7).

Table 5 (continued): Exercise Intensity Production using ratings of exercise: Intermittent exercise protocols and validation analyses with children

STUDY	AGE (y)	PROTOCOL	VALIDITY
		Intermittent Protocols	
Lamb (1996)	9-11	Cycle, random; 4 min. at RPE 8, 12, 15 and 18 or at CERT 3, 5, 7 and 9, separated by 2-min. rest.	CERT: HR higher ($p<0.05$) at 3 CERT levels (CERT 7 > CERT 5 > CERT 3). PO higher ($p<0.05$) at each CERT level. HR vs. CERT; r = 0.37-0.61, $p<0.01$. PO vs. CERT ; r = 0.59-0.75, $p<0.01$. RPE: HR higher ($p<0.05$) at 3 RPE levels (RPE 15> RPE 12> RPE 8). PO higher ($p<0.05$) at each RPE level. HR vs. RPE; r = 0.47-0.73, $p<0.01$. PO vs. RPE; r = 0.57-0.78, $p<0.01$.
Lamb et al. (1997)	9-11	Cycle, random; 3-min at CERT 3, 5, 7 and 9, separated by 3-min rest period.	HR vs. CERT; r = 0.62-0.69, ($p<0.01$). PO vs. CERT ; r = 0.68-0.85, ($p<0.01$). CERT : HR higher ($p<0.05$) at 4 CERT levels (CERT 9> CERT 7 > CERT 5 > CERT 3).
Eston et al. (2000)	7-10	Incremental cycle ergometry. 3-min warm-up at 25W. 3-min. at CALER 2, 5 and 8, separated by 2.5-min. rest period.	Increase in PO across trials (44, 65 and 79W at CALER 2, 5 and 8, respectively) ($p<0.01$). Increase in HR ($p<0.01$) (144, 165.3, 182.8 bpm at CALER 2, 5 and 8, respectively).
Buckley et al. (2000)	14-32	Cycle, random; 3-min. at RPE 9, 11 and 13, (between 50-80 rpm), separated by 10 min. rest period. [8]	Significantly different ($p<0.001$) %VO_2 max at RPE levels 9, 11 and 13 (47%, 53% and 63%, respectively). Significantly different % HR max at RPE levels 9, 11 and 13 ($p<0.001$).
Yelling & Swaine (In Press)	11-15	Stepping ergometry, 4 x 4-minute bouts, random at PCERT levels 3, 5, 7 & 9, separated by 2-minute rest period.	For HR, significant main effect for Levels ($p<0.001$). For approx. PO, significant main effect for levels ($p<0.001$).

8= Braille RPE Scale

12c. Validity of Effort Perception in Children

Where perceptions of exercise effort during production mode have been validated, researchers have compared the objective indicators with expected values calculated via regression analysis of an individual's data from a previous estimation trial. Values of heart rate, power output or oxygen consumption corresponding to each number on the effort perception scale have then been predicted and compared to values achieved in the production trial. The comparisons have then been quantified either by analysis of variance or interclass correlation. This method of comparing the ability of children to use perceptions of exercise effort to actively self-regulate exercise intensity levels using pre-determined RPEs to their ability to passively estimate exercise intensity from a previous test has been criticised (Eston and Lamb, 2000a). For example, in the first full paper published on this theme (Ward and Bar-Or, 1990), it was reported that 9-15 year old obese children could distinguish between four work rates based on predetermined RPE values (7, 10, 13 and 16). However, it was reported that the children produced work rates that were significantly different to expected values. As noted earlier, a fundamental problem with this type of study is that these expected values were derived from a different perceptual process. Similar results have been reported in later studies (Ward et al., 1991; 1995).

These observations have led Eston and Lamb (1997; 2000) 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 with an active perceptual process on a subsequent occasion. Noble's (1982) argument that this involves two dissimilar psychophysical processes is highly pertinent. The issue is further confounded when data collected during a passive, continuous estimation trial are compared to data from an active, intermittent production trial (Eston and Lamb, 2000a).

12d. Reliability of Effort Perception

The test-retest reliability of children's ratings of effort using the RPE and CERT during continuous incremental cycle ergometry have been reported by Lamb (1995). In his study, seventy school children aged 9–10 years were randomly assigned to an RPE group or CERT group. Both groups received two incremental exercise trials, seven days apart. Data analysis yielded significant ($p<0.01$) pearson correlations between perceived effort ratings and objective measures of exercise effort (PO and HR), the correlations for CERT were consistently higher than for RPE. Reported test-retest reliability (ICCs) for the RPE at work rates of 25, 50, 75 and 100W were R = 0.70, 0.81, 0.86 and 0.90 respectively, and R = 0.14, 0.62, 0.84 and 0.83 for the CERT. The intraclass correlations revealed that both scales were reliable, but that higher work rates appeared to be more reliable than lower work rates for both scales.

It was concluded that by using either scale, children's effort perception represented valid reflections of actual (and changing) physiological effort, and that with this group of children the CERT appeared to be as valid as the RPE Scale (Lamb, 1995). For some individuals, however, perceptions of effort were reported as weakly or inconsistently related to changing physiological demands. These comparisons were based on a single test-retest, which was unlikely to provide the period of practice necessary to allow adequate learning to occur, leading to inconsistent results. The observation that relationships between CERT and indices of objective effort were more stable between Trial 1 and Trial 2 (regardless of gender) than those for the RPE suggest that the CERT is preferable to use where practice is not available (Lamb, 1995).

Two studies on adults have comprehensively addressed the issue of reliability of the RPE Scale by employing the Intraclass Correlation Coefficient (ICC) and bias ± 95% limits of agreement (LoA) analysis (Lamb et al., 1999; Buckley et al., 2000). Lamb et al. (1999) employed the 95% LoA to assess the reliability of Borg's 6-20 RPE Scale during progressive treadmill exercise. Sixteen male athletes aged 23.6 ± 5.1 years completed two identical incremental treadmill-running protocols over a period of two to five days. RPEs were recorded during the final 15s of each 3-minute stage until either an RPE of 17 or volitional exhaustion was reached. All participants successfully completed at least four stages in each trial, allowing reliability of RPE responses to be examined at each stage. The 95% LoA were found to widen as exercise intensity increased. For example, reliability results for stage two were reported as $R = 0.80$, and 95% LoA = 0.25 ± 2.53. This means that the trained male athletes could potentially differ in their RPE responses to exercise trials by as much as 3 RPE units (value rounded up). By employing this statistical technique the results questioned the test-retest reliability of the RPE scale when used to monitor subjective estimates of exercise intensity in progressive (graded) exercise tests.

In a later study (Buckley et al., 2000) the 95% LoA analysis was also employed and the study had two main aims. One aim was to assess the validity and reliability of producing and re-producing, (on two further occasions), a given exercise intensity during cycle ergometry using a Braille version of Borg's standard 6-20 RPE Scale. A second aim was to determine whether the exercise responses of blind participants, at a given produced RPE, were similar to those reported in recognised guidelines for sighted individuals. Ten healthy registered blind volunteer participants

(4 females, 6 males, aged 23.2 years ± 9.0) performed an initial graded exercise cycle test to determine maximal HR and maximal VO_2. Three trials of three exercise bouts at RPEs 9, 11, and 13 were then performed in a random order on three separate days of the same week, with expired air and HR measured continuously. Each exercise bout was followed by a 10-minute rest period.

The validity of the Braille RPE Scale, as a means of producing different exercise intensities, was assessed using a two-factor ANOVA, with repeated measures. Inter-trial reliability was assessed via intraclass correlation coefficients (ICC) and the bias ± 95% limits of agreement (95% LoA) procedure. It was reported that participants were able to differentiate between levels of exertion and that in every trial at RPE 13 all participants met the ACSM (1986; 1990) target of 50-85% VO_2 max (the recommended range for developing cardiorespiratory fitness in adults). The ICC between the second and third trial for % HR max was statistically significant (P = .05) for all three RPEs. Similarly for % VO_2 max the ICC was significant for RPE 9 and 11 but not 13. The 95% LoA decreased for both %HR max and % VO_2 max with each successive trial. This indicates that practice improved the reliability of results.

The blind participants were successful in using the Braille RPE Scale to distinguish between three exercise intensity levels on a cycle ergometer. Furthermore, using %HR max as a judge of inter-trial reliability, participants were able to repeat similar exercise intensities after two trials at each of the three RPEs (9, 11, 13), indicating that practice with the scale improved the reliability of results. The same was true for RPE 9 and 11 when using % VO_2 max as a judge, but further trials were required for achieving similar reliability at RPE 13. The participants achieved similar HR and VO_2 responses to sighted individuals using the Braille version of Borg's standard 6-20 RPE Scale.

12e. Discontinuous vs. Continuous Protocols

Studies that have allowed rest periods between exercise bouts (Table 4 and 5) and thereby reduced the influence of fatigue on perception of effort have mainly been incremental in nature. Only seven studies since 1990 (Ward and Bar-Or, 1990; Ward et al., 1991; Ward et al., 1995; Lamb, 1996; Lamb et al., 1997; Buckley et al., 2000; Yelling and Swaine, In Press) have randomised the order of presentation of workloads, without which a scale cannot be used unreservedly (Lamb and Eston, 1997). A study conducted by Lamb et al. (1997) highlighted the problems with inconsistent test methodology. Sixty-six children aged 9–11 years were asked to regulate their exercise output to match experimenter-prescribed ratings of exercise effort. The children were randomly assigned to either a continuous protocol or a discontinuous protocol group. Both groups were required to regulate exercise intensity to match a range of four effort rating levels of CERT 3, 5, 7 and 9 (randomised). The children were allowed 2-minutes to settle on an appropriate resistance, before cycling for a further 1-minute at the chosen intensity. These intensities were recorded as power outputs (W). Heart rates were recorded after 2-minutes and again at the end of the third minute. For children allocated to the discontinuous group, each exercise bout was separated by a 3-minute rest period.

Results revealed that the discontinuous cycle ergometry protocol produced a consistently stronger relationship between CERT and HR levels ($r = 0.66$), suggesting that the 3-minute recovery periods may have assisted the children in their perception of exercise effort. The lower correlations between CERT and HR levels ($r = 0.46$) in the continuous protocol group may have reflected an inaccuracy of perception due to fatigue and/or error of judgement. It is of interest to note however, that mean heart rates for the continuous protocol (176.3 bpm) and discontinuous protocol (176.6 bpm) groups were not significantly different at the hardest prescribed level (CERT 9), implying that nothing was gained by rest periods in the discontinuous protocol. An explanation for the Group x Time interaction in which the 2-minute heart rates were disproportionately lower in the discontinuous protocol group than the continuous group was not obvious. The simple main effect of Time on HR was attributed to the possible non-attainment of steady-state conditions after 2-minutes of exercise. It was not known whether steady state had been reached even after 3-minutes.

The results suggest that children aged 9-11 years might be more able to use effort ratings to control exercise intensity when the exercise protocol is intermittent in nature, rather than continuous. The reliability and validity of effort ratings and physiological measures produced at specified ratings, may be affected by the test protocol (continuous or intermittent), the order of load presentation (incremental or random) and the timing of the data collection (Lamb et al.,1997).

13. CONCLUSIONS

Health-related exercise (HRE) is physical activity associated with enhanced health (Harris, 2000). Within the context of the National Curriculum for Physical Education, HRE relates to the contribution of physical education to health and its role within the curriculum. Delivery of this area includes the teaching of knowledge, understanding, physical competence and behavioural skills, and the creation of positive attitudes and confidence towards current and lifelong physical activity (Harris, 2000).

A whole school approach towards the promotion and encouragement of a healthy, active lifestyle is recommended to ensure coherence and consistency for children (Harris, 2000). A 'Healthy School' aims to achieve healthy lifestyles for the entire school (students, staff, governors and parents) by developing supportive environments that promote health (Harris, 2000). Whereas, an 'Active School' makes a commitment to physical activity levels of the entire school population, in a way that is likely to have a positive and sustained impact on physical activity habits even outside the physical education environment (Harris, 2000). The Active School will implement national curriculum guidelines for health-related exercise through a well planned, delivered and evaluated programme of study.

The application of children's effort sense and its use for Physical Education teachers is an area of paediatric exercise science that merits further investigation. If it were found that children could only distinguish between two levels of exertion on a paediatric effort rating scale (for example, 'Easy' and 'Very Hard'), this would still be of use to physical educators. Effort sense could still be applied in lessons to increase children's awareness of exercise intensity in relation to various activities. This would allow children to achieve attainment targets of health-related exercise (HRE) in the national curriculum for physical education. Examples of attainment targets of HRE in the national curriculum for Physical Education at Key Stage 1 are that pupils should be taught to 'understand the changes that happen to their bodies as they exercise, to recognise the effects and to describe changes to their feelings (tired or more energetic)' (Harris, 2000).

The aim of these studies of effort perception in children is to provide a valid and reliable tool which children might use as part of the Health-Related Exercise National Curriculum, to be made aware of how they feel when they exercise, and maybe to understand why they feel that way. If the external validity of child-specific effort rating scales can be determined within a physical education or games environment, then it could be possible to regulate or control children's physical activity levels. Children's perception of effort might then be used to guide the intensity of exercise during structured activity classes, providing a theoretical concept of HRE to classes, and an awareness of the importance of physical activity in youth. Research results could be brought to the attention of teachers in physical education, sports coaches and health specialists involved in the active promotion of health-related exercise within the national curriculum.

Rationale

To address many of the research questions relating to physical activity and health, it is essential to have a valid measure of the intensity of physical activity. The rationale for this research was the introduction of a newly developed child-specific effort rating scale for assessing effort perception in stepping protocols and across a range of ambulatory movements in physical education circuit training classes; the Bug and Bag Effort (BABE) Scale.

The purpose of the first study was to examine the validity and reliability of the BABE Scale as a measure of exercise intensity for children. This study also investigated if pictorial representation (use of CALER and BABE) helped to improve reliability of effort perception over trials, as compared to the more categorised use of the CERT. Bar-Or and Ward (1989) suggested that young children might improve their ratings of exercise effort if a scale were constructed for them that instead of numbers had pictures or colours, an idea that was adopted in the development of the BABE Scale.

The second study was designed to address a potential limitation arising from the first research study; that children had used the same standard bench height for the stepping protocol. Employing the same standard bench height might have caused mechanical inefficiency in their stepping technique, due to differences in their hip angles or leg length, and this could have led to a distortion in their rating of perceived exertion levels. The second study addressed this potential limitation by examining the effect of step platform height on children's efficiency of stepping.

With the emergence of pictorial child-specific effort rating scales, researchers have not yet investigated the association that children may make between pictorial representation depicted on the scales and the mode of exercise to be undertaken. Such an association might be a factor that hinders or improves a child's reliability of effort production across trials. The third study was therefore designed to investigate the validity and reliability of two pictorial child-specific effort rating scales (CALER and BABE) for intra- and intermodal regulation of effort production across trials using intermittent cycling and stepping protocols.

The applicability of effort perception within physical education lessons, and the use of child-specific effort rating scales by teachers within the health-related exercise (HRE) Physical Education national curriculum, is yet to be explored. If the external validity of using child-specific effort rating scales can be confirmed within a physical education setting, then this would enable physical education teachers to use such a tool within the HRE Physical Education national curriculum. The concept of effort perception could be used to increase children's awareness of the intensity of exercise in relation to various activities. Child-specific effort rating scales could be used within the HRE Physical Education national curriculum to aid the delivery and achievement of specific HRE attainment targets. Such targets require children to be able to describe changes to their feelings during physical activity (tired or more energetic) or to understand what happens to their body when they exercise (Harris, 2000). As part of their normal Physical Education lessons, the aim of the fourth study was to explore the external validity of the BABE Scale in six weeks of circuit training classes with primary school children aged 8 to 11 years.

CHAPTER 3

Validity of two Illustrated Rating of Perceived Exertion Scales for Regulating Exercise Intensity in Children: A Study Using a Stepping Protocol

1. INTRODUCTION

The present study was designed to compare the validity and reliability of the Cart and Load Effort Rating (CALER) Scale and the Bug and Bag Effort (BABE) Scale to regulate exercise intensity production with practice, without reference to objective feedback measures. This study will investigate whether use of the CALER accurately reflects the increasing metabolic costs of physical activity. The CALER depicts a child cycling with a cart of increasing loads, and may therefore be deemed more valid for use with a cycling protocol. With this in mind, an alternative scale is proposed entitled the Bug and Bag Effort (BABE) Scale for children participating in stepping protocols. The scale depicts an ant stepping with a backpack of coloured rocks which increase in load. The number of rocks in the backpack matches the number on the scale, and verbal descriptors compliment the scale with language already proven to be familiar to children (Williams et al., 1994). As recommended by Bar-Or and Ward (1989) colours were added to the pictures on the scale. The character in the BABE Scale was based on the Walt Disney film "A Bug's Life" (Figure 16), which was familiar with most children at the time of the study.

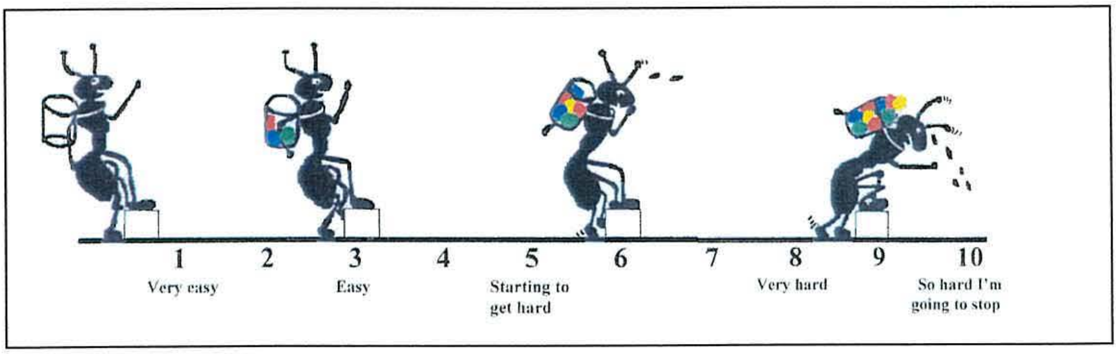


Figure 16: Bug and Bag Effort Scale (BABE Scale)

The purpose of the present study was to collect preliminary information on the validity and reliability of the BABE and CALER Scales as exercise tools for use with children aged 7 to 10 years. Piaget (1972) reported that children (aged 7-10 years) could understand and interpret pictures and symbols rather than words and numbers. This study will also investigate if pictorial representation (use of BABE and CALER) helps to improve reliability of effort perception over trials, as compared to use of the CERT.

2. METHOD

Full ethical approval for these proposed studies on 'The Use of Effort Rating Scales to Control Exercise Intensity in Children' has been gained from the South and West Research Ethics Committee, January 1999. A copy of approval is presented in Appendix A.

2.1 Subjects

Eighteen children aged 7 - 10 years, were selected from a primary school in Great Somerford, England. Descriptive characteristics of the children are presented in Table 6. Prior to data collection, parents or guardians had been supplied with an information sheet and had completed written informed consent for their children to participate in moderate exercise involving simple stepping tasks to be conducted on the school premises, (Appendix B).

Table 6: Descriptive Characteristics of all Participants by Gender

Measure	Boys, n=12		Girls, n=6		All, n=18	
	M	S.D	M	S.D	M	S.D
Age (y)	8.90	(0.9)	9.17	(1.33)	9.0	(1.03)
Stature (m)	1.32	(0.09)	1.36	(0.08)	1.33	(0.08)
Mass (kg)	29.42	(6.23)	31.33	(5.99)	30.06	(6.04)
Resting Heart Rate (b/min)	97	(14)	111	(19)	102	(17)

2.2 Procedures

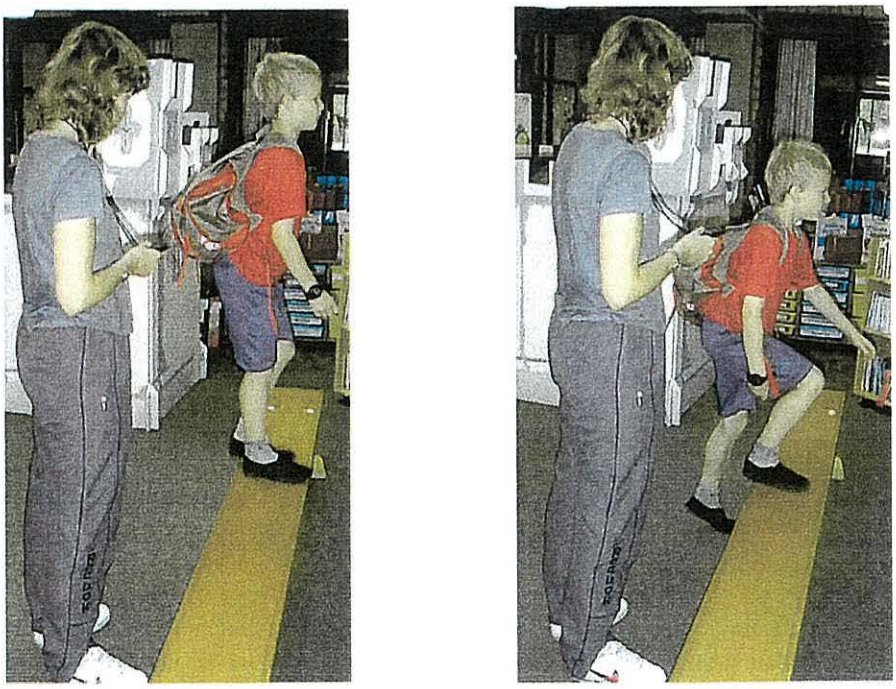
One week prior to testing, the children were introduced to the CERT, BABE and CALER Scales and test methodology. The tester explained how the verbal expressions should be interpreted in numerical form (Appendix C), and provided opportunity for children to ask questions about use of the scales. The tester described verbally the need not to be brave when rating exercise effort. The meaning of the verbal expressions on the scales was confirmed during a question and answer session. The children then practised the correct stepping cadence with and without the backpack. The children were able to quickly comprehend the requirements of the task.

After perceptual anchoring of the scales, 12 boys and 6 girls were randomly allocated to one of three equal sized groups; CERT (Group 1), BABE (Group 2) or CALER (Group 3) (Table 7). Data collection subsequently took place on three occasions for each group, at least one week apart.

Table 7: Group Characteristics of All Participants by Group

Measure	GROUP 1 CERT (n=6)		GROUP 2 BABE (n=6)		GROUP 3 CALER (n=6)	
	M	S.D	M	S.D	M	S.D
Age (y)	10.13	(0.2)	8.3	(1.2)	8.7	(0.5)
Stature (m)	1.41	(0.03)	1.27	(0.08)	1.32	(0.06)
Mass (kg)	35.0	(4.5)	25.2	(4.0)	30.0	(5.5)
Resting Heart Rate (b/min)	105	(6)	99	(13)	91	(16)

Children were tested individually and were fitted with a Polar Fitwatch (Finland) Heart Rate monitor with added aqua conductivity gel. Prior to commencement of the stepping protocol, each child rested in the supine position for several minutes before resting heart rate (bpm) was palpated at the radial artery, and this value recorded. The protocol used has been described by Williams et al. (1993, 1994). Warm-up prior to the test consisted of three minutes of low-intensity exercise which also helped to familiarise children with the testing conditions and decreased anxiety. Children performed an intermittent effort production protocol which required them to step on to and down from a gymnasium bench 0.30m high to a cadence of 25 steps per minute, provided by a metronome (Seiko DM-33, Taiwan). Ratings of exercise effort were manipulated by increasing body weight by loading a backpack fitted to the child (Figure 17 and 17a).



Figures 17 and 17a: Child performing the intermittent stepping protocol

Backpack loads were calculated and selected by the children according to 0, 5, 10, 15, 20 and 25% body mass. Children were required to instruct the tester to adjust their exercise intensity (loading) to three specific levels of CERT: 3, 5, 8 (Group 1), or BABE: 3, 5, 8 (Group 2), or CALER: 3, 5, 8 (Group 3).

Children were briefed on the task and whilst stepping, asked the tester to add weight to the backpack until they reported an intensity of CERT, BABE or CALER rating of 3, 5, and 8 (presented in a randomised order) had been reached. When the child reported that the intensity level and loading were the same, stepping was continued for a further 1-minute and heart rate recorded at the end of this period. A short pilot study to develop appropriate procedure indicated that effort production would be confirmed within 2 to 3 minutes at each level. Investigations in children have demonstrated that 2 to 3 minute stages are sufficient to produce approximate steady state (Skinner et al., 1971; Godfrey, 1974.). Each exercise bout was separated by a 5-minute rest period. Power output (W) was estimated using the equations of (Hanne, 1971) as follows:

Work per one ascent (J) = Body weight (kg) x Step height(m) x 9.80

Work per one descent (J) = Body weight (kg) x 3.92

Assuming N ascents and descents per minute, the mechanical power output is;

$$\frac{[(4/3) \times 9.8 \times \text{Step Ht}] \times [\text{Step Rate}]}{60} = \text{PO (W/kg)}$$

Where: 1.3 includes both the positive component of ascending (1.0) and negative component of descending (0.33).

$$\frac{[(4/3) \times 9.8 \times 0.3] \times [N]}{60} = \text{PO (W/kg)}$$

$$\frac{[(4/3) \times 9.8 \times 0.3] \times [25]}{60} = \text{PO (W/kg)}$$

$$\frac{[3.92] \times [25]}{60} = \text{PO (W/kg)}$$

Therefore;

$$\frac{\text{Body weight (kg)} \times 3.92 \times 25}{60} = \text{PO (W)}$$

For example; A 10 year old female with 30kg body mass, carries 15% of body mass working at CERT 8, the power output is:

$$\text{Power (W)} = \frac{(30\text{kg} + 4.5\text{kg}) \times 3.92 \times 25}{60}$$

$$= 56 \text{ W}$$

This protocol was repeated on two occasions for each group with at least one week between trials to estimate test-retest reliability.

2.3 Analysis of Data

Power output and heart rate were analysed with a Group (3) x Trials (3) x Levels (3) Analysis of Variance (ANOVA) with repeated measures on the last two factors. In addition, a two-way repeated measures ANOVA [Level (3) x Trial (3)] on power output and heart rate data was applied for each effort rating scale (CERT, BABE and CALER). Tukey post hoc tests were performed for any significant interactions or main effects. The use of tukey post hoc comparisons is justified in repeated measures ANOVA design when the assumption of sphericity has been met. Only pairwise comparisons were needed, therefore use of Tukey's honestly significant difference (HSD) test was appropriate. Intraclass correlation coefficients (ICC) and the limits of agreement (LoA) procedure were also applied to assess the reliability of the children to reproduce effort (power output and heart rate) between pairs of trials (Trial 1-2 and Trial 2-3) and for all trials. The LoA procedure calculates the mean difference (bias) and the 95% limits of agreement (± 1.96 S.D. of the bias) between repeated trials. Linear regression analysis was performed to allow a direct comparison for power output and heart rate predictions between this study and the study by Williams et al. (1994), which employed the same stepping protocol with children of comparable ages (4 to 9 years). Linear regression analysis was performed on trial 3 data (after the children had gained adequate practice with the scales and methodology). Data were analysed using SPSS 9.0, Excel 5.0 and Supastat 3.2 statistical packages.

3. RESULTS

3.1 Heart Rate

A Group (3) x Trials (3) x Levels (3) ANOVA on heart rate revealed a significant main effect for Levels ($F_{2,30}$ = 76.18, P<0.01) (Appendix D1). Multiple comparisons (Tukey HSD) revealed that children produced significantly different (P<0.01) heart rates at each effort rating level (3, 5 and 8). This confirmed that the children understood the concept of the scales. For heart rate data, the main effect for Trials was not significant ($F_{2,30}$= 0.95, P> 0.10), as the mean heart rates across the three production trials were found to be consistent; Trial 1 (157 bpm), Trial 2 (158 bpm) and Trial 3 (154 bpm). There were no other significant interactions or main effects.

A Two-way ANOVA (Level x Trial) on heart rate data was applied for each effort rating scale (CERT, BABE and CALER), (Figure 18).

CERT

ANOVA revealed a significant main effect for Levels ($F_{2,10}$ = 28.21, P<0.001). Multiple comparisons revealed a significant difference (P<0.05) between heart rates produced at CERT 3 and CERT 8 only (Table 8 and Figure 18).

BABE

ANOVA revealed a significant main effect for Levels ($F_{2,10}$ = 19.14, P<0.001). Multiple comparisons revealed a significant difference (P<0.05) between heart rates produced at BABE 3 and BABE 8 only (Table 8 and Figure 18).

CALER

ANOVA revealed a significant main effect for Levels ($F_{2,10}$ = 35.78, P<0.001). Multiple comparisons revealed a significant difference (P<0.05) between heart rates produced at CALER 3 and CALER 8 only (Table 8 and Figure 18).

Apart from the main effects reported above, there were no main effects or interactions of levels by trial on heart rate.

3.2 Power Output

A Group (3) x Trials (3) x Levels (3) ANOVA on power output revealed a highly significant main effect for Levels ($F_{2,30}$ = 355.95, P<0.001). Multiple comparisons (Tukey HSD) revealed that the children were able to produce significantly different (P<0.01) power outputs at each effort rating level (3, 5 and 8). This confirmed that children understood the concept of the scales. For power output data, the main effect for Trials was not significant ($F_{2,30}$ = 0.03; P> 0.10), as mean power outputs across the three production trials were found to be consistent at 55 (W). The main effect for Scale was not significant ($F_{2,15}$ = 1.18, P>0.10), there were no significant differences between power outputs by scale. There were no other significant interactions or main effects.

A Two-way ANOVA [Level (3) x Trial (3)] on power output data was applied for each effort rating scale (CERT, BABE and CALER), (Figure 19).

CERT

ANOVA revealed a highly significant main effect for Levels ($F_{2,10}$ = 587.22, P<0.001). Multiple comparisons revealed a significant difference (P<0.01) between power outputs produced at each effort rating level of CERT 3, 5 and 8 (Table 9 and Figure 19). This confirmed the children understood the concept of the scale.

BABE

ANOVA revealed a significant main effect for Levels ($F_{2,10}$ = 45.46, P<0.001). Multiple comparisons revealed a significant difference (P<0.01) between power outputs produced at BABE 3 and BABE 8 only (Table 9 and Figure 19).

CALER

ANOVA revealed a highly significant main effect for Levels ($F_{2,10}$ = 155.4, P<0.001). Multiple comparisons revealed a significant difference between power outputs produced at each effort rating level of CALER 3, 5 and 8 (Table 9 and Figure 19). This confirmed that children understood the concept of the scale.

Apart from the main effects reported above, there was no main effect for trial or interaction which included 'trial' at effort rating levels 3, 5 and 8. Results obtained were consistent across trials and levels. Tables 8 and 9 present mean effort production for heart rate and power output over three trials.

Table 8: Heart rates at Effort Production Levels of 3, 5 and 8 across three trials for the CERT, BABE and CALER Perceived Exertion Scales. Values are mean (± S.D.)

	CERT			BABE			CALER		
Effort Rating	**3**	**5**	**8**	**3**	**5**	**8**	**3**	**5**	**8**
Trial 1	150	155	167	150	156	167	150	156	165
	(32.6)	(31.3)	(19.3)	(12.9)	(12.2)	(13.4)	(15.8)	(14.5)	(13.8)
Trial 2	149	157	162	154	160	169	147	160	165
	(9.8)	(13.6)	(15.1)	(12.1)	(11.5)	(16.4)	(29.8)	(17.8)	(15.6)
Trial 3	140	149	158	150	160	168	148	154	163
	(17.9)	(13.5)	(12.8)	(7.1)	(11.5)	(15.2)	(11.0)	(11.8)	(11.8)
Overall	146	154	162	151	159	168	148	157	164
	(21.4)	(20.1)	(15.4)	(10.5)	(11.2)	(14.2)	(19.3)	(14.2)	(13.0)

Table 9: Power Output (W) at Effort Production Levels of 3, 5 and 8, across three trials for the CERT, BABE and CALER Perceived Exertion Scales. Values are mean (± S.D.)

	CERT			BABE			CALER		
Effort Rating	**3**	**5**	**8**	**3**	**5**	**8**	**3**	**5**	**8**
Trial 1	57.0 (6.9)	60.0 (6.2)	63.0 (6.3)	47.0 (12.9)	49.0 (13.5)	52.0 (15.3)	53.0 (10.4)	55.0 (10.9)	58.0 (11.3)
Trial 2	57.0 (6.7)	60.0 (6.6)	62.0 (6.9)	48.0 (14.0)	50.0 (14.7)	52.0 (15.3)	53.0 (10.4)	55.0 (10.9)	58.0 (11.3)
Trial 3	57.0 (6.3)	60.0 (6.6)	62.0 (6.9)	48.0 (14.0)	50.0 (14.7)	52.0 (15.3)	53.0 (10.4)	55.0 (10.9)	58.0 (11.3)
Overall	57.0 (6.2)	60.0 (6.1)	63.0 (6.3)	48.0 (12.8)	50.0 (13.5)	52.0 (14.3)	53.0 (9.8)	55.0 (10.2)	58.0 (10.6)

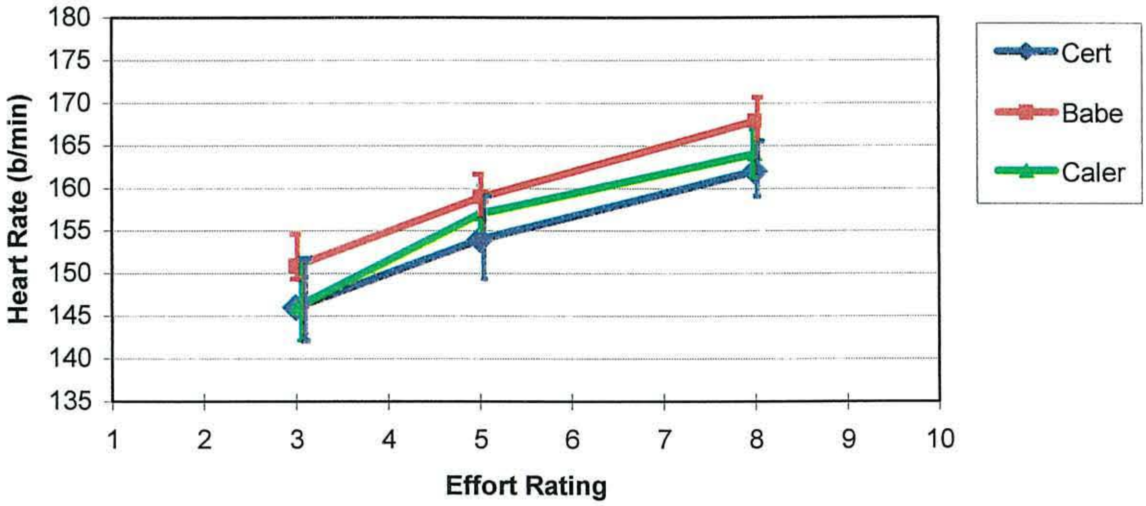


Figure 18: Mean Heart Rate at Effort Production Levels of 3, 5 and 8 for the CERT, BABE and CALER Perceived Exertion Scales. (Values are mean ± SEM)

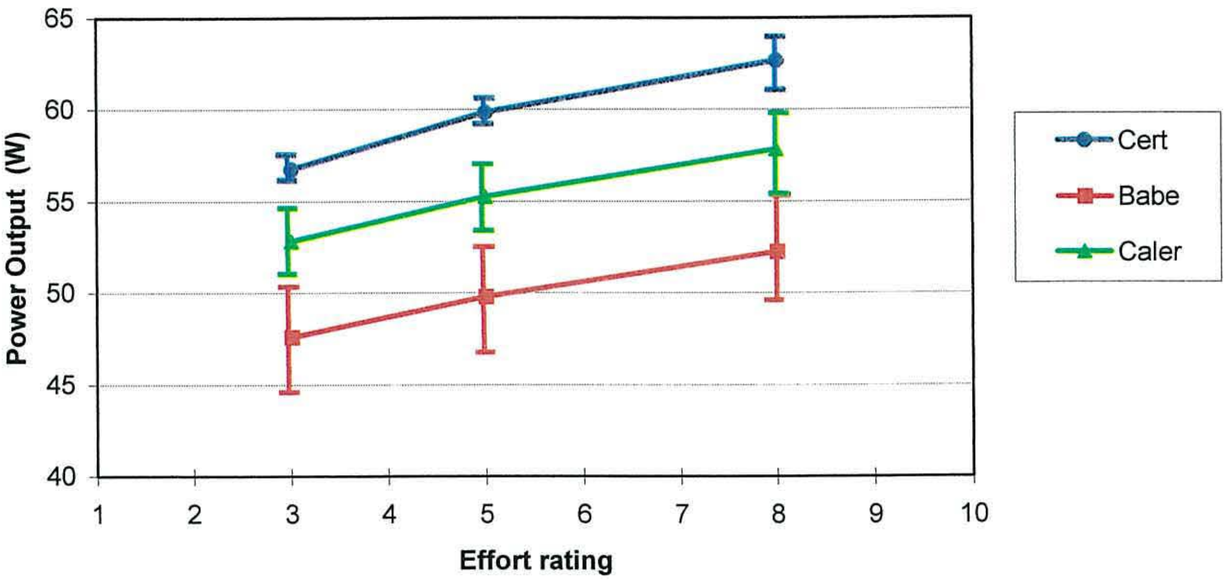


Figure 19: Mean Power Output (W) at Effort Production Levels of 3, 5 and 8 for the CERT, BABE and CALER Perceived Exertion Scales. (Values are mean ± SEM)

3.3 Regression Analyses

Regression analysis performed on Trial 3 data assessed the criterion validity of the CERT, BABE and CALER (Appendix D2). For heart rate, linear regression analyses yielded the predictive ability of CERT, BABE and CALER as;

HR (b/min) = 3.64 (CERT) + 130; $r^2 = 0.23$, $P<0.10$, SEE = 14.5 b/min
HR (b/min) = 3.49 (BABE) + 140; $r^2 = 0.30$, $P<0.10$, SEE = 11.5 b/min
HR (b/min) = 3.05 (CALER) + 139; $r^2 = 0.26$, $P<0.10$, SEE = 11.2 b/min

For power output, linear regression analyses yielded the predictive ability of CERT, BABE and CALER as;

PO (W) = 1.06 (CERT) + 54; $r^2 = 0.11$, $P>0.10$, SEE = 6.4 W
PO (W) = 0.88 (BABE) + 45; $r^2 = 0.02$, $P> 0.10$, SEE = 14.2 W
PO (W) = 1.05 (CALER) + 50; $r^2 = 0.05$, $P>0.10$, SEE = 10.5 W

The relationship between heart rate predictions by linear regression analyses presented in this study were compared to data presented by Williams et al. (1994) (Table 10), which employed the same intermittent stepping protocol, with children aged 4 to 9 years. Power output was manipulated by adjusting percent body mass backpack loadings. It is presumed that data presented in Figure 1 of their 1994 paper was from estimation mode, and yields the predictive ability of CERT as; HR (b/min) = 12 (CERT) + 110; $r^2 = 0.99$, $P<0.01$, SEE = 0.97. Heart rate predictions using linear regression analyses in this study present the predictive ability of CERT as; HR (b/min) = 3.64 (CERT) + 130; $r^2 = 0.23$, $P<0.10$, SEE = 14.5. Likewise, the relationship between power output predictions using linear regression analyses presented in this study were compared to the predictions by Williams et al. (1994) (Table 11). Williams et al. (1994) present the predictive ability of CERT as; PO (W) = 10 (CERT) + 10; $r^2 = 0.99$, $P<0.01$, SEE = 0.29. Power outputs from this study yielded the predictive ability of CERT as; PO (W) = 1.06 (CERT) + 54; $r^2 = 0.11$, $P>0.10$, SEE = 6.4.

Table 10: Heart Rate (b/min) Predictions using Linear Regression Analyses

Effort Rating	Williams et al. (1994) (Step) CERT	Current Study (Step) CERT	Current Study (Step) BABE	Current Study (Step) CALER	Eston et al. (1994) (Cycle) CERT	Lamb (1995) (Cycle) CERT
1	122	134	143	142	134	136
2	134	137	147	145	141	143
3	146	141	150	148	148	151
4	158	145	154	151	154	160
5	170	148	157	154	161	168
6	182	152	161	157	167	176
7	194	155	164	160	174	184
8	206	159	168	163	181	193
9	218	163	171	166	187	201
10	230	166	175	170	194	209

Table 11: Power Output (W) Predictions using Linear Regression Analyses

Effort Rating	Williams et al. (1994) (Step) CERT	Current Study (Step) CERT	Current Study (Step) BABE	Current Study (Step) CALER	Eston et al. (1994) (Cycle) CERT	Lamb (1995) (Cycle) CERT
1	20	56	47	51	34	29
2	30	57	48	52	40	37
3	40	58	48	53	47	45
4	50	59	49	54	54	52
5	60	60	50	55	61	60
6	70	61	51	56	68	68
7	80	62	51	57	74	76
8	90	63	52	58	81	84
9	100	64	53	59	88	92
10	110	65	54	60	95	100

Tables 10 and 11 show that for the stepping protocol, predicted heart rates and power outputs between Williams et al. (1994) and the current study do not compare well. Table 10 shows that heart rate predictions by linear regression analyses from this study, for the higher levels of CERT, are significantly lower than those predicted by Williams et al. (1994). For example; at CERT Effort Level 8, Williams et al. (1994) predict a heart rate of 206 (b/min) compared to 159 (b/min) reported in the current study. It is interesting to note that their reported mean values of CERT 5 (HR = 173.6 bpm ± 14.3) and CERT 7 (HR = 174.4 bpm ± 14.3) for children aged 8 - 9 years do not fit their linear regression model of HR (b/min) = 12 (CERT) + 110.

Due to the nature of the stepping task, the cadence required and the weight of the backpack, the heart rates and power outputs predicted by Williams et al. (1994) (Tables 10 and 11) do not seem possible to attain with young children. It is acceptable to predict that children are more likely to obtain higher values of objective effort during cycling tasks (Eston et al. 1994; Lamb 1995) rather than stepping tasks (Tables 10 and 11). Due to the nature of the stepping exercise, maximum effort may often be halted more quickly by local muscular fatigue. Therefore, the power output prediction equation presented in this study as; PO (W) = 1.06 (CERT) + 54, seems more valid for use with stepping protocols.

Lower overall predicted power outputs at each effort level are shown in (Table 11) for Group 2 (BABE) compared to Group 1 (CERT). A One-Way ANOVA on Group Subject Characteristics [Age (years), Stature (m), Mass (kg), Resting Heart Rate (bpm)] revealed a significant main effect for Group ($F_{2,15}$ = 8.15, P<0.01). Tukey HSD post hoc comparisons revealed that mean subject characteristics were significantly different (P<0.10) between the CERT (15.514) and CALER Group (13.329), and between the CERT (15.514) and BABE Group (11.591) (P<0.01). ANOVA also revealed a significant main effect for Subject Characteristics ($F_{2,30}$ = 563.72, P<0.001). Tukey HSD revealed that mean data for Height (1.334m), Weight (30.056kg) and Age (9.044 years) were significantly different (P<0.01). ANOVA also revealed a significant interaction of Group x Subject Characteristics ($F_{4,30}$=5.74; P<0.01). Tukey HSD post hoc comparisons identified that a significant difference (P<0.01) existed between Group 1 (CERT) (35) and Group 2 (BABE) (25.167) for Body Mass (kg). Therefore, the lower body masses of the children in the BABE group may have accounted for the lower power output production compared to the CERT group. No other significant differences were identified between the CERT, BABE and CALER Groups for their respective subject characteristics.

For heart rate, linear regression predictions by Eston et al. (1994) and Lamb (1995) during cycle ergometry estimation protocols (with test termination criteria a CERT value of 9 or 10) are reported as; HR = 6.6 (CERT) + 127.7, SE = 18.3 bpm (r^2 and P value not cited), and HR = 8.3 (CERT) + 126.3; r^2 = 0.52, P<0.05, SE = 19.4 bpm, respectively. Table 10 shows that these heart rate predictions compare well.

For example, at CERT Effort Level 5, Eston et al. (1994) predict a heart rate of 161 bpm compared to a predicted heart rate of 168 bpm reported by Lamb (1995).

For power output, linear regression analyses during cycle ergometry estimation protocols have been reported by Eston et al. (1994) as; PO (W) = 6.8 (CERT) + 26.7, SE = 19.7W (r^2 and P value not cited), and by Lamb (1995) as; PO (W) = 7.9 (CERT) + 20.8; $r^2 = 0.64$, $P<0.01$, SE = 14.7W. Table 11 shows that these power output predictions during cycle ergometry protocols compare well. For example, at CERT Effort Level 5, Eston et al. (1994) predict a power output of 61 (W) compared to a predicted power output of 60 (W) by Lamb (1995).

3.4 Reliability

Intraclass Correlation Analysis

Reliability was assessed using the Intraclass Correlation Coefficient (ICC) and the Bland and Altman (1986) 95% Limits of Agreement (LoA) procedure. The results observed in Trial 1 were reliable, with exercise intensities produced at each CERT, BABE and CALER level correlating highly with those in Trial 2 and 3 (Table 12). Subjects were able to reproduce objective effort (HR and PO) using BABE and CALER at levels 3, 5 and 8 with a high degree of reliability across three trials. For example, children in the BABE Group at an effort production level of 5 improved in their reliability to reproduce effort (heart rate) from 0.61 between trials 1 and 2 to 0.72 between trials 2 and 3. Similar results were reported for the CERT and CALER groups.

Results indicated that practice improved the reliability of results (Table 12), with a general trend of increased HR reliability between Trials 2 and 3 for all scales. For example; CERT 5 T1-T2 R = 0.54 and T2-T3 R = 0.88. For power output, the BABE group produced highly reliable effort production results, with improvements in reliability observed between trials 2 and 3. This trend was also true for the CERT and CALER groups. Overall reliability of effort production for power output (Table 12) shows that the BABE and CALER Scales were highly reliable tools for effort production, followed by the more categorised use of the CERT. Results indicate that power output production for children was found to be a more reliable measure of exercise intensity than heart rate.

Table 12: Intraclass Correlation Coefficient (ICC) Results

	HEART RATE			POWER OUPUT		
	T1-T2	T2-T3	T1-T2-T3	T1-T2	T2-T3	T1-T2-T3
CERT						
3	0.460*	0.552*	0.563*	0.974	0.990	0.975
5	0.540*	0.879**	0.606*	0.988	1.000	0.992
8	0.819*	0.930**	0.839	0.954	1.000	0.970
OVERALL	**0.705**	**0.848**	**0.702**	**0.979**	**0.996**	**0.983**
BABE						
3	0.485*	0.598*	0.525*	0.995	1.000	0.997
5	0.607*	0.723*	0.590*	0.995	1.000	0.997
8	0.922**	0.751*	0.815	1.000	1.000	1.000
OVERALL	**0.714**	**0.754**	**0.667**	**0.995**	**1.000**	**0.996**
CALER						
3	0.687*	0.560*	0.650**	1.000	1.000	1.000
5	0.893**	0.838*	0.874	1.000	1.000	1.000
8	0.882**	0.893**	0.877	1.000	0.996	0.997
OVERALL	**0.810**	**0.768**	**0.791**	**1.000**	**0.997**	**0.998**

All values $P<0.001$, unless otherwise indicated
** $P<0.01$
* $P<0.05$

Limits of Agreement Analyses

The 95% Limits of Agreement analyses are presented in Tables 13 and 14. The results suggest that the children could reproduce heart rates with a lower bias and less variation around the bias by Trial 3 (Table 13). For example, at an effort level of 5, Trial 2 *vs* Trial 3, the BABE group would be expected to reproduce heart rates of between 0.33 ± 17 (bpm), i.e. within a range of 17 bpm lower or 17 bpm higher than the heart rates in Trial 2. Analysis between trials for HR supports the ICC results by suggesting that reliability improves with practice for each effort rating scale.

Highly reliable results were obtained for power output. This high reliability could be attributed to the low number of possible power output responses. Results indicate that the children could reproduce power outputs with a lower bias and less variation around the bias by Trial 3 (Table 14). These results show that the children in the CERT, BABE and CALER groups varied very little in their power output production over trials at each effort rating level 3, 5 and 8. This could be attributed to the stepping protocol used and the way in which power output was estimated (incorporating percent body mass). For individual power output responses to three effort production levels across three trials all values were within the 95% LoA. Analysis between trials for power output indicated a high reliability of effort production.

Table 13: Limits of Agreement (LoA) (Heart Rate) for CERT, BABE and CALER across Trial 1 (T1) to Trial 3 (T3) showing bias with 95% limits of agreement in brackets.

	CERT		BABE		CALER	
Effort Rating	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	0.5 (± 2 x 25.1)	9.5 (± 2 x 13.7)	-4.0 (± 2 x 12.7)	4.2 (± 2 x 8.9)	2.5 (± 2 x 18.9)	-0.5 (± 2 x 21.1)
5	-2.2 (± 2 x 23.1)	7.3 (± 2 x 6.7)	-3.7 (± 2 x 10.5)	0.33 (± 2 x 8.5)	-3.3 (± 2 x 7.5)	5.3 (± 2 x 8.6)
8	5.0 (± 2 x 10.4)	3.7 (± 2 x 5.2)	-2.0 (± 2 x 5..9)	1.6 (± 2 x 11.2)	0.2 (± 2 x 7.1)	1.7 (± 2 x 6.4)
Overall	1.1 (± 2 x 19.6)	6.8 (± 2 x 9.1)	-3.2 (± 2 x 10.0)	2.1 (± 2 x 9.0)	-0.2 (± 2 x 11.9)	2.2 (± 2 x 13.0)

Table 14: Limits of Agreement (LoA) (Power Output) for CERT, BABE and CALER across Trial 1 (T1) to Trial 3 (T3) showing bias with 95% limits of agreement in brackets.

	CERT		BABE		CALER	
Effort Rating	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	0.0 (± 2 x1.5)	-0.4 (± 2 x 0.9)	-0.5 (± 2 x 1.3)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)
5	0.4 (± 2 x 1.0)	0.0 (± 2 x 0.0)	-0.6 (± 2 x 1.4)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)
8	0.8 (± 2 x 2.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	-0.4 (± 2 x 1.0)
Overall	0.4 (± 2 x 1.5)	-0.1 (± 2 x 0.5)	-0.4 (± 2 x 1.1)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	-1.4 (± 2 x 0.6)

4. DISCUSSION

Results from this study show that children were capable of adjusting their exercise intensity to match specific levels of perceived exertion. Significant differences ($P<0.05$) between effort rating levels of 3 and 8 only, were determined for heart rate for each group (CERT, BABE and CALER). For power output, significant differences were observed ($P< 0.01$) between effort rating levels 3, 5 and 8 for the CERT and CALER groups. This confirmed that the children understood the concept of the scales. These results have also confirmed that the CERT appears to be a valid measure of exercise intensity in this group of children.

For the BABE group, significant differences ($P< 0.01$) in children's heart rate and power output production were observed between Levels 3 (Easy) and 8 (Very Hard) only. These results support the hypothesis that the lower mean body mass of children in the BABE group may account for their ability to distinguish only between Levels 3 and 8 in both their heart rate and power output production. Due to the nature of the stepping task, a child of light body weight has a poorer differentiation between effort (0, 5, 10, 15, 20 and 25% body mass). This difference in the weight lifted between levels is therefore small, and might be non-significant in terms of power output production (W) according to the equation by Hanne (1971). The lower mean age of children in the BABE group (8.3 ± 1.2 years) may have contributed to a more limited range of exercise experiences, which could also contribute to their ability to only be able to distinguish between ratings of 3 (Easy) and 8 (Very Hard).

Evidence to demonstrate that the children had learned how to self-regulate exercise intensity is suggested by both the increase in intraclass R values, and the limits of agreement analysis between trials. With one exception, the overall intraclass correlation coefficients (ICCs) showed an increase between trials 2 and 3, and would have been expected to increase further with additional trials for all groups. For example the R values for the CERT group (heart rate) were 0.71 for T1 to T2, but this had improved to 0.85 by Trial 2 to 3. When the limits of agreement values are compared a more comprehensive picture is obtained. Results indicated that the children could reproduce heart rates with a lower bias and less variation around the bias by trial 3. For example, the BABE Group at effort production level 5, improved in their ability to regulate exercise effort. By trial 3, they could reliably reproduce heart rate with an accuracy of ± 17 bpm.

The 95% LoA analysis showed that the children varied very little in their power output production over trials at each effort rating level 3, 5 and 8. This could be attributed to the stepping protocol used, the way in which power output was estimated and the limited percent body mass options. Analysis of power output data ICCs across trials confirmed that the BABE and CALER Scales were highly reliable, followed by the more categorised use of the CERT. We can conclude from this that pictorial representation of BABE and CALER may have assisted subjects in producing highly reliable readings of objective effort across trials.

Although not formally interviewed for their views on the perceived exertion scales, discussion with the children during the introductory session confirmed that their preferred choice of scale to use would be the BABE. Reasons for their preferred choice were given as; i) 'Fun-looking' and 'Interesting' due to use of colours. ii) Character association with the hit movie 'A Bug's Life' (topical), 44% (n = 8) of subjects had seen the film and all subjects were familiar with the storyline and characters. iii) Other comments made were that it was clear to see from the pictures that the Bug was struggling with the exercise at the higher levels of effort, with the facial expressions and dripping beads of sweat. It is important to note that there was no experimenter bias in 'leading' children towards any particular opinion / remark. The children were not aware that the tester had designed the BABE Scale. The tester remained wholly impartial when recording comments obtained during the introductory session. The children felt the pictures on the BABE Scale gave a clearer interpretation of exercise effort compared to the CALER or CERT. iv) The children also commented that the Bug is shown stepping up onto and down from a bench wearing a backpack, thus depicting the stepping action required. There was an association between the BABE Scale and the stepping protocol, which seemed to enhance understanding.

This study has provided evidence to support the use of the CERT and CALER Scale as tools for quantifying children's effort perception and for regulating exercise output during intermittent stepping tasks. Data from this study provide preliminary evidence that the BABE Scale is potentially a valid and highly reliable tool for exercise intensity regulation during randomised intermittent stepping ergometry in children aged 7-10 years. Pictorial and verbal representation of the BABE and CALER Scales may enhance children's interpretation of exercise effort, compared to use of the CERT. This study has confirmed that practice improves the reliability of using effort rating scales. It would be worthwhile to extend the number of trials to identify if accuracy improves any further than recorded in the current study. Improvements in children's regulation of exercise effort might be more marked with use of the BABE Scale, since it was specifically designed for children participating in stepping protocols.

Future studies could further explore validation of the CERT, BABE and CALER Scales by linear regression analyses for intermittent effort production protocols using a variety of exercise modalities, including stepping tasks. Further comparisons between the predictive abilities of these scales may then be possible. Owing to the small sample tested in each group, this study would warrant verification by repeating the same production protocol, across three or more trials, with larger numbers. Recommendations for scale modifications could include the addition of verbal cues (familiar to children) to *all* numbers (1 to 10) on the BABE and CALER scales, to further aid interpretation of exercise effort. Children suggested this several times to the tester during the study.

If effort rating scales are to be validated externally in the future within Physical Education or games lessons, then the educational aspect of introducing these scales into a school environment requires some thought. Physical educators, prior to using effort rating scales with children, need to be introduced to the concept of effort perception and the use of such scales. For example, within a games lesson, the educational aspect of effort perception could be delivered from both an active (production) and passive (estimation) aspect. For the production aspect, children could be asked to apply or attempt a certain effort and exertion level during an activity. For example, how hard to make a penalty shot in football or a serve in tennis. Alternatively, after participating in a basketball game, children could be asked to perceive how hard the game actually was. This would be use of perceived exertion from an estimation aspect. Teachers could then, dependent on the reported ratings of exercise effort; modify the intensity over a period of time. Children's preferred effort rating levels could also be explored. Such practical exercise tasks could assist in the achievement of HRE attainment targets in the physical education national curriculum. However, physical educators would firstly need to be introduced to the use of effort rating scales and understand their application before their use can be disseminated to children.

Effort rating scales could be integrated into a health-related based physical education curriculum, as reviewed by Kirk (1986a), to encourage children to become more physically active. Introduction of child-specific effort rating scales to a Physical Education environment would help to determine if children can understand and apply effort sense, which would also provide a theoretical aspect of intensity to classes. Effort perception could also help to determine if Physical Education classes are optimally challenging, conferring physiological benefits.

This study has already raised an awareness of health-related fitness, exercise intensity and perception of effort amongst pupils and staff in the school involved in data collection. The tester was invited back to the school to present the research results to the children (including those children who did not participate in this study). Staff have already planned that the children will produce a number of projects based on this and other exercise experiences. Educational tasks such as these could act as an induction process for pupils and staff, in order to effectively introduce effort rating scales into physical education classes.

A potential limitation of this study was that children had used the same standard bench height for the stepping protocol. A potential limitation of the results could therefore be a distortion of the children's RPE levels due to inter-individual differences in the children's hip angles or leg length whilst stepping with a fixed bench height of 0.30m. If the children who participated in this study were disadvantaged due to mechanical inefficiency in their stepping technique then the validity of results could be questioned. The following study was therefore conducted to examine the effect of step platform height on stepping efficiency in children.

CHAPTER 4

The Effect of Step Height on Stepping Efficiency in Children

1. INTRODUCTION

The development of valid and reliable tests of physical fitness for children is an area of concern for fitness and exercise specialists. There has been extensive research into the study, measurement, and development of cardiorespiratory fitness in adults (Francis 1987; Francis and Brasher, 1992). In the mid 1990's, the American Heart Association (1994) identified a need for valid field tests of aerobic fitness, specifically for young children. Stepping protocols (maximal and submaximal) have been widely used because of their mechanical simplicity and administrative ease. However, certain criticisms relating to the validity and reliability of stepping tests have been raised (Thomas et al., 1993; Francis et al., 1998). One contributing factor to this controversy appears to be the conflicting evidence linking anthropometric parameters (particularly leg length and hip angles) to exercise performance and physiological efficiency in both adults and children. Studies by Howe and Collis (1973), Miyamura et al. (1975) and Cicutti et al. (1991), indicate that in adults and children, overall leg length does not affect stepping efficiency. In contrast, studies on adults by Shahnawaz (1978) and Thomas et al. (1993), and those on children by Francis et al. (1998), report that hip angles or leg length do affect the efficiency of bench-stepping.

If children are mechanically disadvantaged by using a fixed bench height for a stepping protocol (for example a child of small stature), then this may result in distortion of RPEs and other physiological measures such as heart rate and oxygen consumption.

Cicutti et al. (1991) examined the effect of leg length on relative oxygen consumption (VO_2), heart rate (HR) and minute ventilation (VE) in 30 boys aged 8 - 12 years (mean age 10.1 ± 1.2 years). Children completed a 5-minute intermittent stepping protocol, with 6-minute rests between exercise bouts. Stepping height was varied to correspond to 30, 40 and 50% of the individual's leg length. For each of the three stepping heights (percentage of leg length) for each child, a stepping frequency was calculated to give a constant work rate of 6 metres/minute. A metronome was used to enable children to keep to the desired cadence.

A basic requirement of the study was that no appreciable fatigue be present between bouts of exercise in order to sustain the children's motivation and interest, and to minimise the contribution of anaerobic processes to total energy cost. For these reasons a low intensity stepping rate (6 metres/ minute) was selected to examine the efficiency of variations in stepping height as a percentage of leg length. Overall leg length was measured as the vertical distance between the proximal greater trochanter and the plantar surface of the foot. The anatomical landmark employed to identify the upper limit of the lower leg segment was the proximal surface of the head of the fibula, the lower limit was the plantar surface of the foot. The difference between total leg length and the length of the lower leg segment represented the length of the upper leg segment. Heart rate was recorded via a Sport Tester PE 3000, and a Roxon Medi-Tech System was used to measure VO_2.

To examine the effects of overall leg length relative to stepping height, a one-way ANOVA with three repeated measures was carried out for the variables VO_2, HR and VE. To assess the influence of knee joint angle, leg length and leg length to body weight on VO_2, HR and VE, two groups of 10 children were formed by comparing the top third and bottom third of the anthropometric parameters. A two-factor ANOVA with three repeated measures was used to test for significant differences between high and low groups for the three physiological variables.

The authors reported that the three conditions of stepping elicited similar values of relative VO_2, HR and VE. ANOVA revealed no significant differences in relative VO_2, HR or VE between the three experimental conditions. These results indicate that alterations in the pattern of stepping did not affect the metabolic cost of effort when the total external workrate was held constant at 6 metres/minute. Therefore, the relationship of stepping height to overall leg length was not of critical importance. It was concluded that leg length did not influence the physiological responses of young boys during the moderate stepping task (Cicutti et al., 1991)

The results reported by Cicutti et al. (1991) support previous studies by Miyamura et al. (1975) and Howe and Collis (1973), which reported that in children and adults, overall leg length did not affect stepping efficiency. Therefore, alterations in stepping height to suit differences in leg length among participants were not warranted.

Nagle et al. (1965) and Kamon (1970) reported that for a given work rate, stepping frequency was of greater importance to the oxygen requirements of the task than stepping height. Therefore, in the study by Cicutti et al. (1991), the shorter-legged individuals should have been at a physiological disadvantage compared to their longer-legged counterparts. However, ANOVA revealed there were no significant differences between the two groups with regards to oxygen consumption and heart rate. The lack of any intraindividual differences for oxygen consumption would appear to disagree with the results of Nagle et al. (1965, 1971). No significant intergroup physiological differences were revealed by Cicutti et al. (1991), except for minute ventilation. Minute ventilation was significantly higher ($p < 0.01$) in the longer-legged boys. This could be explained by the fact that because absolute ventilation is mainly dependent on size, the longer-legged (and in most cases heavier) boys were required to ventilate more. In conclusion, at the level of work employed (6 metres/minute), the longer-legged and shorter-legged boys were effectively matched for cadence and were working at a relative pace that was energetically comparable.

Thomas et al. (1993) in their study of 121 subjects aged 15-67 years indicated that the variability in oxygen demand during the modified Canadian Aerobic Fitness Test (mCAFT) was large enough to significantly affect the prediction of maximal oxygen uptake. The authors examined the relationship between leg length and the oxygen demand of stepping at specific work levels. The amount of variation in oxygen consumption that could be explained by age, fitness, body size, gender and leg length was assessed using correlations and regression analyses.

Leg length was found to have a significant but weak effect on the oxygen demand of stepping for women at level 5 of the mCAFT ($r = 0.30$, P value not cited). The relationship observed between leg length and oxygen demand was rather weak for both males and females at any stepping level. Leg length, age and VO_2 max were reported as significant but weak correlates of the oxygen demand of stepping. Age was the strongest correlate of oxygen demand ($r = 0.58$, $P<0.05$) for women at level 6 of the stepping test. A very weak correlation between age and oxygen demand ($r = 0.26$, P value not cited) was reported for male subjects. A weak correlation between age and oxygen uptake might have occurred if the older subjects had performed more work when stepping vigorously or if they used more energy to perform the same work (Bartlett et al., 1986). Variations in the biomechanics of stepping (hip and knee angles) may have altered the amount of work done in the stepping test and thus the oxygen demand. Regression analyses indicated that variation in the oxygen demand of stepping could not be explained by simple descriptors of the subjects. Thomas et al. (1993) therefore suggested that other variables might be involved in the variability of oxygen demand, such as mood state, which has been shown to affect the oxygen demand between trials for the same subject during treadmill running (Williams et al., 1991a).

A number of other factors have been investigated that may alter the oxygen demand of stepping. Possible factors include body weight (Astrand and Rodahl, 1986), mechanical efficiency (Gaesser, 1975), knee joint angle (Ariel, 1969), and leg length (Shahnawaz, 1978).

Shahnawaz (1978) was the first to conclude that mean VO_2 was significantly related to limb length in a height-adjusted stepping protocol with adults. Ten male subjects aged between 20 and 31 years participated in the study. A standard work load was achieved by ensuring that participants performed the same amount of work at various work rates for each of the bench heights tested. The workload was equivalent to 10 metres/minute multiplied by the participant's body weight (e.g., stepping on to a 40cm high bench 25 times/minute multiplied by the body weight in kg). Variations in participant's body weight were negligible (less than 0.4% of their weight). All participants initially performed on a 40cm bench at a rate of 25 steps/minute as a standard familiarisation procedure (standard bench). They then performed the 5-minute stepping protocol for bench heights which corresponded to 30-60% of their limb length with intermediate increments of 5% of their limb length (8 different tests in all, including the standard test). The order of performances (apart from the standard test) were randomised in order to minimise any influence due to practice or habituation. Expired air was collected using Douglas bags in the last minute of exercise only, the assumption being made that participants were already at steady state before the last minute. The participant's ECG was continuously monitored throughout the protocol.

A U-shaped relation between oxygen demand and step height was observed, with a minimum cost at step heights near 50% of leg length. The consumption of oxygen at the 40-55% bench heights was significantly lower (at 0.05 confidence level) than at any of the other three bench heights. The results indicated that there was an optimal bench height for the stepping protocol (expressed as a percentage of the participant's limb length), but the results were not sufficiently sensitive to show exactly where in the range 40-55% bench height, the optimum fell.

Shahnawaz (1978) concluded that the optimum oxygen consumption for a given work load during stepping protocols might be a compromise between low stepping rate (less wasted energy in lifting the leading limb) and a high bench, where energy is wasted adjusting body posture and maintaining balance. The practical implication of this is that step test validity could be improved if bench height were related to the participant's limb length (allowing discrete intervals of 5cm) rather than using a fixed height for all participants.

In a study of the aerobic requirement of bench stepping, Stanforth et al. (1993) reported that leg length significantly affected oxygen uptake. They recommended that for optimal efficiency, adjustment of the step height to leg length might be beneficial to activities that use a bench for performing aerobic exercise. Such an adjustment may also better facilitate the use of heart rate as an accurate predictor of exercise intensity. Many step aerobics classes that use HR to monitor intensity of stepping assume that the same VO_2-HR relationship holds true regardless of the participant's stature (Stanforth et al., 1993).

Results reported for children by Cicutti et al. (1991) do not corroborate the results reported by Shahnawaz (1978) for adults. This may be due to differences in the workloads selected for stepping or to factors related to maturity.

Francis et al. (1998) examined the effect of leg length on VO_2 and HR in 19 healthy, non-smoking, non-obese children aged 8-17 years. Five different bench heights were selected that corresponded to hip angles of 65, 73, 82, 90, or 98 degrees (see calculation below). Workrate was kept constant at 8 metres/minute. Oxygen consumption was measured using open circuit spirometry. Heart rate was measured via an ECG (Physiocontrol Lifepak Cardiac Monitor). Test-retest reliability was determined with five of the participants chosen at random. These children repeated a test using a randomly chosen hip angle. Data were analysed using a repeated measures ANOVA performed on VO_2, HR and efficiency *vs.* the hip angle of stepping to examine the effects of stature relative to stepping height. The intraclass correlation coefficient was used to test the statistical relationship between test and retest. Results indicated that VO_2 and HR in children were influenced by leg length when working at a rate of 8 metres/minute and that, of the five hip angles tested in the study, stepping efficiency was maximal at a hip angle of 82 degrees.

Calculation of step platform height

Determined from the geometric relationship of an individual's stature and femur length.

Hf = (h) (1 - cos 0) *where;*

Hf = platform height (cm)
h = length of femur (cm)
0 = hip angle

Length of Femur

Determined using orthoroentgenograms, Anderson et al. (1948, 1978). Using these established relationships, the length of the femur (h) for each age was determined to be Lf times the stature (Ih).

Therefore;

$$Hf = (Lf \times Ih)(1 - \cos 0) \quad \textit{where;}$$

Hf = platform height (cm)
Lf = ratio of femur length
Ih = stature (cm)
0 = hip angle

In adults, Shahnawaz (1978) reported that a hip angle of 86 degrees resulted in the lowest mean VO_2 (i.e. greatest efficiency) during a stepping task. Francis and Minard (1997) found that the highest efficiency and lowest VO_2 in adults were recorded at a hip angle of 82 degrees whilst working at a rate of 10 metres/minute.

These results and those reported by Francis et al. (1998) suggest that leg length does influence efficiency of stepping. The practical implication of these findings suggest that the validity of any step test should be enhanced if bench height is related to a child's stature or hip angle (ideally 82 degrees), rather than using a fixed bench height. This practical implication is not supported by Cicutti et al. (1991), who reported that in young boys, there was no significant difference between VO_2 and HR when stepping at calculated hip angles of 68, 80 and 92 degrees. The difference between the results reported by Francis et al. (1998) and those reported by Cicutti et al. (1991) may be related to the limited age and leg length of subjects used by Cicutti and colleagues. The more heterogeneous group of subjects used by Francis et al. (1998) may have allowed for distinguishing changes in VO_2, that were not detectable with the more homogeneous group of 10 year olds with a similar stature used by Cicutti et al. (1991). The controversy over the relationship between effect of step platform height and stepping efficiency in children still exists in the literature. The purpose of the following study was to determine if the children who had participated in Study 1 had been mechanically disadvantaged during the stepping protocol by using the same standard bench height (0.30m). If the children had been inefficient in their stepping technique due to inter-individual differences in their hip angles or leg length whilst stepping with a fixed bench height, then this could have distorted their RPE levels. This study was designed to address this potential criticism.

2. METHOD

2.1 Subjects

Eighteen children aged 7 to 10 years from a Primary School in Great Somerford, England, participated in this study. Descriptive characteristics are presented in Table 15. As indicated in Study 1 (2.2 Procedures), the 12 boys and 6 girls were randomly allocated to one of three equal sized groups; CERT (Group 1), BABE (Group 2) or CALER (Group 3) (Table 16).

Table 15: Descriptive Characteristics of all Participants by Gender

Measure	Boys, n=12		Girls, n=6		All, n=18	
	M	S.D	M	S.D	M	S.D
Age (y)	8.90	(0.9)	9.17	(1.33)	9.0	(1.03)
Stature (m)	1.32	(0.09)	1.36	(0.08)	1.33	(0.08)
Mass (kg)	29.42	(6.23)	31.33	(5.99)	30.06	(6.04)
Resting Heart Rate (b/min)	97	(14)	111	(19)	102	(17)

Table 16: Group Characteristics of All Participants by Group

Measure	GROUP 1 CERT (n=6)		GROUP 2 BABE (n=6)		GROUP 3 CALER (n=6)	
	M	**S.D**	**M**	**S.D**	**M**	**S.D**
Age (y)	10.13	(0.2)	8.3	(1.2)	8.7	(0.5)
Stature (m)	1.41	(0.03)	1.27	(0.08)	1.32	(0.06)
Mass (kg)	35.0	(4.5)	25.2	(4.0)	30.0	(5.5)
Resting Heart Rate (b/min)	105	(6)	99	(13)	91	(16)

In order to explore the relationship further between hip angle and stepping efficiency in children, the equations presented by Francis et al. (1998) were applied to the subject characteristics for the children who participated in the first study (Chapter 3) in order to determine the range of hip angles that they were working at during the stepping task. Data were analysed using Excel 5.0 and SPSS 9.0.

According to Francis et al. (1998);

Hf = **(Lf x Ih) (1 - cos 0)** *where;*

Hf = platform height (cm)
Lf = ratio of femur length to stature
= [predicted by age and gender according to data from Francis et al., (1998)]
Ih = stature (cm)
0 = hip angle *Therefore;*

$$\cos 0 = 1 - \left[\frac{Hf}{Lf \times Ih}\right]$$

Hip angles were calculated for the children who had participated in the first study. An example is presented here;

Subject 1 (CERT)

Hf = **(Lf x Ih) (1 - cos 0)** *where;*

Hf = 30 cm
Lf = 0.264 (10 year old female)
Ih = 141 cm
0 = hip angle *Therefore;*

$$\cos 0 = 1 - \left[\frac{30}{0.264 \times 141}\right]$$

$$\cos 0 = 0.194$$

$$= 78.8°$$

3. RESULTS

Hip angles ranged from 77 to 91°, with a cluster of values around 80 - 82° (Figure 20). As reported by Francis et al. (1998), an angle of approximately 82° is the most efficient angle in bench stepping protocols. Hence the physiological responses measured at the three effort production levels for the CERT, BABE and CALER groups, were at, or close to, the most efficient hip angle. Mean hip angles and standard deviations for each group are presented in Table 17.

Table 17: Mean Hip Angle degrees (± S.D) for the CERT, BABE and CALER Groups

Group (n = 6 each)	Mean Hip Angle (degrees)	S.D. (±)	Standard Error
CERT	78.9	1.3	0.5
BABE	85.2	3.8	1.6
CALER	83.1	2.3	0.9

For heart rates, the CERT, BABE and CALER groups are similar to those reported by Francis et al. (1998), suggesting the children had not been at mechanical disadvantage during the stepping protocol (Figure 21). It appears however that the CERT group was slightly more efficient than the BABE or CALER group (lower mean heart rates) at *each* effort rating level of 3, 5 and 8 (Figure 22). The lower hip angle in the CERT group and their larger body size (increased stroke volume) may have accounted for the lower heart rates at each effort rating level, compared to the heart rate results for a mean hip angle of 85.2° (BABE) and 83.1° (CALER). Nevertheless, there is good agreement between results from this study and those of Francis et al. (1998) for hip angle and stepping efficiency, in that mean hip angles for the CERT, BABE and CALER groups fall within 82 degrees ±3 (optimal efficiency).

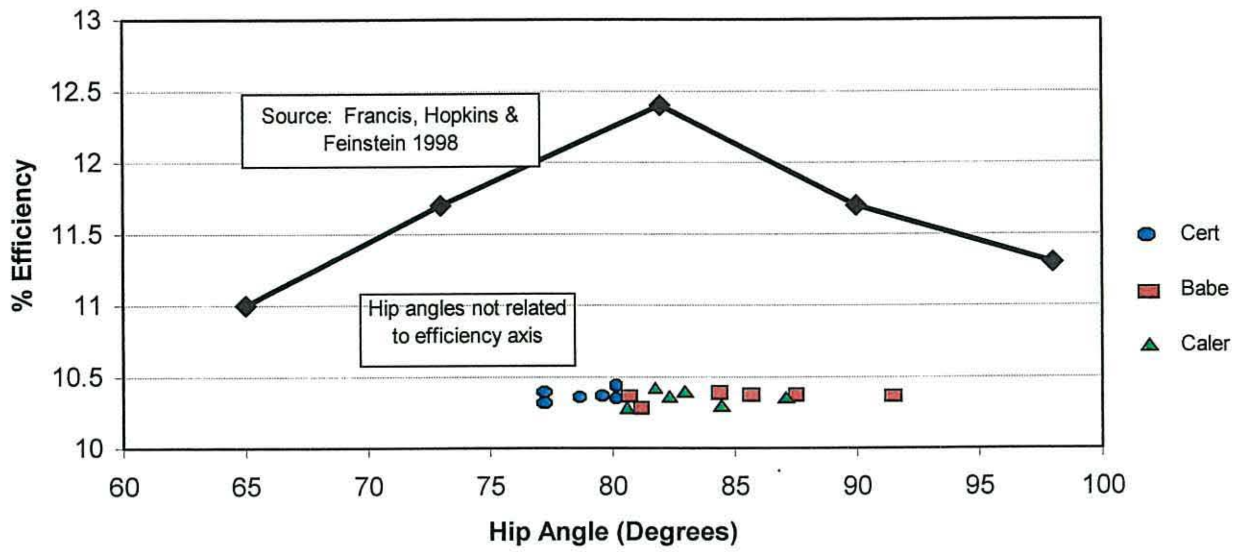


Figure 20: Relationship between Stepping Efficiency and Hip Angle. (Individual points are shown within each group as indicated)

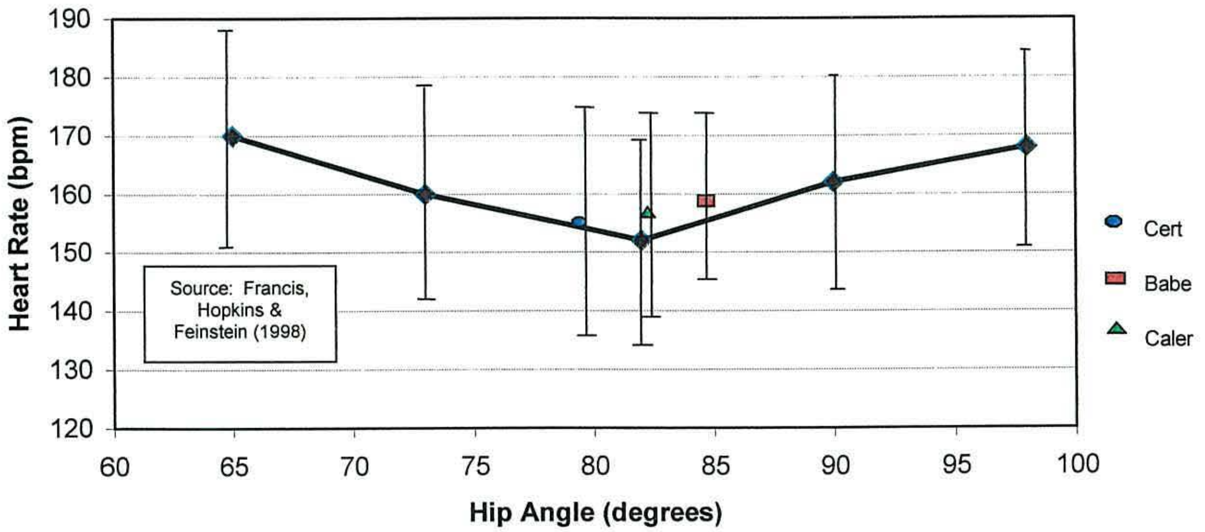


Figure 21: Variation of Heart Rate with Hip Angle during Stepping. Values for each group are shown as indicated. (Values are mean ± S.D. to compare to data from Francis et al. 1998)

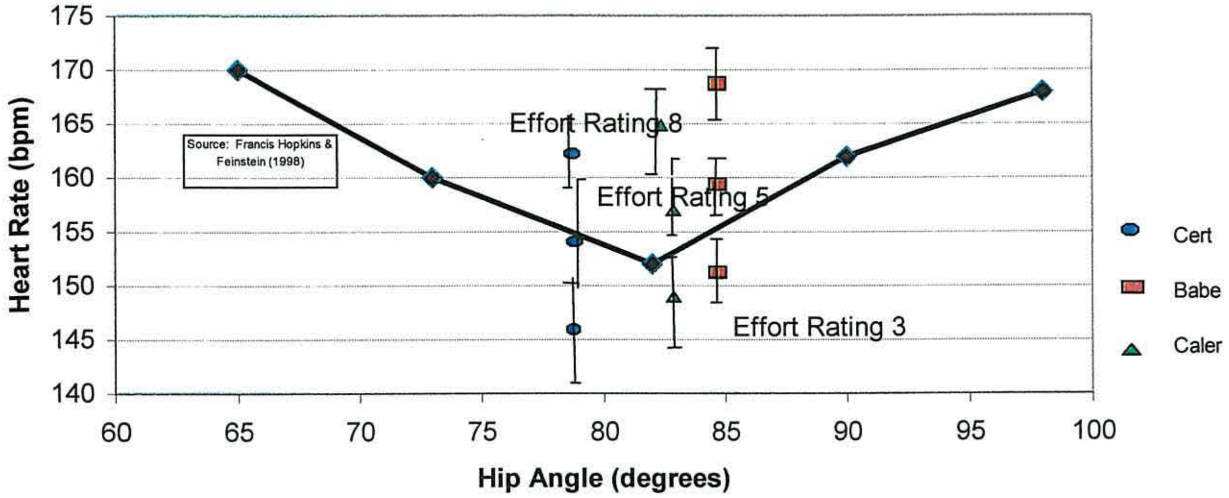


Figure 22: Relationship between Mean Heart Rate and Hip Angle for three Effort Production Levels of the CERT, BABE and CALER Scales. (Values are mean ± SEM).

Tables 18 and 19 support these results. Stature did not appear to affect the power output or heart rate response using a fixed bench height of 0.30m. Analysis of individual heart rate responses to three effort production levels across three trials (Bland and Altman 1986; 1995), found that only one value from the CERT group (at CERT 3 between trials 1 and 2) was outside the 95% LoA. This child was stepping with a calculated hip angle of 80.4 degrees, which closely reflects optimal stepping efficiency in children (Francis et al., 1998). A reason for this one anomalous result between trials 1 and 2 is not known, but is unrelated to mechanical disadvantage. Highly reliable results were reported for the BABE and CALER groups, with heart rate values for all subjects at BABE and CALER 3, 5 and 8, across trials, within the 95% LoA.

Analysis between trials for power output indicated a high reliability of effort production. Indeed, even a child from the BABE Group who had the smallest stature (1.14m) and largest hip angle (91.4 degrees) was not more variable (due to possible mechanical disadvantage) in their effort production. Table 19 shows a high level of agreement in power production between trials at each effort rating level for the CERT, BABE and CALER groups. The Intraclass Correlation Coefficients (Table 12, Chapter 3) support these results. Children were able to reproduce objective effort using the CERT, BABE and CALER scales with a high degree of reliability across three trials. Results suggest that practice improved reliability of results, with improvements occurring between trials two and three.

Table 18: Limits of Agreement (LoA) (Heart Rate) for CERT, BABE and CALER across Trial 1 (T1) to Trial 3 (T3) showing bias with 95% limits of agreement in brackets.

	CERT		BABE		CALER	
Effort Rating	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	0.5 (± 2 x 25.1)	9.5 (± 2 x 13.7)	-4.0 (± 2 x 12.7)	4.2 (± 2 x 8.9)	2.5 (± 2 x 18.9)	-0.5 (± 2 x 21.1)
5	-2.2 (± 2 x 23.1)	7.3 (± 2 x 6.7)	-3.7 (± 2 x 10.5)	0.33 (± 2 x 8.5)	-3.3 (± 2 x 7.5)	5.3 (± 2 x 8.6)
8	5.0 (± 2 x 10.4)	3.7 (± 2 x 5.2)	-2.0 (± 2 x 5..9)	1.6 (± 2 x 11.2)	0.2 (± 2 x 7.1)	1.7 (± 2 x 6.4)
Overall	1.1 (± 2 x 19.6)	6.8 (± 2 x 9.1)	-3.2 (± 2 x 10.0)	2.1 (± 2 x 9.0)	-0.2 (± 2 x 11.9)	2.2 (± 2 x 13.0)

Table 19: Limits of Agreement (LoA) (Power Output) for CERT, BABE and CALER across Trial 1 (T1) to Trial 3 (T3) showing bias with 95% limits of agreement in brackets.

	CERT		BABE		CALER	
Effort Rating	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	0.0 (± 2 x1.5)	-0.4 (± 2 x 0.9)	-0.5 (± 2 x 1.3)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)
5	0.4 (± 2 x 1.0)	0.0 (± 2 x 0.0)	-0.6 (± 2 x 1.4)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)
8	0.8 (± 2 x 2.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	-0.4 (± 2 x 1.0)
Overall	0.4 (± 2 x 1.5)	-0.1 (± 2 x 0.5)	-0.4 (± 2 x 1.1)	0.0 (± 2 x 0.0)	0.0 (± 2 x 0.0)	-1.4 (± 2 x 0.6)

4. DISCUSSION

Although somewhat equivocal, previous studies suggest that leg length does influence the efficiency of stepping in children. In the present study step height was 0.30m, which elicited hip angles of, or close to, 82 degrees. This infers that children were unlikely to be at a mechanical disadvantage, because research has shown that a hip angle of 82 degrees represents the greatest efficiency for children participating in a stepping protocol (Francis et al., 1998). In addition, the 95% LoA analysis showed that children (of varying stature) were not significantly variable in their effort production.

In summary, no significant intraindividual differences were revealed for heart rate or power output when the children stepped with mean hip angles of 78.9 degrees ± 1.3 (CERT), 85.2 degrees ± 3.8 (BABE) and 83.1 degrees ± 2.3 (CALER), while keeping the external work rate constant at 7.5 metres/minute. Alterations between subjects for relative leg length and hip angle did not result in significant changes in the physiological economy of the stepping task. Analysis of variance revealed no significant intergroup physiological differences in the production of exercise effort.

For a fixed bench height of 0.30m and work rate of 7.5 metres/minute employed in this study, the relationship between stepping height and hip angle or leg length did not significantly influence intraindividual or intergroup physiological responses to three effort production levels of CERT, BABE and CALER. The stepping protocol and physiological data collected are therefore valid. The validity of future studies utilising a stepping protocol with children could be enhanced if hip angles were pre-calculated based on the fixed bench height to be used. Stepping with a hip angle of, or close to 82 degrees is advised (Francis et al., 1998) in order to avoid mechanical disadvantage and to optimise stepping efficiency.

With the development of a range of pictorial child-specific effort rating scales, researchers have not yet investigated their intermodal efficacy. Validity and reliability studies using pictorial child-specific effort rating scales depicting a child cycling (Eston et al., 1999; Robertson et al., 1999; Eston et al., 2000) have typically been employed with cycle ergometry protocols. The intermodal efficacy of such scales is yet to be examined. The following study was designed to explore the intermodal efficacy of two pictorial child-specific effort rating scales.

CHAPTER 5

An Examination of the Relationship between Two Child-Specific Effort Rating Scales and the Mode of Exercise

1. INTRODUCTION

With the development of child-specific effort rating scales, few researchers have questioned their intermodal efficacy. Researchers have tended to focus their validity and reliability studies using the CALER Scale (Eston et al. 1999, 2000) and OMNI Scale (Robertson et al. 1999) which both depict a child cycling, specifically within cycle ergometry protocols. Questions have remained regarding the appropriateness of using such scales with other exercise modes, such as stepping. Similarly, it is unknown whether the BABE Scale, designed specifically to assess perceived exertion by children during stepping protocols, could be used for cycling tasks. The importance (and association) that children may make between the pictorial representation depicted on the scales and the exercise task to be completed could be a factor that hinders or improves a child's reliability of effort production across trials.

The purpose of the current investigation was to evaluate the validity and reliability of the CALER and BABE Scales for intra- and intermodal regulation of effort production using intermittent cycling and stepping protocols.

2. METHOD

2.1 Subjects

Data were collected on 30 children aged 7 - 11 years, representing 48% of a Primary School in Wiltshire, England. All subjects provided parental informed consent to participate in the study and were free of known contraindications prior to testing. Ethical approval was granted from the South and West Region Medical Ethics Committee.

2.2 Procedures

One week before testing, the experimenter introduced the children to both effort rating scales (CALER and BABE) and the exercise equipment. After perceptual anchoring of the scales, children were randomly allocated to Group 1 (CALER) or Group 2 (BABE). Following an explanation of how the verbal expressions for each scale should be interpreted in numerical form, the children in each group were given copies of their designated scales to study and keep. Data collection for both groups took place on the school premises on three occasions, one week apart. The testing environment was kept constant at a comfortable 22°C by use of a Vent-Axia air cooling system.

Discontinuous Cycle Ergometry Protocol

On the first occasion each group performed a discontinuous effort production protocol (production trial 1) on a mechanically braked (Monark 824E) cycle ergometer (Figure 23). Each subject was fitted with a radio telemetry system (Polar Fitwatch, CE0537, Finland) with added aqua conductivity gel, for monitoring heart rate. Immediately prior to exercise, subjects were re-introduced to either the CALER Scale (Group 1) or BABE Scale (Group 2) and given standard instructions concerning its use and the purpose of the test. Common to both groups was the requirement to regulate exercise intensity to match a range of three effort rating levels (randomly presented for each child); 3, 5 and 8. Each production trial commenced with a 3-minute 50 W warm-up (50 rpm against a resistance of 1.0 kg), followed by a 2.5-minute rest. Each subject then instructed the experimenter to adjust the cycling resistance (to add or subtract weights in multiples of 0.1, 0.5 or 1.0 kg units), in accordance with the specified perceived levels (Figure 24).

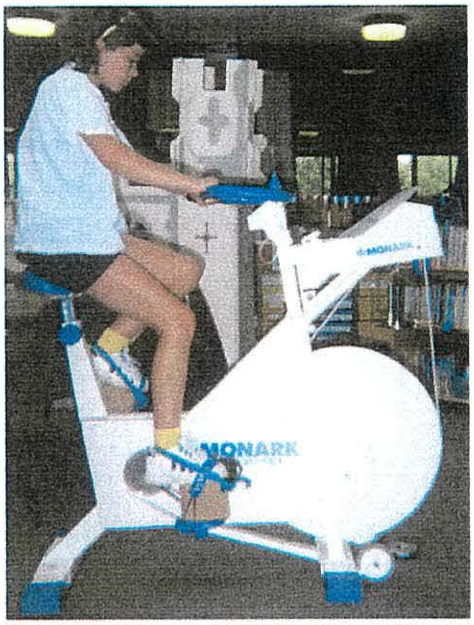


Figure 23:
Child performing the discontinuous cycle ergometry protocol

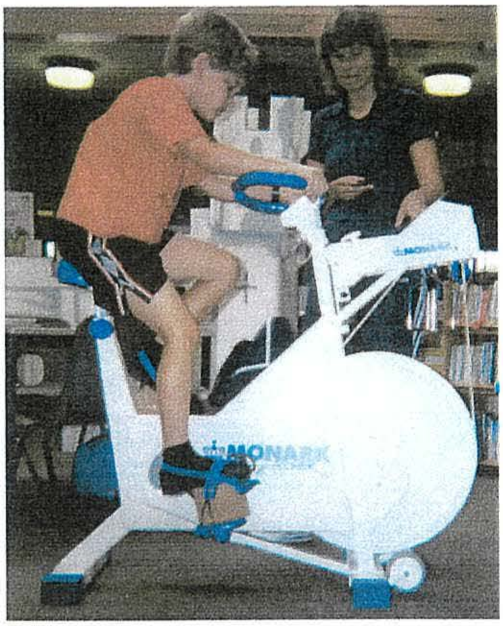


Figure 24:
Child performing the discontinuous cycle ergometry protocol: Adjustment of the cycling resistance

The number of revolutions per minute were kept constant at 50 rpm. The cycle ergometer was fitted with wooden pedal blocks (to accommodate the shortest children). A metronome (Seiko DM-33, Taiwan) was used to ensure constant pedalling rate. A 'shield' was placed to hide the weights being applied to the basket by the experimenter throughout the testing. The children were allowed 2 minutes to settle on the appropriate resistance, before cycling for a further 1 minute at the designated intensity. These intensities were recorded as power output, expressed in watts. Heart rate was recorded at the end of the third minute as recommended by Lamb et al. (1997). The load in the basket was also recorded at this time in order to calculate power output (W). Exercise bouts were interspersed with a 2.5-minute rest period. Following completion of the protocol, each child performed a 3-minute cool down, cycling at 25-50 rpm against no resistance. Production trial 2 (T2) and

Production trial 3 (T3) were performed at one week intervals to assess the test-retest reliability of each scale during cycling mode.

Intermittent Stepping Protocol

Following completion of the cycling protocol, Group 1 (CALER) and Group 2 (BABE) then performed an intermittent effort production stepping protocol, with data collection for both groups taking place on the school premises on three occasions, one week apart. One week prior to testing, the children were re-introduced to the CALER (Group 1) and BABE (Group 2) Scales and test methodology. The children then practised the correct stepping cadence with and without a loaded backpack. Subjects were tested individually, and were required to wear a radio telemetry system (Polar Fitwatch CE0537, Finland) with added aqua conductivity gel, for monitoring heart rate. The stepping protocol used has been described by Williams et al. (1993; 1994). Warm-up prior to the test consisted of 3-minutes low-intensity exercise which helped to familiarise subjects with the testing conditions and decrease anxiety. Subjects performed an intermittent effort production protocol that required them to step on to and down from a gymnasium bench 0.30m high to a cadence of 25 steps per minute, provided by a metronome (Seiko DM-33, Taiwan). Ratings of perceived exertion were manipulated by increasing body weight by loading a backpack fitted to the subject (Figure 25).

Figure 25: Child performing the intermittent stepping protocol

Backpack loads were calculated and selected by the children according to 0, 5, 10, 15, 20 and 25% body mass. Common to both groups was the requirement to adjust their exercise intensity (loading) by instructing the experimenter to add or remove weight from the backpack until they reported a range of three effort rating levels (randomly presented for each child); 3, 5 and 8. When the subject reported that the intensity level and loading were the same, stepping continued for a further 1-minute and heart rate recorded at the end of this period. Exercise bouts were separated by a 2.5-minute rest period. Power output was estimated via the equations of Hanne (1971) (Chapter 3, section 2.2). Following completion of the protocol, each child performed a 3-minute cool down consisting of low-intensity exercise. Production trial 2 (T2) and Production trial 3 (T3) were performed at one week intervals in order to obtain a measure of the consistency of effort production with each scale during stepping mode.

2.3 Analysis of Data

Data were analysed using mixed factorial ANOVAs [Group (2) x Mode (2) x Trial (3)] on heart rate and power output, applied to each of the three effort rating levels (3, 5 and 8). In addition, a mixed factorial ANOVA on trial 3 data [Group (2) x Mode (2) x Level (3)] on heart rate and power output, with repeated measures on each of the last two factors (Appendix E). Post hoc comparisons were analysed where appropriate using the Tukey test in order to identify any significant interactions or main effects. Intraclass correlation coefficients (ICCs) and the 95% limits of agreement (LoA) were calculated to give a quantitative indicator of the overall test-retest reliability (T1, *vs* T2, *vs* T3) of effort production between trials using the CALER and BABE Scales. The LoA calculated the mean difference (bias) and the 95% limits of agreement (± 2 S.D. of the bias) between repeated trials.

In order to explore whether the scales were intra- or intermodal, the coefficient of variation (%) was calculated on power output and heart rate data for CALER and BABE during the cycling and stepping tasks (Appendix F). Furthermore, following indication from the first study that given the choice children may prefer to use the BABE Scale, a Chi-squared analysis was performed on questionnaire data in order to explore the children's scale preference.

Femur length was determined using data derived from orthoroentgenograms (Anderson et al. 1948, 1978) and calculated hip angles determined from the geometric relationship of an individual's stature and femur length (Francis et al., 1998). Statistical procedures examined the relationship between children (n=11) with a pre-calculated inefficient hip angle outside 82 ° (± 3°) Francis et al. (1998), and the variability in their effort production during the stepping task. All analyses were performed using SPSS 9.0, Excel 5.0 and Supastat 3.2. statistical packages.

3. RESULTS

Subject characteristics are shown in Table 20. A series of t-tests confirmed that there were no significant differences between the biometric data of the two groups (CALER) and (BABE).

Table 20: Subject Characteristics (Means and Standard Deviations)

Measure	CALER (n=15)		BABE (n=15)		t ratio	All (n=30)	
	M	**S.D**	**M**	**S.D**	**P>0.05**	**M**	**S.D**
Age (y)	9.70	1.50	9.80	1.50	-0.12	9.80	1.50
Stature (m)	1.38	0.06	1.40	0.09	-0.82	1.39	0.08
Mass (kg)	29.70	3.70	33.50	6.90	-1.89	31.60	5.80
Resting HR (b/min)	98.00	8.00	95.00	12.00	0.77	97.00	10.00
Calc. Hip Angle (°)	80.30	2.65	79.70	3.60	0.64	80.00	3.12

Group mean (±S.D) heart rates and power outputs at each of the three effort rating levels (3, 5, 8) are presented in Table 21 for the Stepping Protocol and Table 22 for the Cycling Protocol.

Table 21: Heart Rates and Power Outputs produced Across Trial 1 to Trial 3 at each prescribed perceived effort level (Stepping Protocol). Values are mean (±S.D).

		CALER			BABE	
Effort Level	**3**	**5**	**8**	**3**	**5**	**8**
Heart Rate (b/min)	153	163	173	156	165	175
(S.D)	(14.0)	(15.0)	(15.4)	(14.2)	(15.7)	(14.7)
Power Output (W)	52	55	58	58	61	64
(S.D)	(6.5)	(6.6)	(6.9)	(11.3)	(11.9)	(12.4)

Table 22: Heart Rates and Power Outputs produced Across Trial 1 to Trial 3 at each prescribed perceived effort level (Cycling Protocol). Values are mean (± S.D).

	CALER			BABE		
Effort Level	**3**	**5**	**8**	**3**	**5**	**8**
Heart Rate (b/min)	155	168	180	156	171	183
(S.D)	(16.3)	(15.1)	(12.5)	(18.9)	(17.6)	(16.5)
Power Output (W)	55	71	85	56	73	87
(S.D)	(7.5)	(8.9)	(10.4)	(9.4)	(10.8)	(13.2)

Table 23 summarises the group values for CALER (mean heart rates and power outputs) across three trials at each of the three effort rating levels (3, 5, and 8). Values shown are for the cycling and stepping protocols.

Table 23: Heart Rates (HR) and Power Outputs (PO) by perceived effort level and Trial (CALER). Values are mean (± S.D).

CALER GROUP		Cycling Protocol		Stepping Protocol	
Effort Level	**Trial**	**HR (b/min)**	**PO (W)**	**HR (b/min)**	**PO (W)**
3	1	157.3 (18.8)	54.0 (5.7)	154.4 (12.3)	52.4 (6.6)
	2	152.3 (16.6)	53.7 (5.5)	153.1 (14.8)	52.8 (6.6)
	3	156.7 (13.9)	58.3 (9.9)	150.8 (15.4)	52.3 (6.7)
5	1	171.1 (16.6)	69.0 (6.3)	163.6 (13.3)	55.0 (6.9)
	2	164.3 (15.3)	69.7 (8.8)	162.8 (14.8)	55.3 (6.6)
	3	167.9 (13.5)	74.3 (10.7)	161.9 (17.7)	55.0 (6.6)
8	1	181.3 (13.4)	84.3 (10.7)	173.5 (13.5)	57.7 (7.0)
	2	178.3 (12.6)	83.7 (10.3)	173.0 (16.4)	57.7 (6.9)
	3	180.7 (12.2)	86.7 (10.8)	171.1 (16.9)	57.8 (7.1)
Overall	1	169.9 (18.9)	69.1 (14.7)	163.8 (15.0)	55.1 (7.0)
	2	165.0 (18.1)	69.0 (14.9)	163.0 (17.1)	55.3 (6.9)
	3	168.4 (16.3)	73.1 (15.6)	161.3 (18.3)	55.0 (7.0)

Table 24 summarises the group values for BABE (mean heart rates and power outputs) across three trials at each of the three effort rating levels (3, 5, and 8). Values shown are for the cycling and stepping protocols.

Table 24: Heart Rates (HR) and Power Outputs (PO) by Perceived Effort Level and Trial (BABE). Values are mean (± S.D).

BABE GROUP		Cycling Protocol		Stepping Protocol	
Effort Level	**Trial**	**HR (b/min)**	**PO (W)**	**HR (b/min)**	**PO (W)**
3	1	152.3 (19.8)	52.3 (5.3)	155.8 (13.8)	57.6 (11.3)
	2	157.8 (18.7)	56.7 (10.3)	154.4 (13.2)	58.4 (11.9)
	3	158.9 (18.7)	59.7 (10.6)	158.0 (16.3)	59.0 (11.5)
5	1	171.6 (17.3)	72.0 (10.1)	164.3 (15.6)	60.9 (12.0)
	2	170.1 (19.7)	73.3 (13.0)	163.1 (13.4)	61.2 (12.4)
	3	170.8 (17.0)	73.7 (9.5)	167.0 (18.5)	61.8 (12.1)
8	1	183.5 (17.6)	87.3 (12.2)	174.2 (15.5)	63.8 (12.3)
	2	182.1 (17.6)	88.0 (15.9)	172.7 (11.6)	63.9 (13.0)
	3	182.1 (15.2)	86.3 (11.9)	177.3 (17.1)	64.7 (12.7)
Overall	1	169.1 (22.1)	70.6 (17.3)	164.8 (16.5)	60.7 (11.9)
	2	170.0 (20.8)	72.7 (18.3)	163.4 (14.6)	61.2 (12.4)
	3	170.6 (19.2)	73.2 (15.2)	167.4 (18.7)	61.8 (12.1)

3.1 Analysis of heart rate and power output differences between levels

Heart Rate

A Group (2) x Mode (2) x Level (3) ANOVA on trial 3 data revealed a highly significant main effect for Level on heart rate data ($F_{2,56}$ = 1198.69, P<0.001). Post hoc analysis (Tukey HSD) revealed that the differences between heart rates at effort ratings of 3, [155 bpm (15.9)], 5 [167 bpm (16.1)] and 8 [177 bpm (15.2)] were significant (P<0.01). This confirmed that the children understood the concept of the scales. ANOVA also revealed a significant main effect for Mode ($F_{1,28}$ = 5.50, P<0.05), with higher overall mean heart rates achieved during the cycling protocol [169 bpm, (19.2)] than the stepping protocol [164 bpm, (16.7)]. There was also a significant interaction of Mode x Level on heart rate ($F_{2,56}$ = 10.99, P<0.01). Post hoc analysis (Tukey HSD) revealed no significant difference between heart rates produced at an effort rating level of 3 for cycling and stepping, but heart rates for the stepping protocol were significantly lower (P<0.01) at effort rating levels of 5 and 8 than those produced during the cycling protocol (Figure 26). This shows that the increase in heart rate is moderated by the mode of exercise, being greater for cycling compared to stepping. There were no significant differences in heart rates between the CALER and BABE groups.

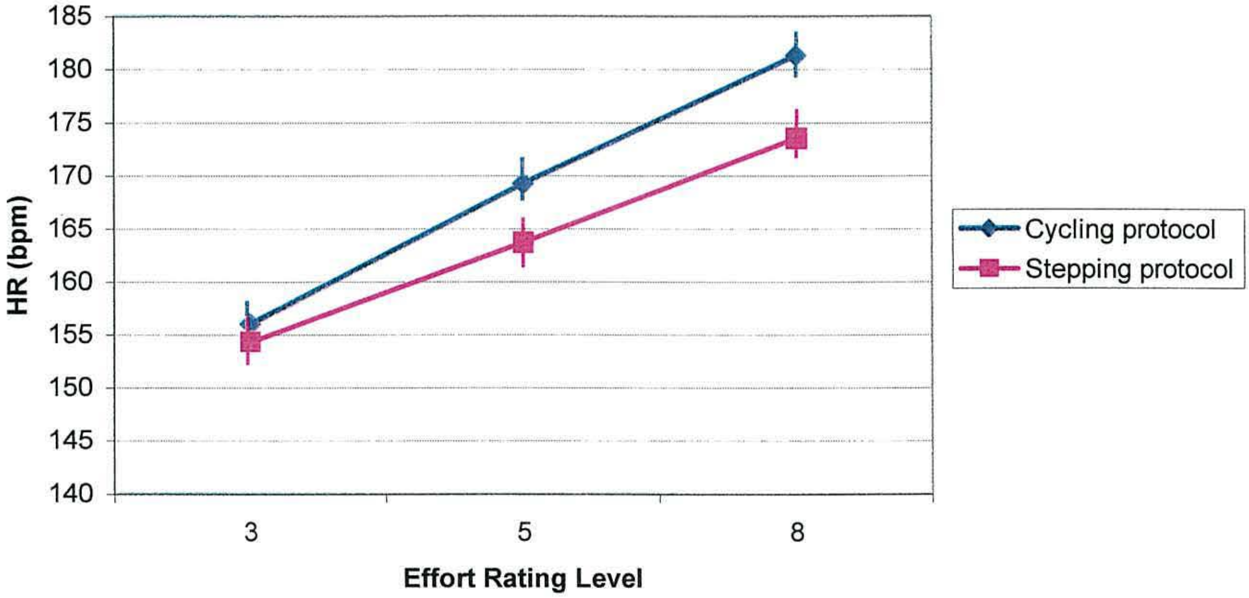


Figure 26: Interaction Graph: Heart rate response at effort production levels (5 and 8) is moderated by the mode of exercise. (Values are mean ± SEM).

Power Output

A Group (2) x Mode (2) x Level (3) ANOVA on trial 3 data revealed a significant main effect for perceived exertion level on power output ($F_{2,56} = 593.87$, $P<0.001$). Post hoc analysis (Tukey HSD) revealed that power outputs at effort rating Level 3, [55.6 W (9)], Level 5 [65.1 W (12)] and Level 8 [73.5 W (17)] were significantly different ($P<0.01$). This provided additional confirmatory evidence that the children understood the concept of the scales. ANOVA revealed a significant main effect for Mode ($F_{1,28} = 39.97$, $P<0.01$), with significantly higher ($P<0.01$) mean power outputs achieved during the cycling protocol [71.3 W, (16)] than the stepping protocol [58.2 W, (10)]. There was also a significant interaction of Mode x Level on power output ($F_{2,56}$ = 287.13, P<0.001). Tukey HSD revealed no significant difference between power outputs produced at an effort rating level of 3 for cycling and stepping, but power outputs for the stepping protocol were significantly lower (P<0.01) at effort rating levels of 5 and 8 than those produced during the cycling protocol (Figure 27). This shows that the increase in power output is moderated by the mode of exercise, being greater for cycling compared to stepping. There was no significant difference in power outputs between the CALER and BABE groups.

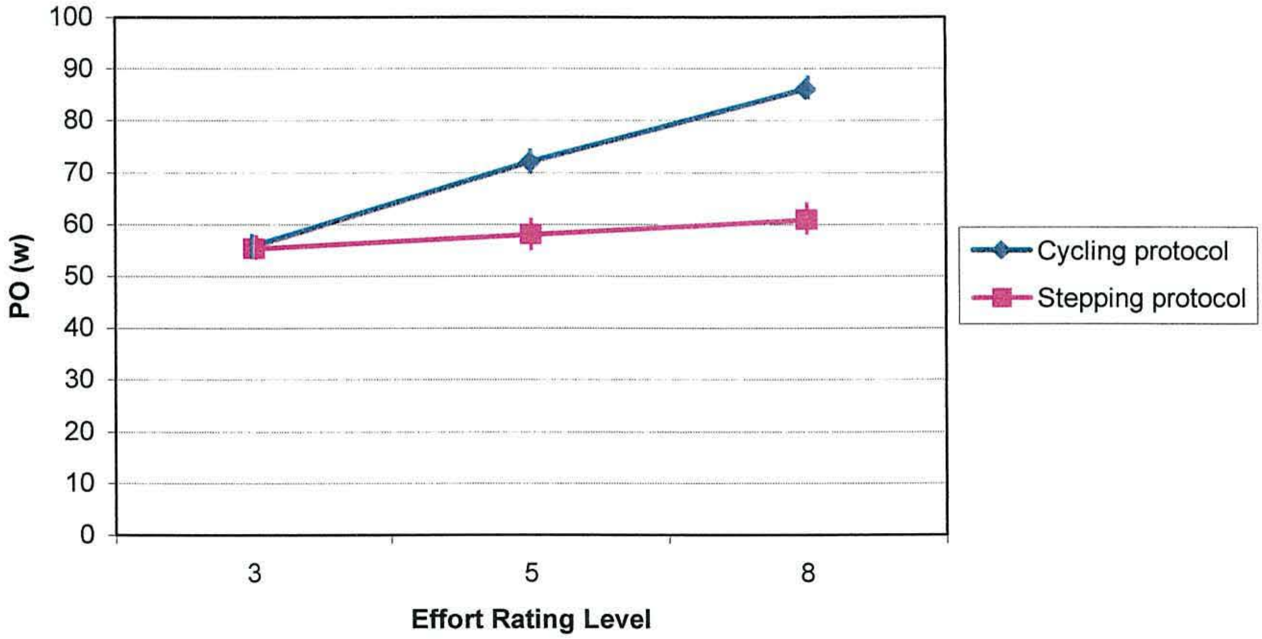


Figure 27: Interaction Graph: Power output response at effort production levels (5 and 8) is moderated by the mode of exercise. (Values are mean ± SEM)

3.2 Analysis of heart rate and power output within trials

A Group (2) x Mode (2) x Trials (3) ANOVA on heart rate and power output was applied to each of the three effort rating levels (3, 5 and 8). This analysis was chosen in order to determine consistencies of effort ratings over trials.

Heart Rate at Effort Rating Level 3

There was no significant difference between the heart rates produced during the cycling and stepping protocols at an effort rating level of 3 (Easy). There were no significant main effects or interactions at this effort rating level.

Heart Rate at Effort Rating Level 5

ANOVA revealed a significant main effect for Mode ($F_{1,28} = 5.61$, $P<0.05$). Mean heart rate for the cycling protocol [169 bpm, (16.4)] was significantly higher than the mean heart rate produced during the stepping protocol [164 bpm, (15.3)].

Heart Rate at Effort Rating Level 8

ANOVA revealed significant main effect for Mode ($F_{1,28} = 13.01$, $P<0.01$). Mean heart rate for the cycling protocol [181 bpm, (14.6)] was significantly higher than the mean heart rate produced during the stepping protocol [174 bpm, (15)].

Apart from the main effects and interactions already reported above, there were no main effects for *trial* and no interactions which included *trial* for effort rating levels 3, 5 and 8.

Power Output

Power Output at Effort Rating Level 3

ANOVA revealed a significant main effect of Trials on Effort Rating 3 ($F_{2,56} = 8.63$, $P<0.01$). Tukey post hoc analysis revealed a significant difference ($P<0.05$) between the power output produced during Trial 1 and Trial 3 only. This provided confirmatory evidence that practice improved the consistency of ratings of exercise effort. There was also a significant interaction for Mode x Trials ($F_{2,56} = 6.54$, $P<0.01$) (Figure 28).

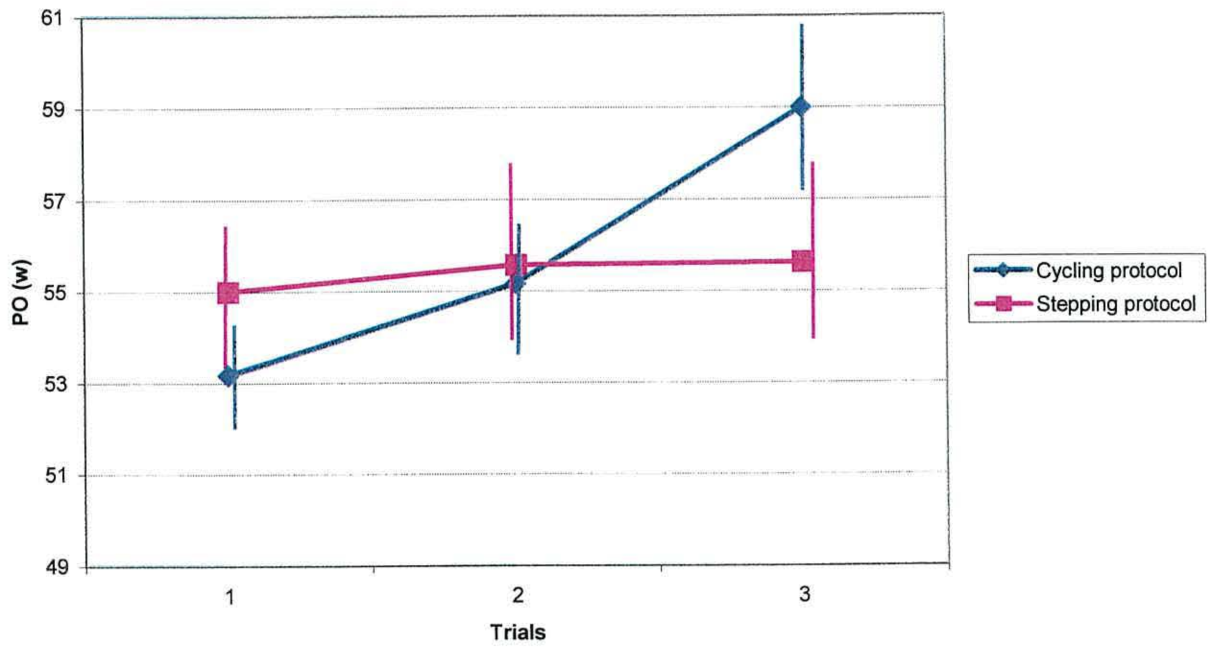


Figure 28: Interaction between Mode of exercise and Trials on Power Output at perceived effort rating level of 3 (Easy). (Values are mean ± SEM).

Tukey post hoc analysis revealed a significant difference in power outputs produced during the cycling protocol between Trial 1 [52.3 W, (6)] and Trial 3 [59.0 W, (10)] ($P<0.01$), and between Trial 2 [55.2 W, (8)] and Trial 3 [59.0 W, (10)] ($P<0.05$). There were no other significant main effects or interactions.

Power Output at Effort Rating Level 5

ANOVA revealed a significant main effect for Mode ($F_{1,28} = 41.31$, $P<0.001$). Mean power output produced during the cycling protocol [72 W, (10)] was significantly higher ($P<0.01$) than the mean power output produced during the stepping protocol [58.2 W, (10)].

Power Output at Effort Rating Level 8

ANOVA revealed a significant main effect for Mode ($F_{1,28}$ = 114.63, P<0.001). Mean power output produced during the cycling protocol [86.1 W, (12)] was significantly higher (P<0.01) than the mean power output produced during the stepping protocol [60.9 W, (11)]. The children were more variable in their production of power output during the cycling protocol across trials at an effort rating level of 3 (Easy), than at the higher levels of exertion of 5 (Starting to get hard) and 8 (Very hard). Power output across the three trials for the stepping protocol were found to be consistent.

Critically, there was no significant interaction for Mode x Trials, indicating that power output was consistent within Mode (Cycling and Stepping) across Trials, at effort ratings levels 5 and 8. There were no other significant main effects or interactions.

3.3 Reliability

Intraclass Correlation Analysis

Table 25 shows the intraclass reliability (ICC) values for power output and heart rate for the three effort rating levels (3, 5, 8) of CALER and BABE across trials during cycling mode.

Table 25: Individual Intraclass Correlation Coefficient (ICC) for Heart Rate and Power Output during Cycling Protocol for CALER and BABE across Trial 1 (T1) to Trial 3 (T3).

(Cycling	Heart Rate			Power Output		
Protocol)	T1-T2	T2-T3	T1-T2-T3	T1-T2	T2-T3	T1-T2-T3
CALER 3	0.56*	0.76	0.69	0.29*	0.63**	0.43**
CALER 5	0.77	0.76	0.73	0.82	0.56*	0.60
CALER 8	0.74	0.80	0.72	0.92	0.55*	0.65
OVERALL	**0.74**	**0.81**	**0.74**	**0.58**	**0.57**	**0.51**
BABE 3	0.71**	0.93	0.78	0.31*	0.69**	0.55
BABE 5	0.85	0.88	0.86	0.81	0.64**	0.73
BABE 8	0.88	0.88	0.87	0.78	0.77	0.76
OVERALL	**0.84**	**0.90**	**0.84**	**0.69**	**0.77**	**0.71**

All values $P<0.001$ unless otherwise stated
** $P<0.01$
* $P<0.05$

Evidence to demonstrate that the children learned how to self-regulate exercise intensity is shown by the increase in the intraclass R values (heart rate) between trials. For example, at an effort production level of 3, the children in the CALER group improved their ability to reproduce heart rate from 0.56 between Trials 1 and 2 to 0.76 between Trials 2 and 3. Intraclass R values for power output suggest that children improved in their ability to self-regulate exercise intensity at an effort rating level of 3, but did not improve reliability at effort rating level 5 or 8 using the CALER or BABE Scale (Table 25). Overall ICCs suggest that the BABE Group were more reliable than the CALER Group in their reproduction of heart rate and power output during the cycling exercise.

Table 26 shows the intraclass reliability values for power output and heart rate for the three effort rating levels of CALER and BABE across trials during stepping mode.

Table 26: Individual Intraclass Correlation Coefficient (ICC) for Heart Rate and Power Output during Stepping Protocol for CALER and BABE across Trial 1 (T1) to Trial 3 (T3).

(Stepping	Heart Rate			Power Output		
Protocol)	T1-T2	T2-T3	T1-T2-T3	T1-T2	T2-T3	T1-T2-T3
CALER 3	0.75	0.75	0.73	0.97	0.99	0.98
CALER 5	0.86	0.80	0.82	0.98	0.99	0.98
CALER 8	0.81	0.84	0.84	0.99	0.99	0.99
OVERALL	**0.84**	**0.85**	**0.83**	**0.99**	**0.99**	**0.99**
BABE 3	0.76	0.84	0.77	0.99	1.00	0.99
BABE 5	0.85	0.89	0.84	0.99	1.00	0.99
BABE 8	0.89	0.73	0.79	0.99	1.00	0.99
OVERALL	**0.88**	**0.87**	**0.84**	**0.99**	**1.00**	**0.99**

All values $P<0.001$

For example, at an effort production level of 3, the children in the BABE Group improved their ability to reproduce heart rate from 0.76 between Trials 1 and 2, to 0.84 between Trials 2 and 3. Highly reliable results were produced for heart rate and power output for the CALER and BABE groups during the stepping task.

Overall, the BABE group were slightly more reliable (Tables 25 and 26) in their production of exercise effort (heart rate and power output) across trials for the Cycling and Stepping protocol than the CALER group. For example, overall T1-T2-T3 R for power output during the Cycling protocol for BABE was R = 0.71 *vs.* CALER overall R = 0.51.

Limits of Agreement Analyses

Tables 27 and 28 show the bias ± 95% Limits of Agreement (LoA) (Bland and Altman 1986, 1995) for power output for CALER and BABE at effort rating levels 3, 5 and 8, for the Cycling and Stepping Protocols respectively. Tables 29 and 30 show the bias ± 95% LoA for heart rate for CALER and BABE at effort rating levels 3, 5 and 8, for the Cycling and Stepping Protocols respectively.

Table 27: Limits of Agreement (LoA) for CALER and BABE across Trial 1 (T1) to Trial 3 (T3) for Power Output, showing Bias with 95% Limits of Agreement in brackets (Cycling Protocol)

	CALER		BABE	
Effort Level	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	0.3 (± 2 x 6.7)	-4.7 (± 2 x 6.9)	-4.3 (± 2 x 9.6)	-3.0 (± 2 x 8.2)
5	-0.7 (± 2 x 4.6)	-4.7 (± 2 x 9.2)	-1.3 (± 2 x 7.2)	-0.3 (± 2 x 9.7)
8	0.7 (± 2 x 4.2)	-3.0 (± 2 x 10.0)	-0.7 (± 2 x 9.4)	1.7 (± 2 x 9.6)
Overall LoA	0.1 (± 2 x 5.2)	-4.1 (± 2 x 8.6)	-2.1 (± 2 x 8.8)	-0.5 (± 2 x 9.2)

Table 28: Limits of Agreement (LoA) for CALER and BABE across Trial 1 (T1) to Trial 3 (T3) for Power Output, showing Bias with 95% Limits of Agreement in brackets (Stepping Protocol)

	CALER		BABE	
Effort Level	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	-0.34 (± 2 x 1.5)	0.5 (± 2 x 1.0)	-0.82 (± 2 x 1.4)	-0.61 (± 2 x 1.1)
5	-0.3 (± 2 x 1.3)	0.3 (± 2 x 0.9)	-0.28 (± 2 x 1.3)	-0.61 (± 2 x 1.1)
8	0.0 (± 2 x 1.2)	0.02 (± 2 x 1.0)	-0.13 (± 2 x 1.5)	-0.82 (± 2 x 1.2)
Overall LoA	-0.2 (± 2 x 1.3)	0.3 (± 2 x 1.0)	-0.4 (± 2 x 1.4)	-0.7 (± 2 x 1.1)

Table 29: Limits of Agreement (LoA) for CALER and BABE across Trial 1 (T1) to Trial 3 (T3) for Heart Rate, showing Bias with 95% Limits of Agreement in brackets (Cycling Protocol).

	CALER		BABE	
Effort Level	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	5.0 (± 2 x 16.6)	-4.4 (± 2 x 10.6)	-5.5 (± 2 x 14.7)	-1.1 (± 2 x 7.1)
5	6.8 (± 2 x 10.8)	-3.6 (± 2 x 9.9)	1.5 (± 2 x 10.1)	-0.7 (± 2 x 9.0)
8	3.1 (± 2 x 9.4)	-2.4 (± 2 x 7.8)	1.4 (± 2 x 8.7)	0.1 (± 2 x 8.1)
Overall LoA	5.0 (± 2 x 12.5)	-3.5 (± 2 x 9.3)	-0.8 (± 2 x 11.7)	-0.6 (± 2 x 7.9)

Table 30: Limits of Agreement (LoA) for CALER and BABE across Trial 1 (T1) to Trial 3 (T3) for Heart Rate, showing Bias with 95% Limits of Agreement in brackets (Stepping Protocol).

	CALER		BABE	
Effort Level	**T1-T2**	**T2-T3**	**T1-T2**	**T2-T3**
3	1.1 (± 2 x 9.6)	2.3 (± 2 x 10.6)	1.5 (± 2 x 9.4)	-3.6 (± 2 x 8.4)
5	0.8 (± 2 x 7.5)	0.1 (± 2 x 10.6)	1.1 (± 2 x 8.1)	-3.9 (± 2 x 7.7)
8	0.5 (± 2 x 9.3)	1.9 (± 2 x 9.4)	1.5 (± 2 x 6.5)	-4.5 (± 2 x 10.7)
Overall LoA	0.8 (± 2 x 8.7)	1.5 (± 2 x 10.0)	1.4 (± 2 x 7.9)	-4.0 (± 2 x 8.8)

The LoA analyses, together with the ICC results provide a more comprehensive picture of scale reliability. In general, results indicate that the reliability to reproduce effort over the three trials improved with practice for both groups for the cycling protocol. For example, at an effort production level of 3, Trial 2 *vs.* Trial 3 (Table 27), the BABE group reproduced a power output of between –3.0 ± 16W i.e., within a range of 19W lower or 13W higher than the power output produced in Trial 2. However, the CALER group did not show improved production of power output across trials for the cycling protocol (Table 27). The Overall LoA for heart rate for both groups during the cycling protocol showed improvement in reliability across trials. For the stepping protocol, production of effort (heart rate) did not improve with practice across trials for either the CALER or BABE groups (Table 30). Whereas, the production of effort (power output) during the stepping protocol (Table 28) generally remained consistent for both groups across trials. This could be attributed to the way in which power output production was manipulated in the stepping protocol employed (using percent body mass backpack loadings). For the stepping protocol, 5 subjects in the CALER group and 6 subjects in the BABE group had pre-calculated hip angles outside 82° +/- 3° (optimal efficiency) (Francis et al., 1998). Analysis of individual 95% LoA showed that these children were not more variable in their production of effort over trials, with results falling within the 95% LoA. These findings are supported by the ICC results (Table 26), which indicate that both groups were highly reliable in their production of exercise effort across trials.

3.4 Coefficient of Variation

Figures 29 and 30 show the coefficient of variation ([S.D/ Mean] x 100) % on power output and heart rate data for CALER and BABE during cycling and stepping tasks (trial 3 data).

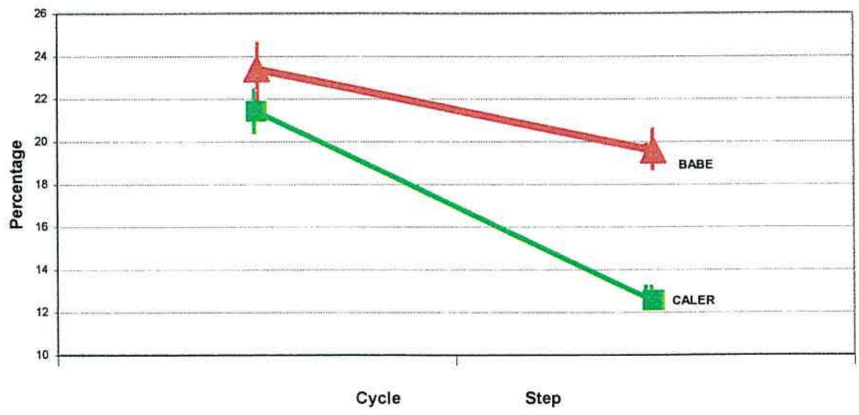


Figure 29: Coefficient of variation (Power Output)

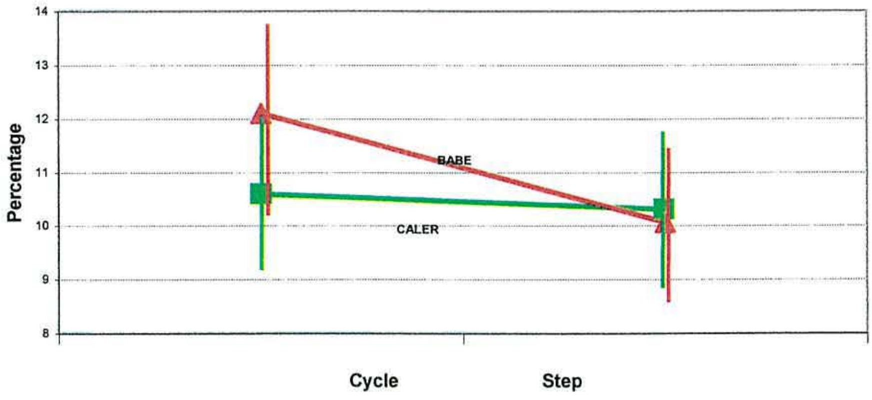


Figure 30: Coefficient of variation (Heart Rate)

CALER produced slightly lower variance in power output (12.6%) compared to BABE (19.6%) during the stepping task (Figure 29). During the cycling task the variances were shown to be similar for each group, [CALER (21.4%) and BABE (23.4%)]. BABE produced similar variance (10.1%) compared to CALER (10.3%) for heart rates during the stepping task (Figure 30). During the cycling task the variances in heart rate were also similar; BABE (12.1%) and CALER (10.6%) respectively. These results show that both scales provide similar results across exercise modalities, indicating that either effort rating scale may be used during cycling or stepping tasks. If the scales were found to be mode- specific i.e. the CALER Scale being more reliable for use during cycling tasks, and the BABE Scale being more reliable for use during stepping tasks, then one would expect the variances to be markedly different as indicated in Figure 31.

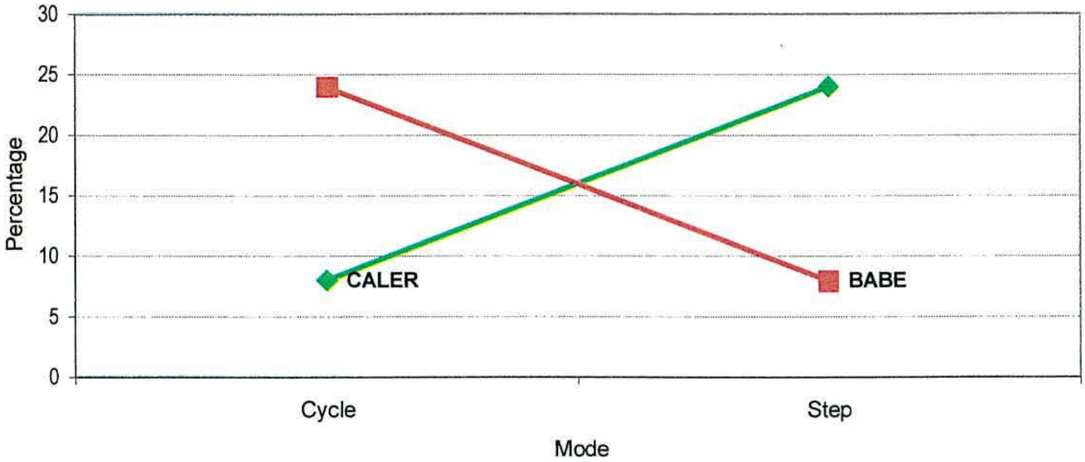


Figure 31: Expected Variances to indicate Effort Rating Scales are Intramodal

3.5 Preference by Children

Following the initial validation study (Chapter 3), it became evident that children seemed to prefer the BABE Scale, with many children disappointed not to be assigned to the BABE group. The BABE Scale was developed to appeal to children, particularly as it contained characters that were similar to characters depicted in the then recent Walt Disney film 'A Bug's Life', the central characters being familiar to most children. During informal discussion in the introductory session, reasons for their preferred choice included that the scale was 'fun-looking' and 'interesting' due to use of colours, and the character association with the hit movie 'A Bug's Life', which all participants were familiar with.

Following the present study, a questionnaire was issued to all participants (Appendix G1). The purpose of this simple questionnaire was to collect quantitative data to confirm if effort rating scale preference existed. The questionnaire was issued under examination conditions to the children in the classroom by their form tutor who explained the need to answer the question truthfully. Children were asked 'if you were to complete the exercises again, which scale would you prefer to use the CALER or BABE Scale?'

They then indicated their choice by placing a tick next to a photocopy-reduced version of the appropriate effort rating scale. Eight out of the thirty children participating in the study had since progressed to secondary school, in these cases questionnaires were forwarded by post. Out of the 30 children who participated in the study, 29 questionnaires were returned, (a response rate of 97%). The questionnaire results revealed that 3/15 (20%) of children who had previously used the BABE scale chose the CALER; 9/14 (64%) of children who had previously used the CALER chose the BABE scale; 12/15 (80%) of children who had previously used the BABE scale still preferred to use the BABE; and 5/14 (36%) of children who had previously used the CALER scale still preferred to use the CALER.

Chi Squared Analysis

A Chi-squared analysis was conducted on the data and revealed a Chi-Squared χ^2 value of $4.171 > 3.841$ with 1df, ($P<0.05$) (Appendix G2). The independent variables for the Chi-Squared analysis were Scale Used and Scale Preference. The results indicated a significant difference ($p<0.05$) between the CALER and BABE groups with regards to preferred choice of effort rating scale. The BABE group showed a higher retention (80%) compared to the CALER group (36%), with less children wishing to change from having previously used the BABE scale to using the CALER scale (20%). A significantly higher ($p<0.05$) percentage of children wished to change from having previously used the CALER scale to using the BABE scale (64%). These results suggest that the most appropriate effort rating scale to use in an external validity study would be the BABE scale, which appears to be preferred by most children.

4. DISCUSSION

Results from this study show that children aged 7-11 years were able to regulate exercise efforts during intermittent cycle ergometry and stepping tasks (with randomised order of levels) by applying their understanding of the CALER or BABE Scale. This study has also confirmed that the CALER and BABE child-specific effort rating scales may be used interchangeably. Results have shown that both scales provide similar consistencies within exercise modes, suggesting that either scale could be employed with paediatric subjects.

The increase in power output (56, 65, and 74W at effort rating levels 3, 5 and 8 respectively, $F_{2,56} = 593.87$, $P<0.01$) and increase in heart rate (155, 166 and 177 bpm at effort rating levels 3, 5 and 8 respectively, $F_{2,56} = 1198.69$, $P<0.01$) confirmed that the children understood the effort-rating scales. Heart rates ($P<0.05$) and power outputs ($P<0.01$) were significantly higher for the cycling protocol than the stepping protocol, irrespective of the scale used. ANOVA revealed a significant interaction of Mode x Trials on power output ($F_{2,56} = 6.54$, $P<0.01$). Tukey post hoc analysis revealed that children were more variable in their production of power output during the cycling protocol across trials at an effort rating level of 3 (Easy), than at higher levels of exertion 5 (Starting to get hard) and 8 (Very hard). Power outputs across three trials for the stepping protocol were found to be consistent.

The Intraclass Correlation Coefficient showed a general trend of increasing reliability across trials. This concurs with previously reported data for power output production during a cycling protocol (Eston et al., 2000), and demonstrates that the children had learned how to self-regulate exercise intensity. However, for the stepping protocol (heart rate data), the limits of agreement analyses showed that practice did not enhance children's production of exercise effort across trials. There is a lack of research on the reliability of children's effort production during intermittent stepping protocols. However, anomalous reliability results obtained from this study might suggest that children aged 7-11 years require more than three effort production trials during intermittent stepping (and cycling) protocols to achieve highly reliable results. Eston et al. (2000) highlighted the importance of three or more trials in the production of highly reliable exercise efforts in children aged 7 to 10 years during intermittent cycle ergometry tasks.

This study has demonstrated that the CALER and BABE scales may be applicable to a variety of exercise environments. The development of additional scales to accommodate different modes of exercise may therefore not be necessary.

In the first study of its kind, results have demonstrated that the CALER and BABE scales are intermodal. Either scale may be used for cycling or stepping tasks with children aged 7-11years. Results have shown that both scales provide valid and reliable measures of effort (heart rate and power output) production across exercise modes. This study has provided evidence that the BABE scale is a valid and reliable tool for quantifying children's effort perception and for regulating exercise output. Questionnaire results confirmed that most children would prefer to use the BABE scale rather than the CALER scale, in future exercise sessions. The BABE Scale is also more pictorially representative of a range of ambulatory movements. External validity studies with children should therefore incorporate the BABE scale into the design.

CHAPTER 6

Use of the BABE Scale to Regulate Exercise Intensity in Circuit Training Classes for Children

1. INTRODUCTION

Although low levels of physical activity in children have been acknowledged as a potential health problem by researchers, and school physical education lessons have been identified as an area where improvements could be made (Public Health Service, 1991), little has been done. Inactivity increases the risk of heart disease, back pain, weak and fragile bones, and obesity in adulthood. Overweight in youth is associated with overweight in adulthood (Serdula et al., 1993; Guo et al., 1994), and obesity or overweight in childhood has been linked to subsequent morbidity and mortality in adulthood (Hoffmans et al., 1988; Nieto et al., 1992). There is some evidence that physical activity in childhood can play a role in reducing the development of risk factors for coronary heart disease, including elevated blood pressure, high cholesterol levels and obesity (Boreham and Riddoch, 2001).

In the late 1990's suggestions were emerging that an appropriately designed, delivered and supported physical education curriculum could enhance current levels of children's physical activity and improve physical skill development through the concept of health-related exercise in the national curriculum (Piernon et al., 1996; Harris, 1997). Schools are important in the provision and promotion of physical activity programmes because they reach virtually all young people, and facilities are available all year round.

For many children, physical activity is not an integral part of every day life. Ways of increasing their activity levels need to be explored. One possibility is to encourage children to walk or cycle to school instead of coming by car or bus. Physical education lessons in schools play a vital role in educating and motivating children. For some children, these lessons might be the only regular opportunity for physical activity.

Child-specific effort rating scales could be incorporated into physical education lessons to encourage physical activity in children, as well as having the desired effect of introducing a theoretical aspect into physical education lessons. Such a tool could help children understand why exercise makes them feel the way they do, an aim set out by the Department for Education and the Welsh Office Education Department (1995).

Inactive children tend to become inactive adults (Allied Dunbar National Fitness Survey, 1992). The concern is that inactivity in childhood will lead to inactivity in adulthood and subsequent increased risk of developing the risk factors for cardiovascular disease (Riddoch et al., 1991). People who exercise regularly in their youth are more likely to exercise in later years. However, there is a lack of research tracking physical activity levels from childhood into adulthood, which could be due to the time and resources required to conduct such longitudinal studies. The Allied Dunbar National Fitness Survey conducted by the Sports Council and the Health Education Authority (1992) revealed that 25% of those who were active between the ages of 14 to 19 were still currently very active. Whereas, of those who had been inactive between the ages of 14 to 19, only 2% were currently active. Data from the survey recommend that an active lifestyle and the benefits of physical activity need to be promoted at an early age. Susan Lewis, the chief inspector of education and training in Wales highlighted in the 2000-2001 report that school children were not interested in physical education, which supports the literature that children are in danger of becoming couch potatoes.

The concept of health-related fitness in the curriculum was increasingly identifiable in schools in the early 1980s, in response to recognition of the links between lack of physical activity, serious disease and mortality. Schools such as Forest School in England (Kirk, 1986a) implemented health-related fitness initiatives to increase student's interest and enjoyment in physical education lessons. 'Health-Related Exercise' became the favoured terminology in the late 1980s, as schools were encouraged to incorporate health-related concepts into the physical education curriculum. Health-Related Exercise (HRE) is exercise that is associated with health benefits such as an improved ability to perform daily activities and a reduced risk of hypokinetic diseases, such as coronary heart disease. Within an educational context, the term 'HRE' refers to knowledge, attitudes, skills and understanding considered essential for the promotion of an active lifestyle (Harris, 2000).

The Health-Related Exercise (HRE) National Working Group was established as a consequence of debates on how health-related exercise was delivered in schools. The group was formed partly as a consequence of inspection findings relating to health-related exercise in England and Wales in the mid 1990's, and also in response to comments expressed at national conferences on Physical Education and Health of the Nation, Higher Education Institutes and school network meetings.

The HRE working group comprises approximately 15 invited representatives and individuals from higher education, the advisory service, primary and secondary schools, and key organisations. Such organisations include the Physical Education Association U.K (PEAUK), the Health Development Agency (HDA) (formerly the Health Education Authority), the Exercise Association, the British Association of Advisors and Lecturers in Physical Education (BAALPE) and the English Sports Council (now Sport England).

The main task of the group was to produce and disseminate 'HRE good practice guidelines' for primary and secondary school teachers. All schools are required to deliver 'fitness and health' as a statutory component of the Physical Education National Curriculum. Understanding and educating children about the benefits of physical activity, undergoing positive exercise experiences, and learning to become independently active throughout their schooling can assist children in making informed decisions concerning physical activity as an integral part of their lifestyle.

The National Curriculum for Physical Education in England and Wales states that HRE should be taught at each key stage (Harris, 2000). One of the four areas of experience within the key stage 4 programme of study is exercise activities (non-competitive forms of exercise, such as step aerobics, jogging, weight-training, cycling, skipping and circuit training). Examples of attainment targets of HRE in the national curriculum for physical education in Wales at Key Stage 1 are that pupils should be taught to 'understand the changes that happen to their bodies as they exercise, to recognise the effects and to describe changes to their feelings (tired or more energetic)' (Harris, 2000). Child-specific effort rating scales could be employed by physical educators to encourage children to be more physically active during lessons and used as a tool for children to quantify and regulate their exercise intensity during such exercise activities. Indeed, recent research (Green and Lamb, 2000; Penney and Yelling, 2001) has strengthened a case for effort perception in applied settings by recommending ways in which children's effort perception could be incorporated as a tool for the delivery of aspects of health-related exercise within the National Curriculum for Physical Education in England and Wales.

Preliminary studies conducted for this thesis have highlighted the potential validity and reliability of the use of the BABE Scale to encourage physical activity in children. In addition, results have suggested that children specifically display a preference for using the BABE.

The following study was designed to explore the efficacy of integrating the BABE Scale into six weeks of Physical Education classes (circuit training) with primary school children aged 8 to 11 years. A further aim was to assess the ability of the children to regulate their exercise intensity in accordance with specific levels of the BABE Scale. The BABE Scale was chosen for this study since previous research had suggested that children preferred to use this scale compared to either the CERT or CALER Scale. The BABE Scale (and the pictures it depicts) may also be more applicable to a range of different circuit exercise activities (running, walking, stepping, hopping, skipping, jumping, marching), than other child-specific effort rating scales such as the OMNI Scale (Robertson and Noble, 1997) and CALER Scale (Eston et al., 1999) whose pictures are restricted to cycling.

2. METHOD

2.1 Subjects

Data were collected on 15 children aged 8-11 years, representing 23% of a Primary School in Wiltshire, England. Descriptive characteristics are presented in Table 31. All children provided parental informed consent to participate in the study and were free from known contra-indications prior to testing. Ethical approval was granted from the South and West Region Medical Ethics Committee.

Table 31: Descriptive Characteristics

Measure	Boys, n = 10		Girls, n = 5		All, n = 15	
	M	S.D	M	S.D	M	S.D
Age (y)	11.0	0.64	10.7	0.77	10.9	0.68
Stature (m)	1.42	0.08	1.45	0.08	1.43	0.08
Mass (kg)	40.2	9.61	35.8	6.00	38.7	8.62

2.2 Procedures

One week before testing, the experimenter introduced the children to the Bug and Bag Effort (BABE) Scale and the exercise circuit. The experimenter completed demonstrations of each circuit station and allowed opportunity for children to practice at each station. The experimenter was able to answer any questions and make alterations to individual participant technique as necessary. Perceptual anchoring of the scale was achieved by the experimenter exposing the children to a range of intensities in the school sports hall involving simple stepping and running tasks used to set the perceptual anchor points at 'low' and 'high' levels (Figures 32 and 32a).

Figure 32: Perceptual anchoring of the BABE scale
at an effort rating level of 3 (Easy)

Figure 32a: Perceptual anchoring of the BABE scale
at an effort rating level of 8 (Very hard)

Following perceptual anchoring of the scale, the experimenter explained how the verbal expressions should be interpreted in numerical form (Figure 33), and the children were given a copy of the BABE scale to study and keep. Data collection took place on the school premises in the sports hall on six occasions, one week apart.

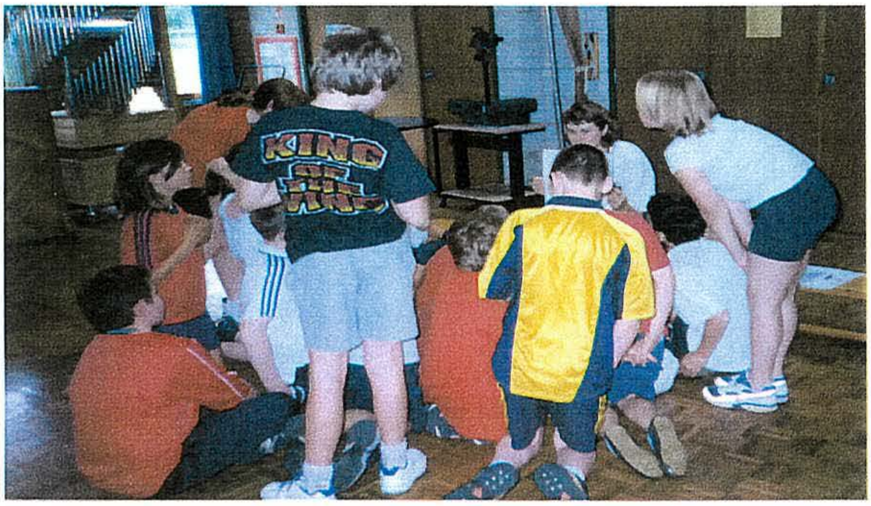


Figure 33: Explanation of verbal cues

Circuit Design

The circuit design is summarised in Table 32 and the layout shown in Figures 34 and 34a. All exercise circuits were led by the experimenter and commenced with a five-minute warm-up consisting of light marching, jogging and stepping tasks followed by stretches of the major muscle groups (Figure 35). The circuit consisted of ten stations, with four stations allowing for physical measurements of number of repetitions and pedometry counts.

In order to replicate a normal circuit training session, children exercised at each circuit station for 30 seconds, with a 60-second rest period between stations. The total duration for each session was 30 minutes, allowing children to complete two full circuits.

Weeks one and two acted as test habituation. The children participated in the exercise circuit, led by the experimenter. The children were told 'we'll work at each station for 30 seconds...Go!' The BABE Scale was not used as part of the exercise circuit and no measurements were taken.

Week three involved the children participating in the exercise circuit without use of the BABE Scale. The children were told 'we'll work at this station for 30 seconds...Go!' The number of repetitions from all participants at stations 1 to 4 were recorded by video analysis and number of steps taken recorded by use of Pedometers (Digi-walker SW-200, Yamax, Japan) during the 60-second rest period between stations.

Week four involved the children participating in the exercise circuit with use of the BABE scale. Repetitions from all participants at stations 1 to 4 were recorded by video analysis and number of steps taken recorded by pedometers during the 60-second rest period between stations. Enlarged BABE scales at each circuit station clearly indicated (by use of an arrow) the level of effort production required (Appendix H1). The children were told 'look at what the Bug says, we'll work at this station for 30 seconds....Go!' Table 32 shows the order of effort production level at these four stations. For example at station 1, all participants exercised during the first circuit at BABE 8, and the second circuit at BABE 3. Effort production levels for stations 5 to 10 are shown in Table 32.

Week five was a repeat of week three. The BABE scale was not used in the circuit and repetitions and pedometry counts at stations 1 to 4 were recorded. Week six was a repeat of week four. The children participated in the exercise circuit with use of the BABE scale. Repetitions from all participants at stations 1 to 4 were recorded by video analysis and number of steps taken recorded by pedometers during the 60-second rest period between stations. The order of effort production level at stations 1 to 4 was reversed (Table 32). For example at station 1, all participants exercised during the first circuit at BABE 3, and the second circuit at BABE 8. Effort production levels for stations 5 to 10 are detailed in Table 32. Each of the six exercise circuit sessions included a five-minute cool-down led by the experimenter and consisted of light marching, jogging and stepping tasks followed by two minutes of static stretching.

Table 32: Study Design

Week	Station Number	Effort Production Level Circuit 1	Circuit 2	Measurements	Additional Details
1	N/A	X	X	X	Habituation
2	N/A	X	X	X	Habituation
3	1 2 3 4	N/A	N/A	Repetitions at stations 1 to 4 and pedometry	
4	1 2 3 4	8 3 8 3	3 8 3 8	Repetitions at stations 1 to 4 and pedometry	Stations 5, 7 & 9 at effort production level 3, and stations 6, 8 and 10 at effort production level 8
5	1 2 3 4	N/A	N/A	Repetitions at stations 1 to 4 and pedometry	
6	1 2 3 4	3 8 3 8	8 3 8 3	Repetitions at stations 1 to 4 and pedometry	Stations 5, 7 & 9 at effort production level 3, and stations 6, 8 and 10 at effort production level 8

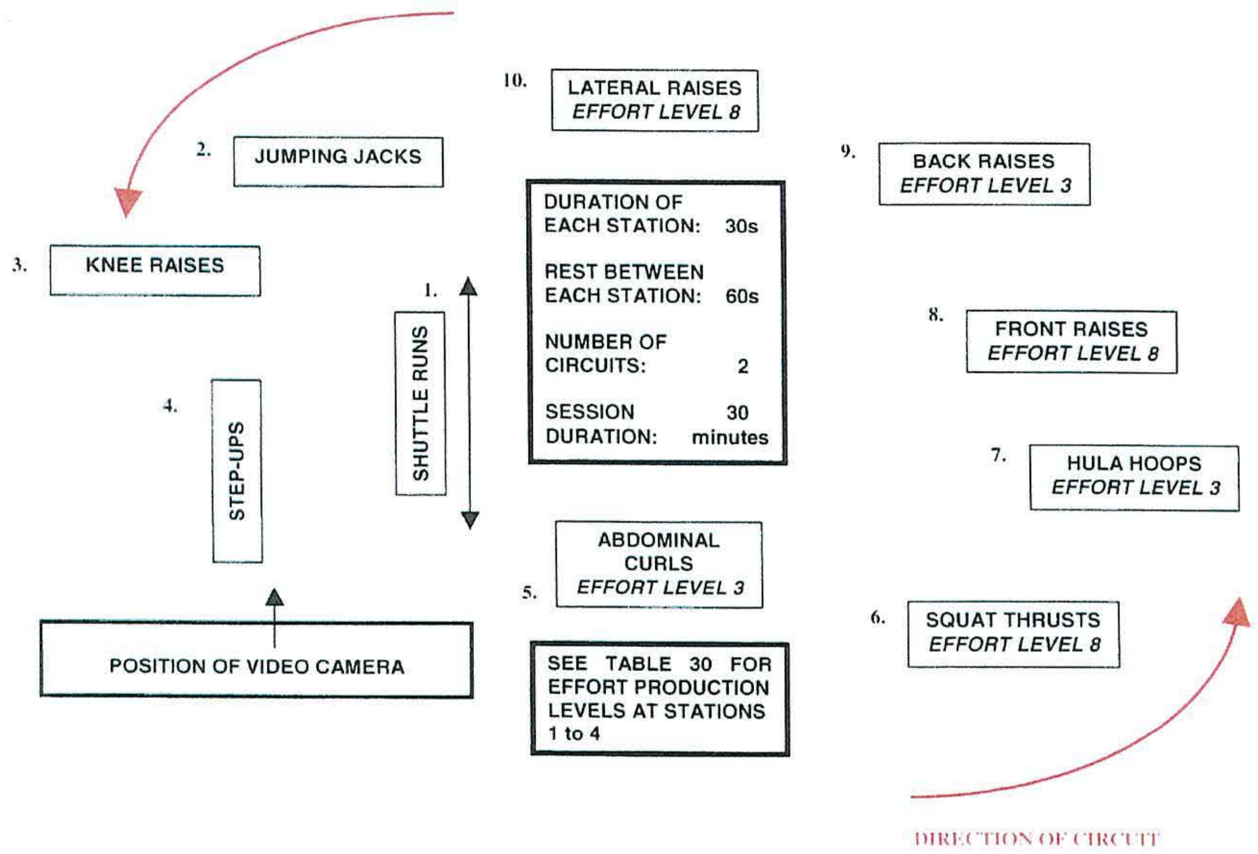


Figure 34: Circuit Design

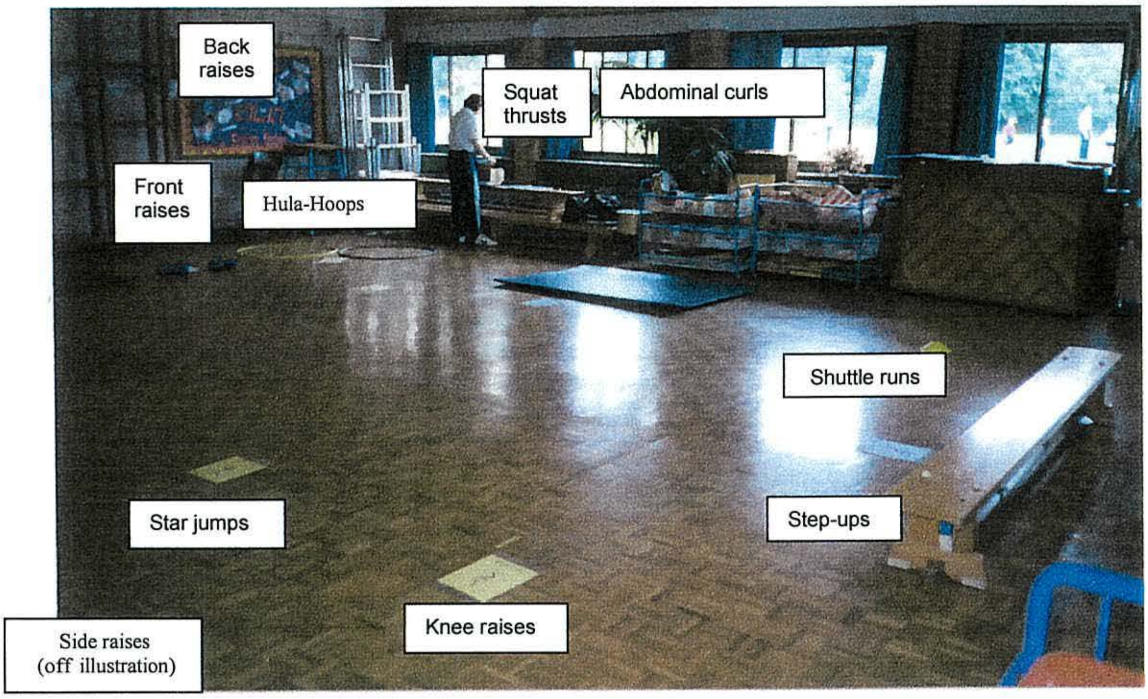
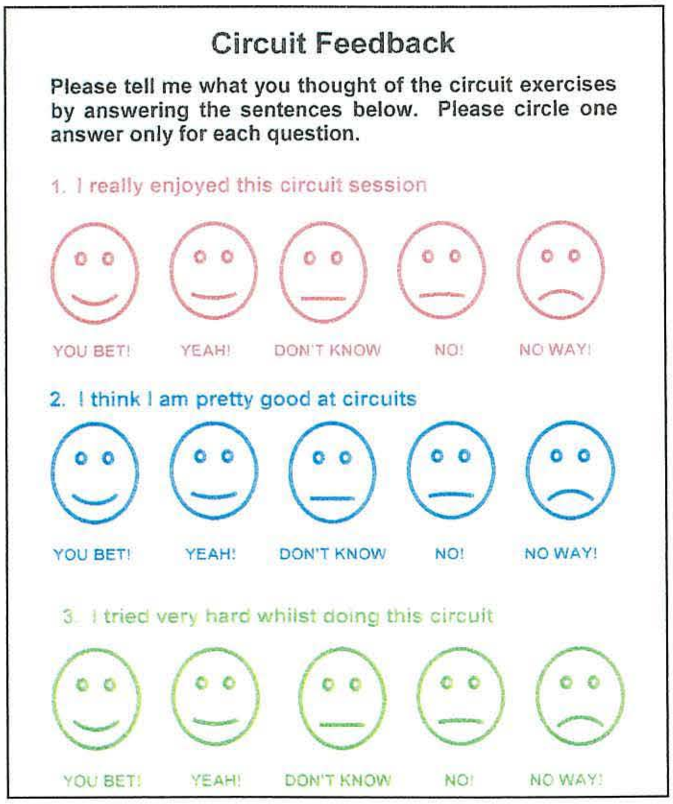


Figure 34a: Circuit layout in school hall

Figure 35: Preparing to participate in the circuit session: Warming-up

After completing the cool-down on weeks 3 to 6, children were issued with a self-designed questionnaire adapted from McAuley and colleagues (1989) Intrinsic Motivation Inventory. The rationale for question selection arose from the strongest item as reported by McAuley et al. (1989), and modified from this, including pictorial and verbal anchors (see below). The purpose of the questionnaire was to obtain feedback regarding the circuit session in order to determine if significant differences in the intrinsic motivation levels of children occurred when the BABE scale was used as part of the exercise circuit (weeks 4 and 6) as opposed to when it was not used (weeks 3 and 5). Children were asked three questions, one from each area of Interest / Enjoyment, Perceived Competence and Effort-Importance, and reported by means of a rating system (Figure 36).


Circuit Feedback

Please tell me what you thought of the circuit exercises by answering the sentences below. Please circle one answer only for each question.

1. I really enjoyed this circuit session

YOU BET! YEAH! DON'T KNOW NO! NO WAY!

2. I think I am pretty good at circuits

YOU BET! YEAH! DON'T KNOW NO! NO WAY!

3. I tried very hard whilst doing this circuit

YOU BET! YEAH! DON'T KNOW NO! NO WAY!

Figure 36: Circuit Feedback Form

2.3. Analysis of Data

Data was analysed using a two-factor Analysis of Variance with repeated measures design [Stations (4) x Effort Level (2)] on pedometry counts and repetitions for circuit training sessions with use of the BABE Scale. In addition, a [Stations (4) x Circuit (2)] repeated measures ANOVA on pedometry counts and repetitions when the BABE Scale was not employed (Appendix H2). This analysis was conducted in order to determine if children were more erratic in their production of exercise effort across four stations between two circuits without use of the BABE Scale. Post hoc comparisons were probed where appropriate using the Tukey test in order to identify any significant interactions or main effects. The Intraclass correlation coefficient (ICC) and 95% limits of agreement (LoA) analyses were calculated to give a quantitative indicator of the relationship between trials 1 and 2 for pedometry and repetitions at effort production levels 3 and 8. In addition, to determine if children were more erratic in their production of exercise effort when the BABE Scale was not used in the exercise session, reliability analyses were calculated for circuit 1 and circuit 2 test-retest on pedometry and repetitions. The data analysis methods were designed to answer the research hypotheses (2.4). All analyses were performed using SPSS version 9.0, Excel 5.0 and Supastat 3.2 statistical packages.

2.4 Hypotheses

H_1: With use of the BABE Scale, children will produce significantly different pedometry counts and repetitions between effort levels 3 and 8, across four circuit stations.

H_2: Without use of the BABE Scale, children will produce significantly different pedometry counts and repetitions between circuit 1 and 2, across four circuit stations.

H_3: With use of the BABE Scale, children are significantly more reliable in their production of exercise effort (pedometry counts and repetitions) than without use of the BABE Scale, at levels 3 and 8 between trial 1 and trial 2.

3. RESULTS

After qualitative analysis of repetitions from the video one child was excluded from the study due to tampering with the pedometer.

3.1. With BABE Scale

Figure 37 shows the circuit in progress with use of the BABE scale and Figure 38 shows the four stations allowing for physical measurement; (Station 1 Shuttles, Station 2 Star Jumps, Station 3 Knee Raises, and Station 4 Step-Ups).

Repetitions (by video analysis)

A Stations (4) x Level (2) repeated measures ANOVA on trial 2 data (week 6) revealed a significant main effect for Stations ($F_{3, 42} = 168.04$, $P<0.001$). Tukey HSD revealed that mean results for repetition data were significantly different ($P<0.01$) between each of the four stations; Shuttle Runs (83), Star Jumps (37), Knee Raises (69) and Step-ups (20).

ANOVA also revealed a significant main effect for Level ($F_{1, 14} = 40.07$, $P<0.001$). Significantly higher ($P<0.01$) repetitions were recorded at an effort production level of 8 'Very Hard' (58) on the exercise stations, compared to an effort production level of 3 'Easy' (46) using the BABE Scale.

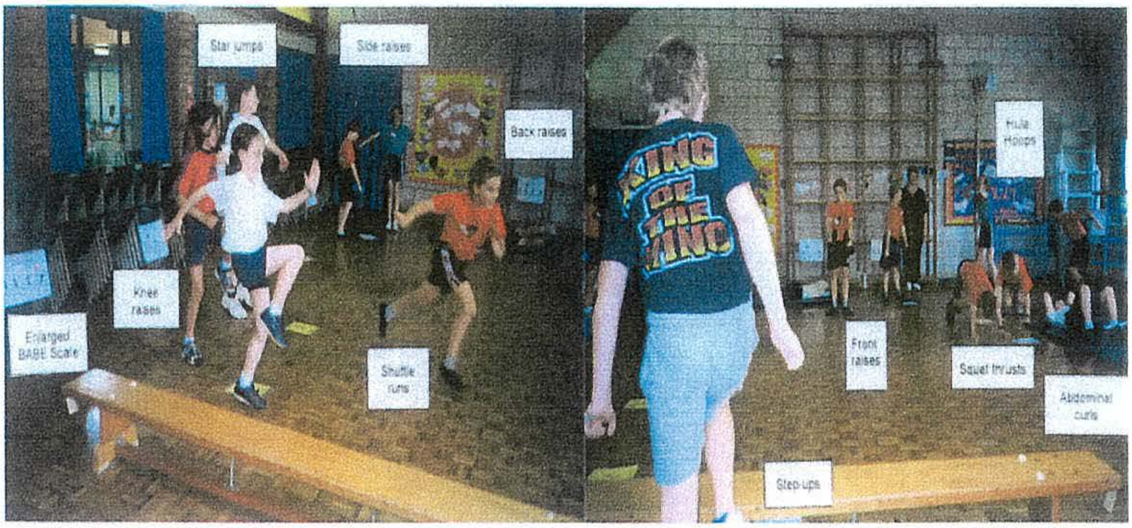


Figure 37: Circuit session in progress with use of BABE Scale

Figure 38: Circuit session in progress with the use of the BABE Scale.
Four stations for physical measurement

ANOVA revealed a significant interaction for Stations x Level on Repetition data ($F_{3, 42} = 6.23$, $P<0.01$) (Figure 39). Table 33 summarises the post-hoc comparison results. When the children used the BABE Scale as part of their circuit session they were able to produce significantly different ($P<0.01$) repetitions between an effort rating level of 3 and 8 for the Knee Raise station, and significantly different ($P<0.05$) repetitions for effort rating levels of 3 and 8 for the Star Jump station. Qualitative analysis of repetitions from video evidence of the circuit sessions revealed that in general, the children displayed poor technique for the Knee Raise station at an effort production level of 3. For this 'Easy' effort rating level, some children did not complete a full knee lift, choosing instead to walk or march on the spot. Whereas, at an effort production level of 8 'Very Hard', some children chose to sprint as fast as possible on the spot, exhibiting low knee lift. Qualitative analysis of the Star Jump station at an effort production level of 8, revealed that children generally displayed improved jumping technique, compared to their techniques displayed at an effort production level of 3.

There was no significant difference between the children's repetition data recorded at an effort production level of 3 and 8 for the Shuttle Run station and Step-up station. In general though, qualitative analysis of video evidence did reveal distinct differences between these two effort production levels. For example, on the Shuttle Run station at an effort production level of 3, some children chose to walk. Whereas, at an effort production level of 8 children were running / sprinting, driving hard with their arms, and some chose to adopt crouch starts! Likewise, at an effort production level of 8 on the Step-up station the children generally stepped up onto and down from the gymnasium bench as fast as they could, whereas at effort production level of 3 some children stepped up onto and down from the bench at a light-walking pace.

Pedometry Counts

A Stations (4) x Level (2) repeated measures ANOVA on trial 2 data revealed a significant main effect for Stations ($F_{3, 42} = 13.36$, $P<0.001$). Tukey HSD revealed that mean results for pedometry were significantly different ($P<0.01$) between the Shuttle Run station (100) and Star Jumps (84), Shuttle Run (100) and Knee Raises (82), and Shuttle Run (100) and Step-ups (74), with significantly higher ($P<0.01$) mean pedometry counts recorded on the Shuttle Run station. Tukey post-hoc comparisons revealed no significant difference between mean pedometry data recorded on the Star Jumps (84) and Knee Raises station (82) or between the Star Jumps (84) and Step-up station (74) or between the Knee Raises (82) and Step-up (74) station.

ANOVA also revealed a significant main effect for Level ($F_{1, 14} = 45.09$, $P<0.001$). Significantly higher ($P<0.01$) pedometry counts were recorded at an effort production level of 8 'Very Hard' (95) on the circuit stations, compared to an effort production level of 3 'Easy' (74) using the BABE Scale.

ANOVA revealed a significant interaction for Stations x Level on Pedometry data ($F_{3, 42} = 5.23$, $P<0.01$) (Figure 40). Table 34 summarises the post-hoc comparison results. When the BABE Scale was used in the circuit training session, the children were able to produce significantly different ($P<0.01$) pedometry counts between an effort rating level of 3 and 8 for the Knee Raise station and Star Jumps station. Tukey HSD also identified significantly different ($P<0.05$) pedometry results between effort production levels of 3 and 8 for the Step-up station. However, tukey HSD identified no significant difference between the children's pedometry counts produced at an effort rating level of 3 and 8 for the Shuttle Run station. This indicates that some children may have had difficulty in distinguishing between effort production levels for this particular station, thus confounding the results.

Table 33: Tukey Post hoc comparison results: Stations x Level on Repetitions

Means Effort Level	Shuttle runs (3)	Shuttle runs (8)	Star jumps (3)	Star jumps (8)	Knee raises (3)	Knee raises (8)	Step-ups (3)	Step-ups (8)
	→	0.534						
	→		53.733***					
	→			38.666***				
	→				26.066***			
	→					1.933		
	→						68.2***	
	→							57.733***
		→	54.267***					
		→		39.2***				
		→			26.6***			
		→				2.467		
		→					68.734***	
		→						58.267***
			→	15.067**				
			→		27.667***			
			→			51.800***		
			→				14.467**	
			→					4.0
				→	12.6*			
				→		36.733***		
				→			29.534***	
				→				19.067***
					→	24.133***		
					→		42.134***	
					→			31.667***
						→	66.267***	
						→		55.800***
							→	10.467

KEY: Arrows in the table indicate means compared. Result is then indicated.

*** = Significant at $P<0.01$

** = Significant at $P<0.05$

* = Significant at $P<0.10$

T = Post-hoc comparison result

$T_{(0.01)} = 6.16 \times \sqrt{116.15/15} = 17.14$

$T_{(0.05)} = 4.94 \times \sqrt{116.15/15} = 13.75$

$T_{(0.10)} = 4.39 \times \sqrt{116.15/15} = 12.22$

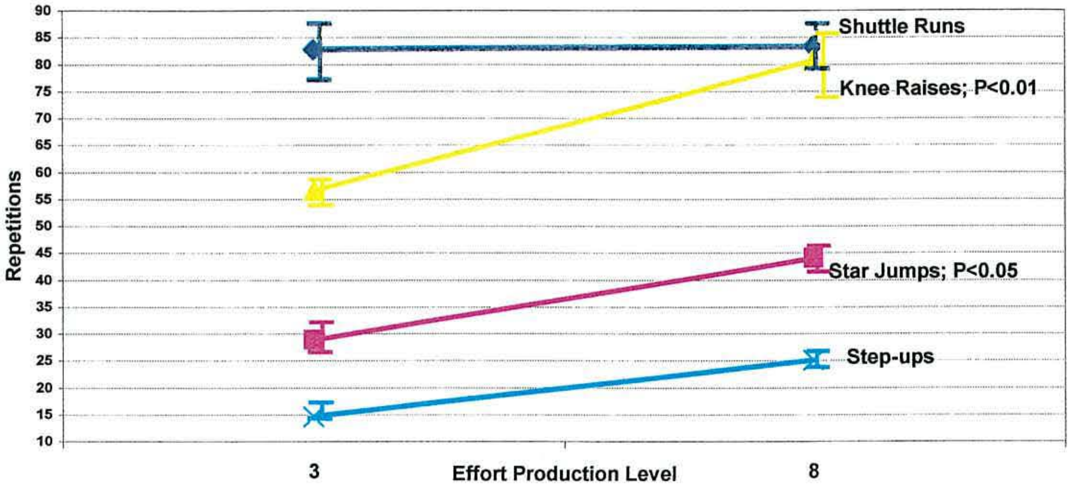


Figure 39: Interaction between Stations and Effort Production Level on Repetitions. (Values are Mean ± SEM)

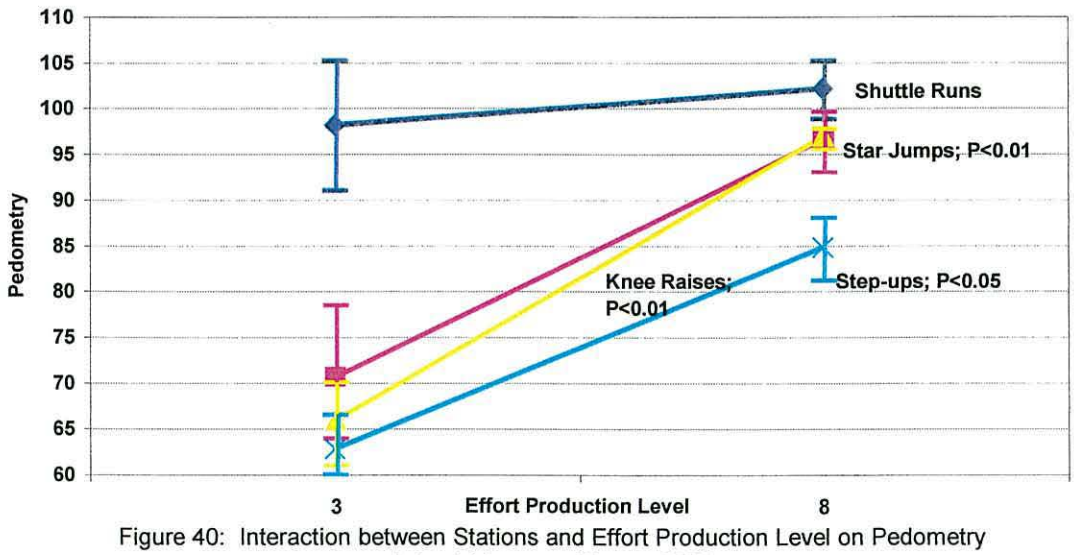


Figure 40: Interaction between Stations and Effort Production Level on Pedometry data. (Values are Mean ± SEM)

Where indicated P = Significant difference between effort level 3 and 8.

Table 34: Tukey Post hoc comparison results: Stations x Level on Pedometry

Means Effort Level	Shuttle runs (3)	Shuttle runs (8)	Star jumps (3)	Star jumps (8)	Knee raises (3)	Knee raises (8)	Step-ups (3)	Step-ups (8)
Shuttle runs (3)		4.0	27.467***	1.467	32.2***	1.133	35.4***	13.4
Shuttle runs (8)			31.467***	5.467	36.2***	5.133	39.4***	17.4*
Star jumps (3)				26.0***	4.733	26.334***	7.933	14.067
Star jumps (8)					30.733***	0.334	33.933***	11.933
Knee raises (3)						31.067***	3.2	18.8**
Knee raises (8)							34.267***	12.267
Step-ups (3)								22.0**

KEY: Arrows in the table indicate means compared. Result is then indicated.

***	= Significant at P<0.01	$T_{(0.01)}$	$= 6.16 \times \sqrt{198.73/15}$
**	= Significant at P<0.05		= 22.42
*	= Significant at P<0.10	$T_{(0.05)}$	$= 4.94 \times \sqrt{198.73/15}$
T	= Post-hoc comparison result		= 17.98
		$T_{(0.10)}$	$= 4.39 \times \sqrt{198.73/15}$
			= 15.98

Table 35: Mean (S.D) Repetitions and Pedometry Counts with Use of the BABE Scale during the Circuit Session.

Station	Repetitions				Pedometry Counts			
	Effort Level 3		Effort Level 8		Effort Level 3		Effort Level 8	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Shuttle Run	82.7	(18.6)	83.3	(17.7)	98.2	(28.2)	102.2	(10.4)
Star Jumps	29.0	(11.9)	44.0**	(8.1)	70.7	(27.6)	96.7***	(12.7)
Knee Raises	56.7	(12.1)	80.8***	(24.3)	66.0	(27.1)	97.1***	(14.1)
Step-Ups	14.5	(5.0)	25.0	(4.6)	62.8	(13.3)	84.8**	(12.5)

Where; *** = Significant at P<0.01
** = Significant at P<0.05
* = Significant at P<0.10

Table 36: Mean (S.D) Repetitions and Pedometry Counts without Use of the BABE Scale during the Circuit Session.

Station	Repetitions				Pedometry Counts			
	Circuit 1		Circuit 2		Circuit 1		Circuit 2	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Shuttle Run	87.1	(13.6)	83.2	(17.0)	96.1	(12.4)	96.1	(17.7)
Star Jumps	32.3	(10.2)	33.4	(12.8)	80.8	(18.1)	80.9	(20.6)
Knee Raises	63.6	(11.4)	55.9	(20.7)	85.4	(20.7)	70.2	(27.4)
Step-Ups	17.9	(6.4)	16.5	(7.0)	70.5	(20.8)	66.6	(19.0)

Table 35 summarises mean (± S.D) repetitions and pedometry counts at an effort production level of 3 and 8 for the Shuttle Run, Star Jump, Knee Raises and Step-up stations. Table 36 summarises mean repetitions and pedometry counts for circuit 1 and circuit 2 when the BABE Scale was not used as part of the circuit session. In general, mean pedometry results suggest that when the BABE Scale was not used in the Circuit session (Table 36), the children chose to work between the range of 'Easy' and 'Starting to Get Hard' on the Star Jumps, Knee Raises and Step-up stations. Whereas, mean pedometry data for the Shuttle Run station (96) and mean repetition data for the Shuttle Run station (83) remained high. Although qualitative analysis from the video showed that some children displayed distinct differences between producing an effort rating level of 3 and 8 for the Shuttle Run station, in general whether the BABE Scale was used or not during the exercise circuit, the majority of children chose to run 'Very Hard' on this station. Thus producing similar mean repetition and pedometry results across exercise conditions (Tables 35 and 36).

Figures 41 and 42 show the circuit in progress without use of the BABE Scale. Figure 41 highlights the four stations allowing for physical measurement.

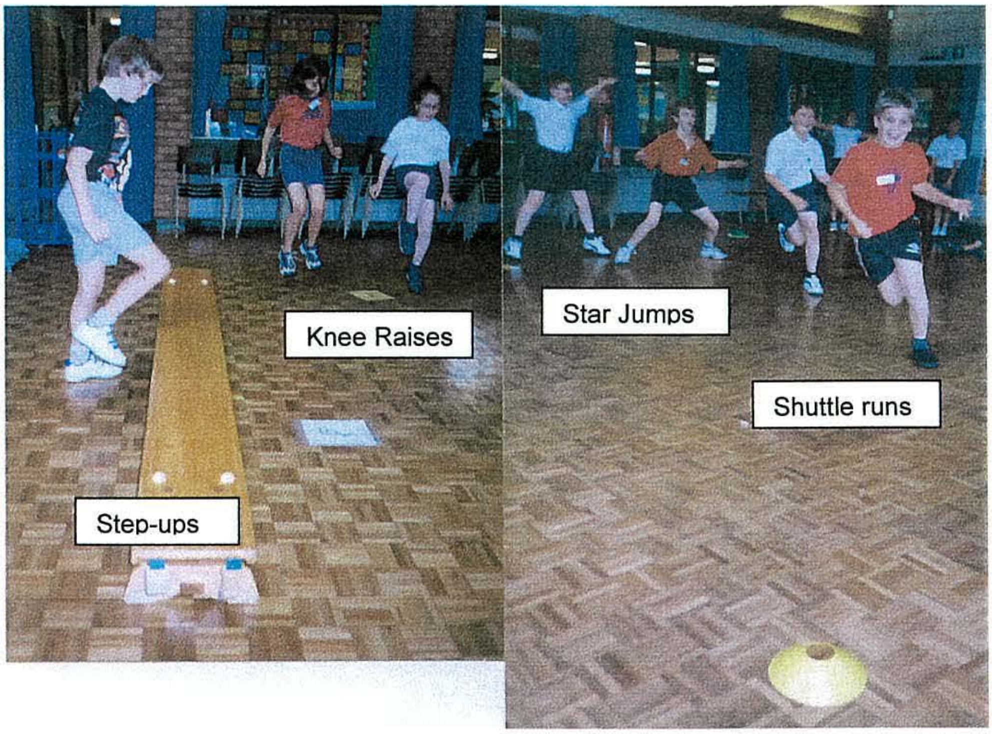


Figure 41: Circuit session without use of the BABE Scale:
Four stations for physical measurement

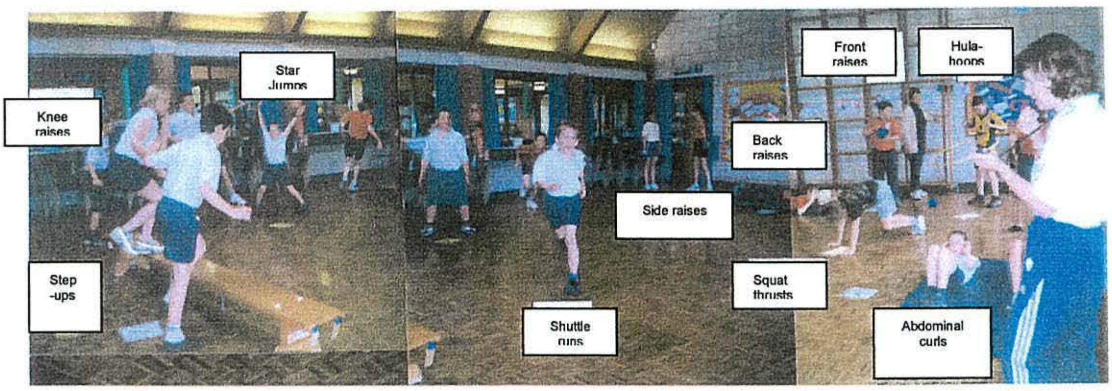


Figure 42: Circuit session in progress without use of the BABE Scale

3.2. Without BABE Scale

Repetitions (by video analysis)

A Stations (4) x Circuit (2) repeated measures ANOVA on trial 2 data (week 5) revealed a significant main effect for Stations ($F_{3, 42} = 186.79$, $P<0.001$). Tukey HSD revealed that mean results for repetition data were significantly different ($P<0.01$) between each of the four stations; Shuttle Runs (85), Star Jumps (33), Knee Raises (60), and Step-ups (17).

ANOVA revealed no other significant main effects or interactions.

Pedometry Counts

A Stations (4) x Circuits (2) repeated measures ANOVA on trial 2 data revealed a significant main effect for Stations ($F_{3, 42} = 13.38$, $P<0.001$). Tukey HSD revealed that mean pedometry counts were significantly different ($P<0.01$) between the Shuttle Run station (96) and Star Jumps (81), Shuttle Run station (96) and Knee Raises (78) and Shuttle Run (96) and Step-ups station (69). Tukey HSD revealed that mean pedometry counts were significantly different ($P<0.05$) between the Star Jumps (81) and Step-ups station (69). Tukey post-hoc comparisons revealed no significant difference between pedometry data recorded on the Star Jumps (81) and Knee Raises (78) or between Knee Raises (78) and the Step-up station (69). ANOVA revealed no other significant main effects or interactions.

3.3. Reliability of Repetitions and Pedometry With and Without Use of the BABE Scale

Tables 37 – 40 provide reliability data for pedometry counts and repetitions with and without use of the BABE scale.

Table 37: Test-retest Analysis of Pedometry Counts at each Exercise Station With Use of the BABE Scale.

Station (Effort Production)	Bias (± 2 x SD)	ICC	r	t
Shuttle run (3)	4.5 (± 2 x 29.4)	0.10	0.11	0.556
Star Jumps (3)	2.7 (±2 x 25.6)	0.12	0.16	0.379
Knee Raises (3)	7.46 (± 2 x 21.5)	0.58 P<0.02	0.65 P<0.05	1.252
Step-Ups (3)	0.31 (± 2 x 12.0)	0.54 P<0.10	0.56 P<0.05	0.093
Overall (3)	**3.8 (± 2 x 22.5)**	**0.59 P<0.001**	**0.61 P<0.05**	**1.200**
Shuttle run (8)	1.08 (± 2 x 12.9)	0.43 P<0.10	0.51 P<0.05	0.301
Star Jumps (8)	-4.0 (± 2 x 14.5)	0.22	0.23	0.995
Knee Raises (8)	1.8 (± 2 x 16.4)	0.02	0.02	0.389
Step-Ups (8)	-1.9 (± 2 x 10.09)	0.65 P<0.01	0.65 P<0.01	0.687
Overall (8)	**-3.5 (± 2 x 15.8)**	**0.29 P<0.02**	**0.29**	**-1.600**

Table 38: Test-retest Analysis of Pedometry Counts at each Exercise Station Without Use of the BABE Scale.

Station (Circuit)	Bias (± 2 x S.D)	ICC	r	t
Shuttle run (C1)	6.53 (± 2 x 11.8)	0.23 P<0.20	0.31 P<0.05	2.135
Star Jumps (C1)	10.33 (± 2 x 22.1)	0.24 P<0.20	0.24	1.809
Knee Raises (C1)	18.53 (± 2 x 30.4)	0.04	0.04	2.364
Step-Ups (C1)	12.13 (± 2 x 23.4)	0.19	0.20	2.011
Overall (C1)	11.9 (± 2 x 22.7)	0.31 P<0.01	0.31 P<0.05	4.049
Shuttle run (C2)	9.4 (± 2 x 22.3)	0.08	0.08	1.631
Star Jumps (C2)	6.4 (± 2 x 28.6)	0.02	0.02	0.867
Knee Raises (C2)	11.4 (± 2 x 34.6)	0.21	-0.11	2.031
Step-Ups (C2)	7.1 (± 2 x 25.7)	0.00	0.00	1.073
Overall (C2)	8.6 (± 2 x 27.5)	0.32 P<0.01	0.32 P<0.05	2.416

Table 39: Test-retest Analysis of Repetitions at each Exercise Station With Use of the BABE Scale.

Station (Effort Production)	Bias (± 2 x S.D)	ICC	r	t
Shuttle run (3)	1.08 (± 2 x 19.1)	-0.06	-0.11	0.204
Star Jumps (3)	-0.85 (± 2 x 10.4)	0.38 P<0.10	0.40	0.294
Knee Raises (3)	3.46 (± 2 x 16.2)	0.41 P<0.10	0.47	0.771
Step-Ups (3)	0.46 (± 2 x 4.8)	0.31 P<0.20	0.45	0.346
Overall (3)	**1.04 (± 2 x 13.4)**	**0.89 P<0.001**	**0.78 P<0.01**	**2.917**
Shuttle run (8)	3.08 (± 2 x 12.9)	0.48 P<0.05	0.70 P<0.01	0.860
Star Jumps (8)	-3.46 (± 2 x 3.4)	0.91 P<0.001	0.92 P<0.01	3.691
Knee Raises (8)	14.69 (± 2 x 29.5)	0.12	0.12	1.797
Step-Ups (8)	-2.77 (± 2 x 3.2)	0.79 P<0.001	0.84 P<0.01	3.153
Overall (8)	**2.9 (± 2 x 17.4)**	**0.85 P<0.001**	**0.85 P<0.01**	**1.196**

Table 40: Test-retest Analysis of Repetitions at each Exercise Station Without Use of the BABE Scale.

Station (Circuit)	Bias (± 2 x S.D)	ICC	r	t
Shuttle run (C1)	13.27 (± 2 x 16.5)	0.02	0.02	3.111
Star Jumps (C1)	4.67 (± 2 x 12.7)	-0.08	-0.09	1.418
Knee Raises (C1)	38.27 (± 2 x 25.7)	0.05	0.07	5.757
Step-Ups (C1)	5.53 (± 2 x 7.0)	0.22	0.23	3.067
Overall (C1)	15.4 (± 2 x 21.5)	0.80 P<0.001	0.83 P<0.01	5.572
Shuttle run (C2)	14.53 (± 2 x 17.9)	0.16	0.19	3.143
Star Jumps (C2)	2.93 (± 2 x 10.8)	0.47 P<0.05	0.54 P<0.05	1.050
Knee Raises (C2)	24.33 (± 2 x 40.2)	-0.20	-0.22	2.347
Step-Ups (C2)	2.93 (± 2 x 9.2)	-0.04	-0.04	1.238
Overall (C2)	11.18 (± 2 x 24.2)	0.73 P<0.001	0.74 P<0.01	3.57

In general, when the BABE scale was employed in the exercise circuit the reliability between test trials improved (reduced mean difference (bias) and S.D), compared to reliability data recorded when the BABE scale was not employed. For example; Step-ups at BABE Scale effort production level of 8, 95% LoA = -1.9 +/- 20.2, ICC = 0.65 ($P<0.01$) (Pedometry data; Table 37) and 95% LoA = –2.77 +/- 6.4, ICC = 0.79 ($P<0.001$) (Repetitions; Table 39). Compared to 95% LoA = 7.1 +/- 51.4, ICC = 0.0 (Pedometry data; Table 38) and 95% LoA = 2.93 +/- 18.4, ICC = -0.04 (Repetitions; Table 40), when the BABE Scale was not employed in the circuit session. Intraclass correlation coefficients for Step-ups (at effort production levels of 3 and 8) when the BABE Scale was employed in the exercise circuit ranged from R = 0.31 – 0.79 for Pedometry and Repetitions (Tables 37 and 39). Reliability of children's effort production across both levels (3 and 8) was higher for the Step-up station compared to the Shuttle Runs, Star Jumps and Knee Raises stations. Overall ICC for Pedometry and Repetitions (Tables 37 and 39) demonstrated that the children were more reliable in their effort production at a BABE level of 3 (Easy) R = 0.59 – 0.89, compared to an effort production level of 8 (Very hard) R = 0.29-0.85. Intraclass correlations for this study involved test-retest across two trials only, and would be expected to improve following three or more trials.

3.4. Questionnaire Results

Data was analysed using a two factor ANOVA with repeated measures design [Trial (2) x Scale (2)] on Interest / Enjoyment, Perceived Competence and Effort-Importance (Appendix H3). Where Scale (2) represented circuit sessions with and without use of the BABE Scale.

Interest / Enjoyment

ANOVA revealed no significant main effects or interactions for children's interest / enjoyment across trials or between circuit sessions when the BABE Scale was or was not employed.

Perceived Competence

Trial

ANOVA revealed a significant main effect for Trial ($F_{1, 12} = 3.87$, $P<0.05$). Tukey HSD revealed that children felt significantly ($P<0.05$) more competent completing the circuit sessions in Trial 1 compared to Trial 2.

Scale

ANOVA revealed a significant main effect for Scale ($F_{1, 12} = 4.46$, $P<0.05$). Tukey HSD revealed that children felt significantly ($P<0.05$) more competent completing the circuit sessions with use of the BABE Scale rather than without use of the BABE Scale.

Trial x Scale

ANOVA revealed a significant interaction for Trial x Scale on perceived competence ($F_{1, 12} = 4.03$, $P<0.05$). Tukey HSD identified that children felt significantly ($P<0.01$) more competent in the first trial of the circuit without use of the BABE Scale compared to the second trial. Likewise, Tukey HSD identified that children felt significantly ($P<0.01$) more competent in the first trial of the circuit session with use of the BABE Scale compared to the second trial. In addition, Tukey HSD revealed that children felt significantly ($P<0.05$) more competent during the second trial of the circuit with use of the BABE Scale, rather than without use of the BABE Scale (Figure 43).

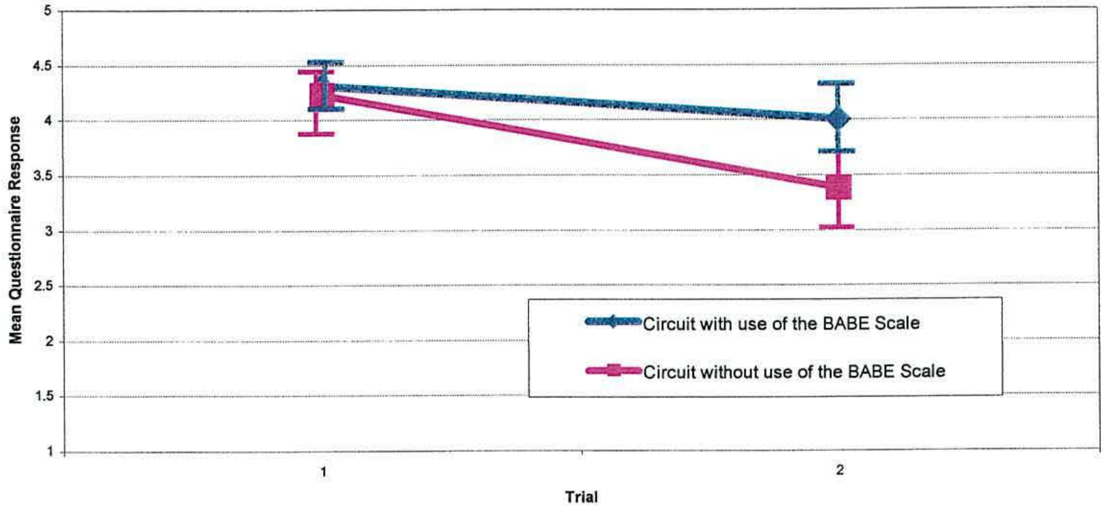


Figure 43: Interaction between Trial and Scale on Perceived Competence. (Values are mean ± SEM)

Effort-Importance

ANOVA revealed a significant main effect for Trial ($F_{1,12}$ =3.86, P<0.05). Tukey HSD identified that children tried significantly harder (P<0.05) during the first trials of the circuit sessions, compared to the second trials. There were no other significant main effects or interactions for children's effort-importance.

3.5 Reliability of Questionnaire Data

Tables 41 to 43 show Mean (±S.D), Intraclass correlation coefficient and 95% limits of agreement post-circuit questionnaire results.

Question One

Table 41: Interest / Enjoyment; (I really enjoyed this circuit session)

Measure	Trial 1 (Wk4) Circuit with use of BABE scale	Trial 2 (Wk6) Circuit with use of BABE scale	Trial 1 (Wk3) Circuit without use of BABE scale	Trial 2 (Wk5) Circuit without use of BABE scale
Mean Result / Interpretation	4.385 / Yes	3.615 / Yes	4.077 / Yes	3.769 / Yes
S.D (±)	1.12	1.76	1.50	1.42
ICC (R)	0.343 (P<0.12)		0.399 (P<0.08)	
Bias (± 2 x S.D)	0.8 (± 2 x 1.7)		3.0 (± 2 x 1.6)	

Question Two

Table 42: Perceived Competence; (I think I am pretty good at circuits)

Measure	Trial 1 (Wk4) Circuit with use of BABE scale	Trial 2 (Wk6) Circuit with use of BABE scale	Trial 1 (Wk3) Circuit without use of BABE scale	Trial 2 (Wk5) Circuit without use of BABE scale
Mean Result / Interpretation	4.308 / Yes	4.0 / Yes	4.231 / Yes	3.385 / Don't know
S.D (±)	0.75	1.08	0.93	1.45
ICC (R)	0.39 (P<0.09)		0.44 (P<0.06)	
Bias (± 2 x SD)	0.3 (± 2 x 1.0)		0.8 (± 2 x 1.3)	

Question Three

Table 43: Effort-Importance; (I tried very hard whilst doing this circuit)

Measure	Trial 1 (Wk4) Circuit with use of BABE scale	Trial 2 (Wk6) Circuit with use of BABE scale	Trial 1 (Wk3) Circuit without use of BABE scale	Trial 2 (Wk5) Circuit without use of BABE scale
Mean Result / Interpretation	4.538 / You bet!	4.231 / Yes	4.308 / Yes	3.538 / Yes
S.D (±)	0.88	1.09	0.85	1.71
ICC (R)	0.373 (P<0.10)		0.493 (P<0.04)	
Bias (± 2 x SD)	0.3 (± 2 x 1.1)		0.8 (± 2 x 1.4)	

These results indicate that children were more consistent in their questionnaire responses (reduced mean difference (bias) and S.D) when the circuit was completed with use of the BABE Scale. This suggests that they maintained their high level of motivation.

4. DISCUSSION

This is the first study to integrate a child-specific effort rating scale into physical education circuit training classes with primary school children. This study has provided preliminary evidence that children aged 8 to 11 years can use effort perception to regulate exercise intensity during 30 seconds on specific activities (Star Jumps, Knee Raises and Step-Ups). The BABE Scale was chosen for this study as previous research conducted as part of this thesis had suggested that children found it easier to understand the BABE Scale for stepping tasks (compared to the CALER Scale), and that they enjoyed exercise using the BABE. The children were able to use their effort perception to alter their production of exercise effort (pedometry counts and repetitions) to match two prescribed BABE ratings. These findings confirm the potential use of pictorial child-specific effort rating scales with children during physical education lessons.

Although qualitative analysis from video evidence showed distinct differences for some children between BABE level 3 and 8 on the shuttle run station (E.g.; children walking at level 3 / crouch starts at level 8), it is evident from pedometry and repetition data that some children experienced difficulty in distinguishing between effort rating levels for this station. Mean repetition and pedometry data suggest that regardless of whether the BABE Scale was employed or not in the exercise circuit, children chose to run 'Very Hard' on this station, thus producing similar mean repetitions and pedometry results across exercise conditions. It may have been pertinent for the circuit card for this station to state 'Shuttle Run / Walk'.

Analysis of Variance on questionnaire data revealed a significant main effect for Scale on Perceived Competence ($F_{1,12} = 4.46$, $P<0.05$). Tukey post hoc comparisons revealed that children felt significantly ($P<0.05$) more competent completing the circuit sessions with use of the BABE Scale rather than without use of the BABE Scale. In addition, smaller bias and higher questionnaire means suggest that children were able to maintain their motivation from Trial 1 to Trial 2 with use of the BABE Scale. This may have implications for future exercise adherence.

The children viewed the BABE Scale as an exciting and 'cool' initiative, and therefore the classes were approached with enthusiasm and vigour. The scale enabled children to control their own intensity levels rather than relying on the strict control of an adult authority figure. Self-reported interest / enjoyment and effort-importance were not significantly different between circuits with or without use of the BABE Scale. Results suggest that children were able to regulate their production of exercise effort on specific circuit stations with use of the BABE. Scale, and this did not result in negative psychological perception of the exercise session. With a balanced, enjoyable Physical Education programme, children may develop a range of motor skills, achieve success at their *own levels*, and feel confident enough in their *own abilities* to want to pursue a more active lifestyle.

Engagement in physical activity is linked strongly to motivational processes (Brustad, 1991). Motivational theories (Bandura, 1977; Harter, 1978) highlight the role self-perceptions of ability and control have as contributors to motivated behaviour. These theories propose that, if individuals perceive they possess the ability and personal control to reach a desired outcome, they will voluntarily engage in an achievement area and whilst engaged display effort and persistence. To voluntarily engage in physical activity, children must possess favourable self-perceptions regarding their personal capacities in this area. Bandura's (1977) self-efficacy theory is competence-based and has four main sources; i. Personal accomplishment, ii. Vicarious experience (children can see others' of similar ability achieving / completing the activity), iii. Verbal persuasion and iv. Emotional arousal (participating in something new). Results suggest that the BABE Scale may assist children in improving perceived competence / achieving favourable self-perceptions.

Intrinsically motivated behaviour is defined as participation in an activity, without reward (Deci and Ryan, 1985). Intrinsic motivation is based on the need to be competent and self-determining in dealing with one's surroundings (Deci, 1975). By actively engaging the environment, by taking on and over-coming challenges that are optimal for their capacities, people often feel a sense of self-efficacy. Deci and Ryan's (1980; 1985) cognitive evaluation theory suggests that events consist of functional aspects, which are either informational or controlling in nature. The informational qualities of the event provide feedback regarding the individual's performance, which, in turn, influences feelings of competence. Depending on the nature of the feedback, intrinsic motivation is either increased or decreased. For example, a child who is able to successfully complete an exercise circuit may have increased feelings of competence and intrinsic motivation. In comparison, a child who is unable to complete a circuit may experience lack of competence and reduced intrinsic motivation.

Deci and Ryan's (1980; 1985) cognitive evaluation theory suggests that positive information (i.e., high information and minimal control) will enhance intrinsic motivation, such activities are described as informational. In the early 1990's cognitive evaluation theory was further developed and renamed self-determination theory (Deci 1992; Deci and Ryan, 1991; 1995). It is the controlling aspects of an activity which are thought to influence feelings of self-determination (Oman and McAuley, 1993). Activities that are perceived as highly controlling (where participants are pressured to behave, think or feel a particular way) result in feelings of low self-determination and subsequently reduced intrinsic motivation. Whereas, if the activity is perceived to be a low controlling event (which provides participants with a sense of choice about what to do or how to do it), then feelings of self-determination and intrinsic motivation are increased. The use of the BABE scale could serve as a source of information and allow the child self-referenced control over the intensity at which they work.

However, a logical extension of the application of Deci and Ryan's (1985) theory would be to allow the children to choose their intensity level. Children's perceptions of being involved in choosing their activity levels (preferred levels), rather than the choice being externally imposed (level 3, level 8) should lead to even greater feelings of self-determination (Thompson and Wankel, 1980). This supports Deci and Ryan's (1980) contention that perceived freedom or self-determination is a primary factor which influences intrinsic motivation behaviour.

The literature suggests that perceived competence is significantly related to perceptions of success. Positive perceptions of success have been reported to be significantly correlated with perceptions of feeling more competent, exerting more effort, and feeling less pressure in physical activity (Oman and McAuley, 1993). McAuley et al. (1991) reported that perceptions of success and self-efficacy were related to intrinsic motivation and that perceived competence played a significant role in the self-efficacy:

intrinsic motivation relationship. Children's positive perceptions of success in the exercise circuit with use of the BABE Scale may have enhanced their perceptions of competence leading to improved intrinsic motivation.

In 1984, a study by Harter and Connell revealed that achievement was a positive predictor of children's perception of competence, and was positively correlated with their affective responses to their perceptions of competence. These feelings were found to be positively and significantly associated with their autonomous judgement (children employ internal criteria for judging success and feel comfortable choosing appropriate tasks without the aid of a teacher) and intrinsic motivation (children display curiosity and desire for challenge and mastery). Harter and Connell's (1984) results represented a chain of events whereby children's perceptions that they have control over their successes and failures were positively associated with achievement, which positively correlated with their perceptions of competence, which in turn positively linked to their levels of intrinsic motivation. Use of the BABE Scale during the exercise circuit may have made the children feel that they had more control over their successful completion of the circuit, by regulating their own physical activity levels, leading to a sense of achievement and thus enhanced competence.

In Greece, Papaioannou (1995) studied the environment of a physical education lesson on the intrinsic motivation and anxiety of high- and low-competence adolescents (aged 13 ± 0.5 years). The results showed that a high task focus sustained motivation in children at all levels of perceived competence. In addition, low-competence children were less anxious about participating in sport and physical activity with high-ability peers when a task-orientated atmosphere was emphasised. Goudas and Biddle (1994) further developed the work of Papaioannou with 13- to 15-year old British children. Results revealed that children who perceived their physical education class to be high in both mastery (self-improvement) and performance, reported greater intrinsic motivation and perceived competence. This evidence suggests that children who adopt a mastery orientation, and perceive that they operate in a teaching / coaching environment that encourages mastery, have a sounder motivational base.

This research supports the practice of increasing perceptions of physical competence through a focus on individual improvement. By using the BABE Scale within health-related exercise aspects of the national curriculum, physical educators could make a difference by helping children to develop a sound motivational base, promoting self-improvement and a sense of personal accomplishment. However, Goudas and Biddle (1994) suggest that children should not be isolated in physical activities. Children's sense of making a valuable contribution to a group in an atmosphere of team mastery or co-operation is also important as it satisfies what self-determination theory has termed the need for 'relatedness'. The aim should be to help children feel that they have some responsibility for, and a sense of ownership towards what physical activity they are doing, rather than feel pressurised to do something. For example, teaching children to use the BABE Scale to regulate their own physical activity levels.

Further research is required to establish the source of improved competence highlighted in the current study. Perceived competence could have been improved because the children were increasing their work rate during the exercise circuit, or it may have been that use of the BABE Scale made children feel that they had taken control of their own exercise levels (regulation) leading to improved self-determination and motivation. Cale and Harris (1993) have noted that, from a behavioural perspective, physical activity needs to be seen by children as a positive and *achievable* experience.

The BABE scale was appropriate for use with this age group (primary school children), but as adolescent changes occur, scales may need to be developed and adapted in order to maintain the same level of enthusiasm. Child-specific effort rating scales would need to be developmentally appropriate, i.e., not viewed as 'babyish!' Developmentally appropriate scales (suitable for use with primary / secondary school children) could be employed in Physical Education lessons for the delivery and achievement of specific HRE attainment targets. In addition, such tools could be used to encourage and increase children's physical activity levels and perceived competence. They may also assist with class discipline.

Before such scales can be employed to assist in the achievement of specific HRE attainment targets, physical educators need to be educated on their application and use. This could be problematic since the majority of primary school teachers who deliver the physical education national curriculum have no formal qualifications in the subject (National Association of Head Teachers and the Central Council for Physical Recreation, 1992). However, one such way of disseminating and promoting use of the BABE Scale for coverage of specific HRE attainment targets could be the production of a specialist video (for Physical Education teachers to show children) together with a teacher's support pack. The video could be cartoon-based, depicting one of the Bugs (as it appears on the scale), participating in a range of exercise activities and producing different effort rating levels. Such a video could also show prior anchoring techniques, to further enhance the children's interpretation of the BABE Scale and its use. The video could be produced in such a way as to be informative (with clear links to HRE in the Physical Education National Curriculum), but also amusing and appealing to children. If such a video were to be produced then this would enable the BABE Scale to be used in the achievement of HRE attainment targets, and instructions on its use disseminated easily and effectively to physical education staff and children.

The Physical Education experience in schools needs to make a positive impact on children to help promote lifelong physical activity. If teachers are to develop successful courses, they need to understand current concepts in exercise and health science and be aware of the growing body of knowledge associated with exercise adherence. This has implications for ongoing teacher education programmes. Physical education teachers play a vital role in promoting health-related fitness in children and youth. To maximise the number and quality of physical activity opportunities, the concept of the 'Active School' is suggested (Fox, 1991; 1994). The active school will be aware of the importance of physical activity promotion and will be constantly working towards devising and implementing policies that will increase the physical activity levels of children and staff in a way that is likely to have a positive and sustained impact on physical activity habits.

CHAPTER 7
CONCLUSIONS

In the 1980's, the American Academy of Physical Education (Malina, 1987), the American Academy of Paediatric Committees on Sports Medicine and School Health (1987), and the American College of Sports Medicine (1988) issued strongly worded statements highlighting the need for school physical education lessons to adopt health-related physical activity goals. In a society in which adult sedentary behaviour contributes significantly to the epidemic of cardiovascular and other chronic diseases, there is a rationale for shifting the orientation of children's physical education to a health focus. Introducing a health focus to physical education lessons could improve children's awareness of the importance of physical activity in their youth. Children do not necessarily need to 'train' to reverse the effects of a sedentary lifestyle. Enhanced physical activity could be achieved by a change in daily routine, for example, by walking to school.

Results from the studies conducted for this thesis have confirmed that the BABE Scale is a valid and reliable tool for quantifying children's production of exercise effort and for regulating exercise output during cycling and stepping tasks. Given the choice, children preferred to use the BABE Scale in exercise activities rather than the CERT or CALER Scale. Reasons for their preference included that the BABE Scale was 'fun-looking' and 'interesting' due to use of colours, and the children were able to associate the character depicted on the BABE Scale with the hit Walt Disney film 'A Bug's Life', on which the pictorial representation of the BABE Scale was based.

The external validity of the BABE Scale was investigated during six weeks of circuit training classes with primary school children in Wiltshire, England. Results suggested that children could adjust their production of exercise effort on specific exercise stations to match two prescribed levels of perceived exertion (3 and 8) using the BABE Scale. In addition, questionnaire data revealed that children felt significantly ($P<0.05$) more competent completing the circuit training classes with use of the BABE Scale rather than without use of the BABE Scale. This may have implications for future exercise adherence.

Results have highlighted the potential for using child-specific effort rating scales in health-related exercise physical education lessons, and could also be used within other exercise settings such as 'Fat Camps'. Use of such scales in exercise activities could result in the achievement of a range of attainment targets specified in national curriculum guidelines. A health-orientated physical education programme needs to prepare children for lifetime physical activity. Health-related exercise physical education programmes should therefore focus on maximising the physical activity participation of all children. Physical education in schools is the only preparation some children will have to develop an active lifestyle, so it is important to use physical education to increase motivation and teach relevant skills to all children to prepare them for lifetime physical activity.

Schools should evaluate, review and revise their physical education curriculum to ensure that it promotes health-related exercise and motor skill development. This will assist in the development of lifelong habits towards reducing risk of disease and encourage the adoption of active lifestyles. Public health benefits from health-related exercise physical education programmes will be determined by the effectiveness of the programme in promoting long-term patterns of physical activity and the number of children who participate in the programme.

Future Recommendations

i. If effort-rating scales are to be used in physical education lessons, such scales would need to be developmentally appropriate, and ideally pictorial representation should encompass a range of exercise activities. The BABE Scale is developmentally appropriate for use with primary school children and has external validity across a variety of exercise activities. A need therefore exists for the development and validation of a scale that could be employed with secondary schoolchildren.

ii. Scale preference is a factor which requires further investigation, if such tools are to be integrated with success into physical education lessons. A scale would need to be an encouraging and motivating factor for children.

iii. Intrinsic motivation levels of children should be further explored to determine if an improvement is evident when effort perception scales are employed in a physical education environment. In addition, the source of improved motivation should be identified.

iv. During introductory sessions conducted with children who participated in the studies for this thesis, several children questioned why the BABE Scale does not have verbal cues against each number. Adding developmentally appropriate verbal cues to all numbers could therefore modify the existing BABE Scale. Such a modification could further aid children's interpretation of exercise effort when using the BABE Scale.

v. Methods need to be developed for teaching and reinforcing the use of child-specific effort rating scales in physical education lessons as part of the Health-Related Exercise National Curriculum. One such method could be the use of video instruction, promoted via structured in-service training (INSET).

vi. Further research using pictorial child-specific effort rating scales with children in applied activity and physical education lessons is justified. Specifically, researchers should concentrate on the effects such scales have on teaching and learning of issues associated with the increase and promotion of physical activity in physical education.

Clearly, the research within this thesis has highlighted the potential of using child-specific effort rating scales in circuit training physical education lessons. Funding is required to support the work of health and exercise professionals involved in the promotion and development of such a concept.

REFERENCES

Activity and Health Research. (1992); *Allied Dunbar National Fitness Survey: Main Findings.* Health Education Authority and Sports Council, London.

Alekseev V.M. (1989); Correlation between Heart Rate and Subjectively Perceived Exertion during Muscular Work. *Human Physiology,* 15: 39-44.

Alpert B.S., Wilmore J.H. (1994); Physical Activity and Blood Pressure in Adolescents. *Pediatric Exercise Science,* 6: 361-380.

American Academy of Pediatric Committees on Sports Medicine and School Health (1987); Physical Fitness and the Schools. *Pediatrics,* 80: 449-450.

American College of Sports Medicine: Position Statement on the Recommended Quantity and Quality of Exercise for Developing and Maintaining Fitness (1978); *Medicine and Science in Sport,* 10: vii-x.

American College of Sports Medicine (1986*); Guidelines for Exercise Testing and Prescription (Third edition).* Lea and Febiger, New York.

American College of Sports Medicine (1988); Opinion Statement on Physical Fitness in Children and Youth. *Medicine and Science in Sports and Exercise*, 20: 422-423.

American College of Sports Medicine (1990); Position Stand on the Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness in Healthy Adults. *Medicine and Science in Sports and Exercise,* 22: 265-274.

American College of Sports Medicine (1991); *Guidelines for Exercise Testing and Prescription (Fourth edition).* Lea and Febiger, Philadelphia.

American College of Sports Medicine (1993); Physical Activity, Physical Fitness and Hypertension: position Stand. *Medicine and Science in Sports and Exercise*, 25 (10): pi-x.

American College of Sports Medicine (1995); *Guidelines for Exercise Testing and Prescription (Fifth edition).* Lea and Febiger.

American Heart Association (1994); Guidelines for Exercise Testing in the Pediatric Age Group. *Circulation,* 90: 2166-2179.

Anderson M., Green W. (1948); Lengths of the Femur and the Tibia. *American Journal of Disabled Children,* 75: 279-290.

Anderson M., Green W., Messner M. (1978); Growth and Prediction of the Growth in Lower Extremities. *Clinical Orthopaedics.* 136: 7-21.

Armstrong N., Balding J., Gentle P., Kirby B. (1990); Patterns of Physical Activity Among 11 to 16 year old British Children. *British Medical Journal*, 301: 203-5.

Armstrong N., Bray S. (1991); Physical Activity Patterns defined by Continuous Heart Rate Monitoring. *Archives of Disease in Childhood,* 66: 245-7.

Armstrong N., Williams J., Balding J., Gentle P., Kirby B. (1991); Cardiopulmonary Fitness, Physical Activity Patterns and Selected Coronary Risk Factor Variables in 11 to 16 Year-Olds. *Pediatric Exercise Science*, 3: 219-228.

Armstrong N. (1993); Promoting Physical Activity in Schools. *Health Visitor*, 66: (10), 362-364.

Armstrong N. (1995); *Keynote Speech: Children, Physical Activity and Health. In: F.J.Ring (Ed). Children in Sport.* Centre for Continuing Education. University of Bath, Avon. 5-16.

Armstrong N. (1995a); Children's Cardiopulmonary Fitness and Physical Activity Patterns -The European Scene. *In: Issues in Paediatric Exercise Science*, Bar-Or O. (Ed). Human Kinetics, Champaign, Illinois. 177-189.

Armstrong N., Welsman J. (1997); *Young People and Physical Activity*. Oxford University Press.

Atomi Y., Iwaoka K., Hatta H., et al. (1986); Daily Physical Activity Levels in Pre-Adolescent Boys Related to VO_2 max and Lactate Threshold. *European Journal of Applied Physiology*, 55: 156-161.

Australian Council for Health, Physical Education and Recreation Inc. (1987); *Australian Health and Fitness Survey*. KB Printing Services Pty, Ltd, Edwardstown.

Bailey D.A. (1973); Exercise, Fitness and Physical Education for the Growing Child. In: Orban W.R. (Ed); *Proceedings of the National Conference on Fitness and Health*, Ottawa: National Health and Welfare.

Bailey D.A., Shephard R.J., Mirwald R.L. (1976); Validation of a Self-Administered Home Test of Cardiorespiratory Fitness. *Canadian Journal Applied Sport Science*, I, 67-78.

Bailey D.A., Martin A.D. (1994); Physical Activity and Skeletal Health in Adolescents. *Pediatric Exercise Science*, 6: 330- 347.

Bailey R.C., Olson J., Pepper S.L., Porszasz J., Barstow T.T., Cooper D.M. (1995); The Level and Tempo of Children's Physical Activity: An Observational Study. *Medicine and Science in Sports and Exercise*, 27: 1033-1041.

Bandura A. (1977); Self-efficacy: Toward a Unifying Theory of Behavioural Change. *Psychological Review*, 84 (2): 191-215.

Baranowski T., Hooks P., Tsong Y., et al. (1987); Aerobic Physical Activity Among Third to Sixth Grade Children. *Journal of Developmental and Behavioural Pediatrics*, 8: 203-206.

Barnett A.H. (1999); A Practical Approach to a Modern Problem. *Obesity in Practice*. Medical Educational Partnership, 1 (1): 1.

Bar-Or O. (1977); Age Related Changes in Exercise Perception. In: Borg G. (Ed); *Physical Work and Effort*. Pergamon Press, New York, 255-66.

Bar-Or O., Reed S.L. (1986*);* Rating of Perceived Exertion in Adolescents with Neuromuscular Disease. In: Borg G. & Ottoson D. (Eds); *The Perception of Exertion in Physical Work*. Macmillan Press Ltd, London, 137-148.

Bar-Or O., Ward D.S. (1989); Rating of Perceived Exertion in Children. In: *Advances in Paediatric Sport Sciences*: *Volume 3, Biological Issues*, Bar-Or O. (Ed). Human Kinetics, Champaign, 151- 168.

Bar-Or O., Baranowski T. (1994); Physical Activity, Adiposity, and Obesity among Adolescents. *Pediatric Exercise Science*, 6, 348-360.

Bar-Or O., Malina R.M. (1995); Activity, Fitness and Health of Children and Adolescents. In: *Child Health, Nutrition and Physical Activity*, Cheung L.W.Y and Richmond J.B. (Eds). Human Kinetics, Champaign, Illinois.

Bartlett S.A., Maki B.E., Fernie G.R., Holliday P.J., Gryfe C.I. (1986); On the Classification of a Geriatric Subject as a Faller or Non-faller. *Medical and Biological Engineering and Computing*, 24: 219-222.

Bassett D.R., Ainsworth B.E., Leggett S.R et al. (1996); Accuracy of Five Electronic Pedometers for Measuring Distance Walked. *Medicine and Science in Sports and Exercise*, 28: 1071-7.

Berenson G.S., McMahon C.A., Voors A.W.(Eds.) (1980); *Cardiovascular Risk Factors in Children: The Early Natural History of Atherosclerosis and Essential Hypertension*. Oxford University Press, New York.

Berenson G.S., Wattigney W.A., Tracy R.E et al. (1992); Atherosclerosis of the Aorta and Coronary Arteries and Cardiovascular Risk Factors in Persons aged 6 to 30 years. *American Journal of Cardiology*, 70: 851-858.

Beunen G.P., Malina R.M., Renson R., Simons J., Ostyn M., LeFevre J. (1992); Physical Activity and Growth, Maturation and Performance: A Longitudinal Study. *Medicine and Science in Sports and Exercise*, 24: 576-585.

Biddle S., Sallis J., Cavill N. (Eds.) (1998); *Young and Active? Young People and Health- Enhancing Physical Activity- Evidence and Implications*. Health Education Authority, 2-16.

Bizley K. (1999); Become Fit Enough to Run for the Coach. In: *Times Education Supplement Friday Magazine*. February 26th, 18.

Blair S.N., Kohl H.W., Paffenbarger R.S., Clark D.G., Cooper K.H., Gibbons L.W. (1989); Physical Fitness and all-cause Mortality: A Prospective Study of Healthy Men and Women. *Journal of the American Medical Association*. 262: 2395-2401.

Bland J.M., Altman D.G. (1986); Statistical Methods for Assessing Agreement between Two Methods of Clinical Measurement. *The Lancet* I, 307-310.

Bland J.M., Altman D.G. (1995); Comparing Two Methods of Clinical Measurement: A Personal History. *International Journal of Epidemiology* 24 (3) (Suppl.l), 57-514.

Board of Education (1905); *Syllabus of Physical Exercises for Public Elementary Schools*. HMSO.

Boreham C.A.G., Savage J.M., Primrose E.D., Cran G.W., Mahoney C.A., Strain J.J., Murphy N.M. (1992); Risk Factor Assessment in School Children: The Northern Ireland 'Young Hearts' Project. *Journal of Sports Sciences*, Conference Communications, 565.

Boreham C.A., Twisk J., Savage M.J., Cran G.W., Strain J.J. (1997); Physical Activity, Sports Participation, and Risk Factors in Adolescents. *Medicine and Science in Sports and Exercise*, 29 (6): 788-793.

Boreham C., Riddoch C. (2001); The Physical Activity, Fitness and Health of Children. *Journal of Sports Sciences*, 19 (12): 915-929.

Boreham C., Twisk J., Murray L., Savage M., Strain J.J., Cran G. (2001); Fitness, Fatness and Coronary Heart Disease Risk in Adolescents: The Northern Ireland Young Hearts Project. *Medicine and Science in Sports and Exercise*, 33 (2): 270-274.

Boreham C., Van Praagh E. (2001); Special Considerations for Assessing Performance in Young Children. In: *Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data (Second Edition)*. (Eston R., and Reilly T., Eds). Routledge, 190-191.

Boreham C., Twisk J., Neville C., Savage M., Murray L., Gallagher A. (2002); Associations between Physical Fitness and Activity Patterns During Adolescence and Cardiovascular Risk Factors in Young Adulthood: The Northern Ireland Young Hearts Project. *International Journal of Sports Medicine*, 23 (Suppl. 1): 22-26.

Borg G., Dahlstrom H. (1959); Psykofysisk undersokning av arbete pa cykelergometer. *Nordisk Medicin*. (Psychophysical Investigation of Work on a Cycle Ergometer. Scandinavian Medicine), 62: 1383-86.

Borg G. (1961); Perceived Exertion in Relation to Physical Work Load and Pulse Rate. *Kungliga Fysiografiska Sallskapets i Lund Forhandlingar* 11 (31): 105-15.

Borg G. (1961a); Interindividual Scaling and Perception of Muscular Force. *Kungliga Fysiografiska Sallskapets i Lund*, University of Lund, Sweden, 12 (31): 117-25.

Borg G. (1962); *Physical Performance and Perceived Exertion. Studia Psychologica et Paedagogica*, Series altera, Investigationes XI. Lund: Gleerup.

Borg G., Linderholm H. (1967); Perceived Exertion and Pulse Rate During Graded Exercise in Various Age Groups. *Acta Medica Scandinavica* (Supplement) 472: 194-206.

Borg G., .Linderholm H. (1970); Exercise Performance and Perceived Exertion in Patients with Coronary Insufficiency, Arterial Hypertension and Vasoregulatory Asthenia. *Acta Medica Scandinavica*, 187: 17-26.

Borg G. (1970); Perceived Exertion as an Indicator of Somatic Stress. Scandinavian *Journal of Rehabilitation Medicine*, 2: 92-98.

Borg G. (1973); Perceived Exertion: A Note on 'History' and Methods. *Medicine and Science in Sports*, 5 (2): 90-93.

Borg G. (1977); *Physical Work and Effort*. Pergamon Press, Oxford. 289-293.

Borg G. (1982); A Category Scale with Ratio Properties for Intermodal and Interindividual Comparisons. In: *Psychophysical Judgement and the Process of Perception*. Geissler H.G. and Petzold P. (Eds), 25-34. Berlin: VEB Deutscher Verlag der Wissenschaften.

Borg G. (1985); *An Introduction to Borg's RPE Scale*. Ithaca, N.Y, Mouvement.

Borg G., Ljunggren G., Ceci R. (1985); The Increase of Perceived Exertion, Aches and Pains in the Legs, Heart Rate and Blood Lactate during Exercise on a Bicycle Ergometer. *European Journal of Applied Physiology*, 54: 343-49.

Borg G., Ottoson D. (Eds.) (1986); *The Perception of Exertion in Physical Work*. London, Macmillan.

Borg G., Van den Burg M., Hassmen P., Kaijser L., Tanaka S. (1987); Relationships between Perceived Exertion, Heart Rate and Lactic Acid in Cycling, Running and Walking. *Scandinavian Journal of Sports Sciences*, 9: 69-77.

Borg G. (1998); *Borg's Perceived Exertion and Pain Scales*. Human Kinetics, Champaign, Illinois, 1-16.

Borg E., Borg G. (1998); Absolute Magnitude Estimation compared with Natural Category-Ratio Scaling. In: Grandin S. and Lacouture Y. (Eds), Fechner Day 98, *Proceedings of the fourteenth Annual Meeting of the International Society for Psychophysics*, 199-204. The International Society for Psychophysics, Quebec, Canada.

Boutcher S.H., Fleischer-Curtain L.A., Gines S.D. (1988); The Effects of Self-Presentation on Perceived Exertion. *Journal of Sport and Exercise Psychology*, 10: 270-80.

Boyd Eaton S., Konner M., Shostak M. (1988); Stone Agers in the Fast Lane: Chronic Degeneration Diseases in Evolutionary Perspective. *American Journal of Medicine*, 84: 739-749.

Brownell K.D., Stunkard A.J. (1980); Physical Activity in the Development and Control of Obesity. In: *Obesity* (A.J. Stunkard, Ed). Saunders, Philadelphia.

Brustad R.J. (1991); Children's Perspectives on Exercise and Physical Activity: Measurement Issues and Concerns. *Journal of School Health*, 61, (5): 228-230.

Buckley J.P; Eston R.G; Sim J. (2000); Ratings of Perceived Exertion in Braille: Validity and Reliability in Production Mode. *British Journal of Sports Medicine*. 34 (4): 297-302.

Buckley J., Holmes J., Mapp G. (2000a); *Exercise on Prescription.* Cardiovascular Activity for Health. Butterworth-Heinmann.

Caiozzo V.J., Davis J.A., Ellis J.F., Azuz J.L., Vandagriff C.A., Prietto C.A., McMaster W.C. (1982); A Comparison of Gas Exchange Indices to Detect Anaerobic Threshold. *Journal of Applied Physiology*, 53: 1184-1189.

Cale L., Almond L. (1992); Physical Activity Levels of Young Children: a Review of the Evidence. *Health Education Journal*, SI/2, 94-99.

Cale L., Harris J. (1993); Exercise Recommendations for Children and Young People. *Physical Education Review*, 16: 89-98.

Calfas K.J., Taylor W.C. (1994); Effects of Physical Activity on Psychological Variables in Adolescents. *Pediatric Exercise Science*, 6: 406-423.

Canadian Fitness Survey (1981); In: Hebbelinck M., Shephard R.J.; (Eds) (1986); *Fitness of a Nation.* Medicine and Sport Science. Karger, Basel, 4-154.

Caspersen C.J., Powell K.E., Christenson G.M. (1985); Physical Activity, Exercise and Physical Fitness: Definition and Distinction for Health-Related Research. *Public Health Report* 100, 126-130.

Caspersen C.J., Merritt R.K., Stephens T. (1994); International Physical Patterns: A Methodological Perspective. In: *Advances in Exercise Adherence and Public Health,* Dishman R.K. (Ed). Human Kinetics, Champaign, 71-108.

Cicutti N., Jette M., Sidney K. (1991); Effect of Leg Length on Bench Stepping Efficiency in Children. *Canadian Journal of Sports Science*. 16 (1): 58-63.

Clarke W.R., Schrott H.G., Leaverton P.E., Connor W.E., Lauer R.M. (1978); Tracking of Blood Lipids and Blood Pressures in School-Age Children: The Muscatine Study. *Circulation*, 58 (4): 626-634.

Corbin C.B., Pangrazi R.P., Welk G.J. (1994); Toward an Understanding of Appropriate Physical Activity Levels for Youth. President's Council of Physical Fitness and Sports. *Physical Activity and Fitness Research Digest*, 1 (8): 1-8.

Cureton K.J. (1994); Physical Fitness and Activity Standards for Youth. In: *Health and Fitness through Physical Education,* Pate R.R. and Hohn R.C. (Eds). Human Kinetics, Champaign, Illinois, 129-136.

Davies C.T.M., Fohlin L., Thoren C. (1980*);* Perception of Exertion in Anorexia Nervosa Patients. In: Berg K, Eriksson B.O (Eds.). *Children and Exercise IX.* Baltimore: University Park Press, 327-333.

Davis J.M., Vodak P., Wilmore J.H., Vodak J., Kurtz P. (1976); Anaerobic Threshold and Maximal Aerobic Power for Three Modes of Exercise. *Journal of Applied Physiology*, 41: 544-550.

Davis J.A. (1985); Anaerobic Threshold: Review of the Concept and Directions for Future Research. *Medicine and Science in Sports and Exercise*, 17: 6-18.

DeBusk R.F., Stenestrand U., Sheehan M., Haskell W.L. (1990); Training Effects of Long versus Short Bouts of Exercise in Healthy Subjects. *The American Journal of Cardiology,* 65: 1010- 1013.

Deci E.L. (1975); *Intrinsic Motivation*. Plenum: New York.

Deci E.L., Ryan R.M. (1980); The Empirical Exploration of Intrinsic Motivational Processes. In: Berkowitz L. (Ed.), *Advances in Experimental Social Psychology*, Pergamon Press: New York, 13: 39-80.

Deci E.L., Ryan R.M. (1985); *Intrinsic Motivation and Self-Determination in Human Behaviour*. Plenum: New York.

Deci E.L., Ryan R.M. (1992); A Motivational Approach to Self: Integration in Personality. In: Dienstbier R. (Ed.), *Nebraska Symposium on Motivation, 38, Perspectives on Motivation.* Lincoln, N.E: University of Nebraska, 237-288.

Deci E.L. (1992); *On the Nature and Function of Motivation. Psychological Science*, 3: 161-171.

Deci E.L., Ryan R.M. (1995); Human Autonomy: The Basis for True Self-Esteem. In: Kernis M, (Ed.), *Agency, Efficacy and Self-Esteem*. Plenum: New York.

Demello J.J., Cureton K.J., Boineau R.E., Singh M.M. (1987); Ratings of Perceived Exertion at the Lactate Threshold in Trained and Untrained Men and Women. *Medicine and Science in Sports and Exercise*, 19 (4): 354-362.

Department of Education and Science (DES) (1989); Physical Education from 5 to 16: *Curriculum Matters* 16. HMSO, London.

Department for Education and the Welsh Office Education Department (1995); *Physical Education in the National Curriculum.* London: HMSO.

Dickenson B., Sparkes A. (1988); Pupil Definition of Physical Education. British *Journal of Physical Education. Supplement*, 2: 6-7.

Dishman R.K. (1982); Compliance/ Adherence in Health-Related Exercise. *Health Psychology*, 1 (3): 237-267.

Dishman R.K. (1982a); Contemporary Sport Psychology. *Exercise Sport Science Reviews,* 10: 120-59.

Dishman R.K., Sallis J., Orenstein D. (1985); The Determinants of Physical Activity and Exercise. *Public Health Reports*, 100: 158-171.

Dishman R.K. (1994); Prescribing Exercise Intensity for Healthy Adults using Perceived Exertion. *Medicine and Science in Sports and Exercise*, 26 (9): 1087-94.

Dunbar C.C., Robertson R.J., Baun R., Blandin M.F., Metz K., Burdett R., Goss F.L. (1992); The Validity of Regulating Exercise Intensity by Ratings of Perceived Exertion. *Medicine and Science in Sports and Exercise,* 24: 94-99.

Dunbar C.C., Glickman-Weiss E.L., Bursztyn D.A et al. (1998); A Submaximal Treadmill Test for Developing Target Ratings of Perceived Exertion for Outpatient Cardiac Rehabilitation. *Perceptual and Motor Skills*, 87: 755-9.

Duncan G.E., Mahon A.D., Gay J.A., Sherwood J.J.(1996); Physiological and Perceptual Responses to Graded Treadmill and Cycle Exercise in Male Children. *Pediatric Exercise Science*, 8: 251-258.

Dwyer T., Coonan W.E., Leitch D.R., Hetzel B.S., Baghurst R.A. (1983); An Investigation of the Effects of Daily Physical Activity on the Health of Primary School Students in South Australia. *International Journal of Epidemiology*, 12: 308-312.

Eakin B.L., Finta K.M., Serwer G.A et al. (1992); Perceived Exertion and Exercise Intensity in Children With or Without Structural Heart Defects. *Journal of Pediatrics*, 120: 90-3.

Ekblom B. (1969); Effect of Physical Training in Adolescent Boys. *Journal of Applied Physiology*, 27: 350-355.

Ekblom B., Goldbarg A.N. (1971); The Influence of Training and Other Factors on the Subjective Rating of Perceived Exertion. *Acta Physiologica Scandinavica*, 83: 399-406.

Elbourn J., Harris J. (1999); Planning a Health-Related Exercise Lesson - Making the most of new resources. *Primary Physical Education Fo*cus, 13-16.

Epstein L.H., Koeske R., Wing R.R. (1984); Adherence to Exercise in Obese Children. *Journal of Cardiac Rehabilitation,* 4: 185-195.

Epstein L.H., Wing R.R., Koeske R., Valoski A. (1985); A Comparison of Lifestyle Exercise, Aerobic Exercise, and Callisthenics on Weight Loss in Obese Children. *Behavioural Therapy*, 16: 345-356.

Erikssen G., Liestol K., Bjornholt J., Thaulow E. (1998); Changes in Physical Fitness and Changes in Mortality. *Lancet,* 352: 759-762.
Eriksson B.O. (1972); Physical Training, Oxygen Supply and Metabolism in 11-13 year-old Boys. *Acta Physiologica Scandinavica.* (Suppl. 384): 1-48.
Eriksson B.O., Koch G. (1973); Effect of Physical Training on Hemodynamic Response during Submaximal and Maximal Exercise in 11-13 year old boys. *Acta Physiologica Scandinavica,* 87: 27-39.
Eriksson B.O., Karlsson J., Saltin B. (1997); Muscle Metabolites During Exercise in Pre-Pubertal Boys. *Acta Paediatrica Scandinavica.* (Suppl. 217): 154-157.
Eston R.G. (1984); A Discussion of the Concepts: Exercise Intensity and Perceived Exertion with Reference to the Secondary School. *Physical Education Review,* 7: 19-25.
Eston R.G., Williams J.G. (1986); Exercise Intensity and Perceived Exertion in Adolescent Boys. *British Journal of Sports Medicine,* 20: 27-30.
Eston R.G., Davies B.L., Williams J.G. (1987); Use of Perceived Exertion Effort Ratings to Control Exercise Intensity in Young Healthy Adults. *European Journal of Applied Physiology and Occupational Physiology,* 56: 222-224.
Eston R.G., Williams J.G. (1988); Reliability of Ratings of Perceived Effort in the Regulation of Exercise Intensity. *British Journal of Sports Medicine,* 22 (4): 153-155.
Eston R.G., Williams J.G. (1989); Determination of the Intensity Dimension in Vigorous Exercise Programmes with Particular Reference to the Use of the Rating of Perceived Exertion. *Sports Medicine,* 8 (3): 177-189.
Eston R.G., Lamb K.L., Bain A., Williams A.M., Williams J.G. (1994); Validity of a Perceived Exertion Scale for Children: A pilot Study. *Perceptual and Motor Skills,* 78: 691-697.
Eston R.G., Thompson M. (1997); Use of Ratings of Perceived Exertion for Predicting Maximal Work Rate and Prescribing Exercise Intensity in Patients taking Atenolol. *British Journal of Sports Medicine,* 31 (2): 114-119.
Eston R,G., Rowlands A.V., Ingledew D.K. (1998); Validity of Heart Rate, Pedometry and Accelerometry for Predicting the Energy Cost of Children's Activities. *Journal of Applied Physiology,* 84: 362-71.
Eston R.G., Campbell L., Lamb K.L., Parfitt G. (1999); Reliability of Effort Perception for Regulating Exercise Intensity in Children: A pilot Study using the Cart and Load Effort Rating (CALER) Scale. *Pediatric Exercise Science* 11: 274-275.
Eston R.G., Parfitt G., Campbell L., Lamb K.L. (2000); Reliability of Effort Perception for Regulating Exercise Intensity in Children Using the Cart and Load Effort Rating (CALER) Scale. *Pediatric Exercise Science* (12): 388-397.
Eston R.G., Lamb K.L. (2000); Effort Perception. In: Armstrong N. and Van Mechelen W. (Eds). *Paediatric Exercise Science and Medicine.* Oxford University Press, 85-91.
Eston R.G. (2001); Lung Function. In: *Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data (second edition). Volume 2: Exercise Physiology.* (Eston R. and Reilly T., Eds). Routledge, 147-174,
Eston R.G., Parfitt G., Shepherd P. (2001); Effort Perception in Children: Implications for Validity and Reliability. In: (Papaionnou A., Goudas M., and Theodorakis Y., Eds). *Proceedings of the10th World Congress of Sport Psychology.* Skiathos, Greece, 5: 104-106.

Eston R.G., Williams J.G. (2001); Control of Exercise Intensity using Heart Rate, Perceived Exertion and other Non-Invasive Procedures. In: *Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data (second edition). Volume 2: Exercise Physiology.* (Eston R. and Reilly T., Eds). Routledge, 219.

Eston R.G. (2002); Use of the Body Mass Index (BMI) for Individual Counselling: The New Section Editor for Kinanthropometry is ' Grade 1 Obese, Overweight'(BMI 27.3) but Dense and Distinctly Muscular (FFMI 23.1) (Editorial). *Journal of Sports Sciences,* 20: 515-518.

Ewing M.E. (1981); Achievement Orientations and Sport Behaviour of Males and Females. *Dissertation Abstracts International.*

Faucette N., McKenzie T.L., Patterson P. (1990); Descriptive Analysis of Non-specialist Elementary Physical Education Teachers' Curricular Choices and Class Organisation. *Journal of Teaching in Physical Education,* 9: 284-293.

Ferguson K.J., Yesalis C.E., Pomrehn P.R., Kirkpatrick M.B. (1989); Attitudes, Knowledge and Beliefs as Predictors of Exercise Intent and Behaviour in School Children. *Journal of School Health,* 59 (3): 112-115.

Fox K.R. (1991); Motivating Children for Physical Activity: Towards a Healthier Future. *Journal of Physical Education Recreation and Dance,* 62: 34-8.

Fox K.R. (1994); Understanding Young Children and their Decision about Physical Activity. *British Journal of Physical Education,* 25 (1): 15-19.

Francis K. (1987); Fitness Assessment Using Step Test. *Comprehensive Therapy,* 13: 36-41.

Francis K., Brasher J. (1992); A Height-Adjusted Step Test for Predicting Maximal Oxygen Consumption in Males. *Journal of Sports Medicine and Physical Fitness,* 32: 282-287.

Francis K., Minard H. (1997); Metabolic Efficiency of Stepping at a Hip Angle of 82 Degrees (abstract). *Physical Therapy,* 77: S7.

Francis K., Hopkins S., Feinstein R. (1998); Effect of Step Platform Height on Stepping Efficiency in Children. *Pediatric Exercise Science,* 10 (4): 337-346.

Freedman D.S., Shear C.L., Shrinivasan S.R., et al. (1985); Tracking of Serum Lipids and Lipoproteins in Children over an 8-Year Period. The Bogalusa Heart Study. *Preventive Medicine,* 14: 203-216.

Gaesser G.A., Rich E.G. (1984); Effects of High Performance and Low Intensity Training on Aerobic Capacity and Blood Lipids. *Medicine and Science in Sports and Exercise,* 16: 269-274.

Gayle R., Montoye H.J., Philpot J. (1977); Accuracy of Pedometers for Measuring Distance Walked. *Research Quarterly for Exercise and Sport,* 48: 632-6.

Gillach M.C., Sallis J.F., Buono M.J, Patterson P., Nader P.R. (1989); The Relationship between Perceived Exertion and Heart Rate in Children and Adults. *Pediatric Exercise Science,* 1: 360-8.

Gilliam T.B., Freedson P.S., Greenan D.L., Shahraray B. (1981); Physical Activity Patterns Determined by Heart Rate Monitoring in Six-to-Seven Year Old Children. *Medicine and Science in Sports,* 13: 65-67.

Gilliam T.B., MacConnie S.E., Greenan D.L., et al. (1982); Exercise Programs for Children: A Way to Prevent Heart Disease? *The Physician and Sports Medicine,* 10: 96-98.

Godfrey S. (1974); *Exercise Testing in Children.* Saunders, London, 73-4.

Gortmaker S.L., Deitz W.H., Sobol A.M., Wehler C.A. (1987); Increasing Pediatric Obesity in the United States. *American Journal of Diseases of Children,* 141: 535-540.

Goudas M., Biddle S.J.H. (1994); Perceived Motivational Climate and Intrinsic Motivation in School Physical Education Classes. *European Journal of Psychology of Education,* 9 (3): 241-250.

Green K., Lamb K.L. (2000); Health-Related Exercise, Effort Perception and Physical Education. *European Journal of Physical Education,* 5: 88-103.

Gruber J.J. (1986); Physical Activity and Self-Esteem Development in Children: A Meta-Analysis. In: Stull G.A & Eckert H.M (Eds); *Effects of Physical Activity on Children.* The American Academy of Physical Education Papers No.19. Human Kinetics, Champaign, Illinois, 30-48.

Guo S.S., Roche A.F., Chumlea W.C., Gardner J.C., Siervogel R.M. (1994); The Predictive Value of Childhood Body Mass Index Values for Overweight at Age 35. *American Journal of Clinical Nutrition,* 59: 810-819.

Gutin B., Basch C., Shea I., Contento I., Delozier M., Rips J., Irigoyen M., Zybert P. (1990); Blood Pressure, Fitness and Fatness in 5-and 6-year old children. *Journal of the American Medical Association.* 264 (9): 1123-1127.

Gutin B., Islam S., Manos T., Cucuzzo N., Smith C., Stachura M.E. (1994); Relation of Percentage of Body Fat and Maximal Aerobic Capacity to Risk Factors for Atherosclerosis and Diabetes in Black and White Seven-to Eleven-Year-Old Children. *Journal of Pediatrics,* 125 (6): 847-852.

Gutin B., Owens S. (1996); Is there a Scientific Rationale Supporting the Value of Exercise for the Present and Future Cardiovascular Health of Children? The Pro Argument. *Pediatric Exercise Science*; 8: 294-302.

Gutman M.C., Squires R.W., Pollock M.L., Foster C., Anholm J. (1981); Perceived Exertion-Heart Rate Relationship during Exercise Testing and Training in Cardiac Patients. *Journal of Cardiac Rehabilitation,* 1: 52-59.

Hampson D.B., Gibson A.S., Lambert M.I., Noakes T.D. (2001); The Influence of Sensory Cues on the Perception of Exertion During Exercise and Central Regulation of Exercise Performance. *Sports Medicine,* 31 (13): 935-952.

Hanne N. (1971); A Step-test for 6 to 12 year old Girls and Boys (in Hebrew). Research Report, Wingate Institute. In: Bar-Or O. (1983); *Paediatric Sports Medicine for the Practitioner: From Physiologic Principles to Clinical Applications.* New York, Springer-Verlag, 322-323.

Hardy C.J., Hall E.G., Prestholdt P.H. (1986); The Mediational Role of Social Influence in the Perception of Exertion. *Journal of Sport Psychology,* 8: 88-104.

Harris J. (1997); *Physical Education: A Picture of Health? The Implementation of Health-Related Exercise in the National Curriculum in Secondary Schools in England and Wales.* Unpublished doctoral dissertation, The University of Loughborough.

Harris J. (2000*); Health-Related Exercise in the National Curriculum. Key Stages 1 to 4.* Human Kinetics, Champaign, Illinois, 2-8.

Harter S. (1978); Effectance Motivation Reconsidered. Towards a Developmental Model. *Human Development,* 21 (1): 34-64.

Harter S. (1982); The Perceived Competence Scale for Children. *Child Development,* 53 (1): 87-97.

Harter S., Connell J.P. (1984); A Model of Children's Achievement and Related Self-Perceptions of Competence, Control and Motivational Orientation. In: Nicholls J. (Ed.), *The Development of Achievement-Related Cognitions and Behaviours.* Greenwich, CT; JAI Press, 219-250.

Haskell W.L. (1986); The Influence of Exercise Training on Plasma Lipids and Lipoproteins in Health and Disease. *Acta Medica Scandinavica,* 711 (Suppl.), 25-37.

Haskell W.L. (1994); Health Consequences of Physical Activity. *Medicine and Science in Sports and Exercise,* 26: 649-660.

Health Education Authority (1994); *Moving On. International Perspectives on Promoting Physical Activity.* Killoran A.J, Fentem P, Caspersen C. (Eds). Health Education Authority, Exeter.

Hetzler R.K., Seip R.L., Boutcher S.H, et al. (1991); Effect of Exercise Modality on Ratings of Perceived Exertion at Various Lactate Concentrations. *Medicine and Science in Sports and Exercise,* 23 (1): 88-92.

Hill D.W., Cureton K.J., Grisham S.C., Collins M.A. (1987); Effect of Training on the Rating of Perceived Exertion at the Ventilatory Threshold. *European Journal of Applied Physiology,* 56: 206-211.

Hillman M., Adams J., Whitelegg J. (1990); *One False Move.* Policy Studies Institute, London.

Hoffmans M.D.A.F., Kromhout D., Coulander C.D. (1988); The Impact of Body Mass Index of 78,612 18-year old Dutch Men on 32-year Mortality from All Causes. *Journal of Clinical Epidemiology,* 41: 749-756.

Howe B.L., Collis M.L. (1973); Validation of the 'U Vic' Step Test as a Practical Measure of Cardiovascular Efficiency. *Journal of Sports Medicine and Physical Fitness,* 13: 226-230.

Hubert H., Feinleib M., McNamara P., Castelli W. (1983); Obesity as an Independent Risk Factor for Cardiovascular Disease: A 26-Year Follow-Up of Participants in the Framingham Heart Study. *Circulation,* 67: 968-977.

Kahle C., Ulmer H.V., Rummel L. (1977); The Reproducibility of Borg's RPE Scale with Female Pupils from 7 to 11 years of age (abstract). *European Journal of Physiology,* 368: R26.

Kamon E. (1970); Negative and Positive Work in Climbing a Laddermill. *Journal of Applied Physiology,* 29:1-5.

Karvonen J., Vuorimaa T. (1988); Heart Rate and Exercise Intensity during Sports Activities. *Sports Medicine,* 5: 303-312.

Kemper H.C.G. (1985); Growth, Health and Fitness of Teenagers. *Medicine and Sport Science,* 20: 1-202.

Kenyon G.S. (1968); A Conceptual Model for Characterising Physical Activity. *Research Quarterly,* 39 (2): 96-104.

King A.C., Taylor C.B., Haskell W.L. (1993); Effects of Differing Intensities and Formats of 12 Months of Exercise Training on Psychological Outcomes in Older Adults. *Health Psychology,* 12: 292-300.

Kirk D. (1986); Health Related Fitness as an Innovation in the Physical Education Curriculum. In: Evans J. (Ed); *Physical Education, Sport and Schooling. Studies in the Sociology of Physical education.* The Palmer Press, 167-181.

Kirk D. (1986a); *Researching the Teacher's World: A Case Study of Teacher-Initiated Innovation.* Unpublished PhD Thesis, Loughborough University of Technology.

Koch G., Rocker L. (1977); Plasma Volume and Intravascular Protein Masses in Trained Boys and Fit Young Men. *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology,* 43: 1085-1088.

Krahenbuhl G.S., Skinner J.S., Kohrt W.M. (1985); Developmental Aspects of Maximal Aerobic Power in Children. In: Terjung R.L. (Ed); *Exercise and Sport Science Reviews,* 13: 503-538.

Lamb K.L. (1995); Children's Ratings of Effort during Cycle Ergometry: An Examination of the Validity of Two Effort Rating Scales. *Pediatric Exercise Science,* 7: 407-421.

Lamb K.L. (1996); Exercise Regulation during Cycle Ergometry Using the CERT and RPE Scales. *Pediatric Exercise Science,* 8: 337-350.

Lamb K.L., Eston R.G. (1997); Effort Perception in Children. *Sports Medicine,* 23 (3): 139-148.

Lamb K., Eston R.G., Trask S. (1997); The Effect of Discontinuous and Continuous Testing Protocols on Effort Perception in Children. Effort Perception in Children: A Focus on Test Methodology. In: Armstrong N., and Welsman J. (Eds). *Children and Exercise XIX.* E and FN Spon, London, 258-264.

Lamb K.L., Eston R.G., Corns D.(1999); Reliability of Ratings of Perceived Exertion during Progressive Treadmill Exercise. *British Journal of Sports Medicine.* 33 (5): 336-339.

Lee I.M., Paffenbarger R.S., Hennekens C.H. (1997); Physical Activity, Physical Fitness and Longevity. *Aging (Milano),* 9 (1-2): 2-11.

Lee I.M., Paffenbarger R.S. (1998); Physical Activity and Stroke Incidence: The Harvard Alumni Health Study. *Stroke,* 29 (10): 2049-2054.

Lee I.M., Paffenbarger R.S. (2000); Associations .of Light, Moderate and Vigorous Intensity Physical Activity with Longevity. The Harvard Alumni Health Study. *American Journal of Epidemiology,* 151 (3): 292-299.

Lee I.M., Sesso H.D., Paffenbarger R.S. (2000a); Physical Activity and Coronary Heart Disease Risk in Men: Does the Duration of Exercise Episodes Predict Risk? *Circulation,* 102 (9): 981-986.

Leon A.S., Connett J., Jacobs D.R.J., Raurama R. (1987); Leisure-Time Physical Activity Levels and Risk of Coronary Heart Disease and Death: Multiple Risk Factor Intervention Trial. *Journal of the American Medical Association,* 258: 2388-2395.

Lind A.R. (1970); Cardiovascular Responses to Static Exercise. *Circulation,* 41: 173-176.

Louie L., Eston R.G., Rowlands A.V., Tong K.K., Ingledew K., Fu F.H. (1999); Validity of Heart Rate, Pedometry and Accelerometry for Estimating the Energy cost of Activity in Hong Kong Chinese Boys. *Pediatric Exercise Science,* 11: 229-39.

Lowry A. (1995); The Development of a Pictorial Scale to Assess Perceived Exertion in School Children. Unpublished Bachelor of Science Thesis. University College Chester. In: Welsman J., Armstrong N., Kirby B. (1997); *Children and Exercise XIX Volume II.* Washington Singer Press, Exeter.

Mahon A.D., Marsh M.L. (1992); Reliability of the Rating of Perceived Exertion at the Ventilatory Threshold in Children. *International Journal of Sports Medicine,* 13: 567-571.

Mahon A.D., Ray M.L. (1995); Ratings of Perceived Exertion at Maximal Exercise in Children Performing different Graded Exercise Tests. *Journal of Sports Medicine and Physical Fitness,* 35: 38-42.

Mahon A.D., Duncan G.E., Howe C.A., Corral P.D. (1997); Blood Lactate and Perceived Exertion Relative to Ventilatory Threshold: Boys vs. Men. *Medicine and Science in Sports and Exercise*, 29 (10): 1332-1337.

Mahon A.D., Gay J.A., Stolen K.Q. (1998); Differentiated Ratings of Perceived Exertion at Ventilatory Threshold in Children and Adults. *European Journal of Applied Physiology*, 78: 115-120.

Mahon A.D., Stolen K.Q., Gay J.A. (2001); Differentiated Perceived Exertion During Submaximal Exercise in Children and Adults. *Pediatric Exercise Science*, 13 (2): 145-153.

Mahon A.D., Cheatham C.C. (2002); Ventilatory Threshold in Children: A Review. *Pediatric Exercise Science*, 3: 333-341.

Malina R.N. (1987); President's Message. *The American Academy of Physical Education News*, 8: 1-2.

Marriott H.E., Lamb K.L. (1996); The Use of Ratings of Perceived Exertion for Regulating Exercise Levels in Rowing Ergometry. *European Journal of Applied Physiology*, 72: 267-71.

Maynard E.J., Coonan W.E., Worsley A., Dwyer T., Baghurst P.A. (1987); The Development of the Lifestyle Education Program in Australia. In: Hetzel B.S. and Berenson G.S. (Eds), *Cardiovascular Risk Factors in Children: Epidemiology and Prevention, 1*23-149. Elsevier, Amsterdam.

McAuley E., Duncan T., Tammen V.V. (1989); Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. *Research Quarterly for Exercise and Sport*, 60: 48-58.

McAuley E., Duncan T.E., Wraith S. (1991); Self-Efficacy, Perceptions of Success, and Intrinsic Motivation for Exercise. *Journal of Applied Social Psychology*, 21 (2): 139-155.

McAuley E., Courneya K.S. (1994); The Subjective Exercise Experiences Scale (SEES). Development of Preliminary Validation. *Journal of Sport and Exercise Psychology*, 16: 163-177.

McNair D.M., Lorr M., Droppleman F. (1971); *Profile of Mood States Manual*. San Diego, CA: Educational and Industrial Testing Service.

Meyer F., Bar-Or O., Wilk B. (1995); Children's Perceptual Responses to Ingesting Drinks of Different Compostion During and Following Exercise in the Heat. *International Journal of Sports Nutrition*, 5: 13-24.

Mihevic P.M. (1981); Sensory Cues for Perceived Exertion: A Review. *Medicine and Science in Sports and Exercise*, 13 (3): 150-163.

Mirwald R.L., Bailey D.A. (1981); Longitudinal Comparison of Aerobic Power in Active and Inactive Boys aged 7 to 17 years. *Annals of Human Biology*, 8: 405-414.

Miyamura M., Kuroda H., Hirata K., Honda Y. (1975); Evaluation of Step Test Scores based on the Measurement of Maximal Aerobic Power. *Journal of Sports Medicine and Physical Fitness*, 15: 316-322.

Miyashita M., Onedera K., Tabata I. (1986); How Borg's RPE Scale has been applied to Japanese. In: Borg G., Ottoson D., (Eds); *The Perception of Exertion in Physical Work*. Macmillan Press Ltd, Basingstoke, 27-34.

Morris J.N., Heady J.A., Raffle P.A.B., Roberts C.G., Parks J.W. (1953); Coronary Heart Disease and Physical Activity of Work. *Lancet*, 2: 1053-1057, 1111-1120.

Morris J.N., Heady J., Raffle P.A.B. (1956); Physique of London Busmen: The Epidemiology of Uniforms. *Lancet*, 2: 569-570.

Morris J.N., Kagan A., Pattison D.C., Gardner M., Raffle P. (1966); Incidence and Prediction of Ischemic Heart Disease in London Busmen. *Lancet,* 2: 553-559.

Morris J.N., Everitt M.G., Semmence A.M. (1987); Exercise and Coronary Heart Disease. In: Macleod D., Maughan R., Nimmo M., Reilly T., Williams C., (Eds), *Exercise Benefits Limits and Adaptations*. London, E and FN Spon, 4-17.

Nagle F.J., Balke B., Naughton J.P. (1965); Gradational Step Tests for Assessing Work Capacity. *Journal of Applied Physiology*, 20: 745-748.

Nagle F.J., Balke B., Baptista G., Alleyia J., Howley E. (1971); Compatibility of Progressive Treadmill Bicycle and Step Tests based on Oxygen Uptake Responses. *Medicine and Science in Sports*, 3:149-154.

National Association of Head teachers and Central Council for Physical Recreation (1992*); National Survey of Physical Education in Primary Schools*. London: Central Council for Physical Recreation.

Nieto F.J., Szklo M., Comstock G.W. (1992); Childhood Weight and Growth Rate as Predictors of Adult Mortality. *American Journal of Epidemiology,* 136: 201-213.

NIH Consensus Development Panel on Physical Activity and Cardiovascular Health (1996); Physical Activity and Cardiovascular Health. *Journal of the American Medical Association,* 276: 241-246.

Newman W.P., Friedman D.S., Voors A.W., et al. (1986); Relation of Serum Lipoprotein Levels and Systolic Blood Pressure to Early Atherosclerosis. The Bogalusa Heart Study. *New England Journal of Medicine*, 314: 138-144.

Nishikido N., Kashiwazaki H., Suzuki T. (1982); Pre-school Children's Daily Activities: Direct Observations, Pedometry or Questionnaire. *Journal of Human Ergology,* 11: 214-8.

Noble B.J. (1982); Clinical Application of Perceived Exertion. *Medicine and Science in Sports and Exercise,* 14: 406-411.

Noble B.J., Borg G.A.V., Jacobs I., Ceci R., Kaiser P. (1983); A Category-Ratio Perceived Exertion Scale: Relationship to Blood and Muscle Lactates and Heart Rate. *Medicine and Science in Sports and Exercise*, 15: 523-28.

Noble B.J., Robertson R.J. (1996); *Perceived Exertion*. Human Kinetics. Champaign, Illinois.

Northern Ireland Curriculum Council (NICC) (1990); *Physical Education 11-16: A Curriculum Framework.*

Nystad W., Oseid S., Mellbye E.B. (1989); Physical Education for Asthmatic Children: The Relationship between Changes in Heart Rate, Perceived Exertion, and Motivation for Participation. In: Oseid S. and Carlsen K. (Eds); *Children and Exercise XIII.* Human Kinetics Books, Champaign, Illinois, 369-377.

Oman R., McAuley E. (1993); Intrinsic Motivation and Exercise Behaviour. *Journal of Health Education,* 24 (4): 232-238.

Paffenbarger R.S., Hyde R.T., Wing A.L., Hsieh C. (1986); Physical Activity, All-Cause Mortality and Longevity of College Alumni. *New England Journal of Medicine,* 314: 605-613.

Paffenbarger R.S., Kampert J.B., Lee I.M., Hyde R.T., Leung R.W., Wing A.L. (1994); Changes in Physical Activity and Other Lifeway Patterns Influencing Longevity. *Medicine and Science in Sports and Exercise,* 26 (7): 857-865.

Paffenbarger R.S., Lee I.M. (1997); Intensity of Physical Activity Related to Incidence of Hypertension and All-Cause Mortality: An Epidemiological View. *Blood Pressure Monitoring,* 2 (3): 115-123.

Pandolf K.B. (1983); Advances in the Study and Application of Perceived Exertion. In: Terjung R.L. (Ed); *Exercise and Sport Science Reviews* 11. Franklin Institute Press, 118- 158.

Papaioannou A. (1995); Differential Perceptual and Motivational Patterns when Different Goals are Adopted. *Journal of Sport and Exercise Psychology,* 17: 18-34.

Parfitt G., Rose E.A., Markland D. (2000); The Effect of Prescribed and Preferred Intensity Exercise on Psychological Affect and the Influence of Baseline Measures of Affect. *Journal of Health Psychology,* 5 (2): 231-240.

Pate R.R., Long B.J., Heath G. (1994); Descriptive Epidemiology of Physical Activity in Adolescents. *Pediatric Exercise Science,* 6: 434-447.

Pate R.R., Pratt M., Blair S.N., Haskell W.L., Macera C.A., Bouchard C., Buchner D., Ettinger W., Heath G.W., King A.C., Kriska A., Leon A.S., Marcus B.H., Morris J., Paffenbarger R.S., Patrick K., Pollock M.L., Rippe J.M., Sallis J., Wilmore J.H. (1995); Physical Activity and Public Health. A Recommendation from the Centres for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association,* 273 (5): 402-407.

Pavlou K., Krey S., Steffee W.P. (1989); Exercise as an Adjunct to weight Loss and Maintenance in Moderately Obese Subjects. *American Journal of Clinical Nutrition,* 49: 1115-1123.

Penney D., Yelling M. (2001); Implementation of the Revised National Curriculum for Physical Education: Juggling Interests and Achieving What Outcomes? *Sport Pedagogy,* 7: 1-23.

Piaget J. (1972); Intellectual Evolution from Adolescence to Adulthood. *Human Development,* 15: 1-12.

Piernon M., Cloes M., Delfosse C., Ledent M. (1996); An Investigation of the Effects of Daily Physical Education in Kindergarten and Elementary Schools. *European Physical Education Review,* 2: 116-132.

Pollock M.L., Foster C., Rod J.L., Wible G. (1982); Comparison of Methods of Determining Exercise Training Intensity for Cardiac Patients and Healthy Adults. In . Kellermann J.J (Ed.), *Comprehensive Cardiac Rehabilitation,* 129-33.

Pollock M.L., Jackson A.S., Foster C. (1986); The Use of the Perception Scale for Exercise Prescription. In: Borg G. and Ottoson D. (Eds.); *The Perception of Exertion in Physical Work.* Macmillan, London, 161-176.

Pollock M.L., Pels A.E., Foster C., Ward A. (1986b*);* Exercise Prescription for Rehabilitation of the Cardiac Patient. In: M.L. Pollock and D.H. Schmidt (Eds.), *Heart Disease and Rehabilitation (Second edition).* John Wiley: New York, 477-516.

Poulus A.J., Docter H.J., Westra H.G. (1974); Acid-base Balance and Subjective Feelings of Fatigue during Physical Exercise. *European Journal of Applied Physiology,* 33 (3): 207-213.

Powell K.E., Thompson P.D., Caspersen C.J., Kendrick K.S. (1987); Physical Activity and the Incidence of Coronary Heart Disease. *Annual Review of Public Health,* 8: 281-287.

Powers S.K., Dodd S., Deason R., Byrd R., McKnight T. (1983); Ventilatory Threshold, Running Economy and Distance Running Performance of Trained Athletes. *Research Quarterly for Exercise and Sport,* 54: 179-182.

Prentice A.M. (1997); Obesity –The Inevitable Penalty of Civilisation. *British Medical Bulletin,* 53 (2): 229-237.

Prentice A.M., Jebb S.A. (2001); Beyond Body Mass Index. *Obesity Review,* 2(3): 141-147.

Public Health Service (1991); *Healthy People 2000: National Health Promotion and Disease Prevention Objectives: Full Report with Commentary.* DHHS Publication no. (PHS) 91-50212. US Department of Health and Human Services, Washington, D.C.

Puhl J. Greaves K., Hoyt M., Baranowski T. (1990); Children's Activity Rating Scale (CARS): Description and Calibration. *Research Quarterly for Exercise and Sport,* 61 (1): 26-36.

Purvis J.W., Cureton K.W.J. (1981); Ratings of Perceived Exertion at the Anaerobic Threshold. *Ergonomics,* 24: 295-300.

Revell P. (1999); It's Not the Winning that Counts. In: *Times Education Supplement Friday Magazine.* February 26th, 16-17.

Riddoch C.J., Savage J.M., Murphy N., Cran G.W., Boreham C. (1991); Long Term Health Implications of Fitness and Physical Activity Patterns. *Archives of Disease in Childhood,* 66: 1426-1433.

Riddoch C.J., Boreham C.A. (1995); The Health-Related Physical Activity of Children. *Sports Medicine,* 19 (2): 86-102.

Riddoch C. J. (1998); Relationships between Physical Activity and Physical Health in Young People. In: Biddle S., Sallis J., Cavill N. (Eds), *Young and Active? Young People and Health-Enhancing Physical Activity – Evidence and Implications.* Health Education Authority, 17-47.

Robertson R.J. (1982); Central Signals of Perceived Exertion during Dynamic Exercise. *Medicine and Science in Sports and Exercise,* 14: 390-396.

Robertson R.J., Goss F.I., Auble T.E., Cassinelli D.A., Spina R.J., Glickman E.L., Galbreath R.W., Silberman R.M., Metz K.F. (1990); Cross-modal Exercise Prescription at Absolute and Relative Oxygen Uptake using Perceived Exertion. *Medicine and Science in Sports and Exercise,* 22: 653-659.

Robertson R.J., Nixon P.A., Caspersen C.J et al. (1992); Abatement of Exertional Perceptions Following Dynamic Exercise: Physiological Mediators. *Medicine and Science in Sports and Exercise,* 24 (3): 346-353.

Robertson R.J., Noble B. (1997*);* Perception of Physical Exertion: Methods, Mediators and Applications. In: *Exercise and Sport Sciences Reviews,* 25: 407-452. Holloszy J.O (Ed). American College of Sports Medicine. Williams and Wilkins, Baltimore.

Robertson R.J. (1997); Perceived Exertion in Young People: Future Directions of Inquiry. In: Welsman J., Armstrong N., Kirby B.; *Children and Exercise XIX International Symposium of Pediatric Work Physiology Vol II.* Washington Singer Press, Exeter, 33-39.

Robertson R.J., Goss F.L., Boer N.F., Peoples J.A., Foreman A.J., Dabayebeh I.M., Millich N.B., Balasekaran G., Riechman S.E., Gallagher J.D., Thompkins T. (1999); Children's OMNI Scale of Perceived Exertion: Mixed Gender and Race Validation. *Medicine and Science in Sports and Exercise,* 32: 452-458.

Robertson R. J., Goss F.L., Boer F., et al. (2000); Children's OMNI Scale of Perceived Exertion for Walking/Running. *Medicine and Science in Sports and Exercise,* 32: 452-458.

Ross J.G., Pate R.R. (1987); The National Children and Youth Fitness Study II: A Summary of Findings. *Journal of Physical Education Recreation and Dance,* 58 (1), 51-56.

Rowlands A.V., Eston R.G., Ingledew D.K. (1999); The Relationship between Activity Levels, Aerobic Fitness, and Body Fat in 8-to 10-Year-Old Children. *Journal of Applied Physiology,* 86: 1428-1435.

Rowlands A.V., Ingledew D.K., Eston R.G. (2000); The Effect of Type of Physical Activity Measure on the Relationship between Body Fatness and Habitual Physical Activity in Children: A Meta-Analysis. *Annals of Human Biology*, 27 (5): 479-497.

Rowlands A.V. (2001); Field Methods of Assessing Physical Activity and Energy Balance. In: *Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data (Second edition); Volume 1: Anthropometry.* (Eston R.G and Reilly T., Eds.). Routledge.

Sady S.P. (1986); Cardiorespiratory Exercise Training in Children. *Clinical Sports Medicine*, 5: 493-514.

Sallis J.F., Patterson T.L., Buono M.J., Nadder P.R. (1988); Relation of Cardiovascular Fitness and Physical Activity to Cardiovascular Disease Risk Factors in Children and Adults. *American Journal of Epidemiology*, 127: 933-941.

Sallis J.F. (1993); Epidemiology of Physical Activity and Fitness in Children and Adolescents. *Critical Reviews in Food Science and Nutrition*, 33: 403-8.

Sallis J.F., Patrick K. (1994); Physical Activity Guidelines for Adolescents: A Consensus Statement. *Pediatric Exercise Science*, 6: 302-314.

Saris W.H.M., Binkhorst R.A. (1977); The Use of Pedometer and Actometer in Studying Daily Physical Activity in Man. Part II. Validity of Pedometer and Actometer Measuring the Daily Physical Activity. *European Journal of Applied Physiology*, 37: 229-35.

Saris W.H.M. (1985); The Assessment and Evaluation of Daily Physical Activity in Children: A Review. *Acta Paediatrica Scandinavica*, Supplementum 318: 37-48.

Serdula M.K., Ivery D., Coates R.J., Freedman D.S., Williamson D.F., Byers T. (1993): Do Obese Children become Obese Adults? A Review of the Literature. *Preventive Medicine*, 22: 167-177.

Shahnawaz H. (1978); Influence of Limb Length on a Stepping Exercise. *Journal of Applied Physiology*, 44: 346-349.

Shea S., Basch C.E., Gutin B., Stein A.D., Contento I.R., Irigoyen M., Zybert P. (1994); The Rate of Increase in Blood Pressure in Children 5 Years of Age is Related to Changes in Aerobic Fitness and Body Mass Index. *Journal of Pediatrics*, 94 (4): 465 –470.

Shephard R.J., Lavallee H. (1977); *Frontiers of Physical Activity and Child Health.* Quebec City: Editions du Pelican.

Shephard R.J. (1987); *Exercise Physiology.* B.C.Decker Inc, Philadelphia .

Simon J.A., Smoll F.L. (1974); An Instrument for Assessing Children's Attitudes towards Physical Activity. *Research Quarterly*, 45 (4): 407-415.

Simons-Morton B., O'Hara N.M., Simons-Morton D., Parcel G.S. (1987); Children and Fitness: A Public Health Perspective. *Research Quarterly for Exercise and Sport*, 58: 295-302.

Simons-Morton B.G., Parcel G.S., O'Hara N.M., Blair S.N., Pate R.R. (1988); Health-Related Physical Fitness in Childhood. *Annual Review of Public Health*, 9: 403-425.

Simons-Morton B.G., et al. (1990); Children's Frequency of Participation in Moderate to Vigorous Physical Activities. *Research Quarterly for Exercise and Sport*, 61: 307-314.

Skinner J.S., Bar-Or O., Bergsteinova V., Bell C.W., Royer D., Buskirk E.R. (1971); Comparison of Continuous and Intermittent Tests for Determining Maximal Oxygen Uptake in Children. *Acta Paediatrica Scandinavica*, 217 (Suppl.): 24-28.

Skinner J.S; Hustler R., Bergsteinova V., et al. (1973); The Validity and Reliability of a Rating Scale of Perceived Exertion. *Medicine and Science in Sports and Exercise*, 5: 94-6.

Sleap M., Warburton P. (1990); *Physical Activity Patterns of Primary School Children.* Health Education Authority.

Smoll F.L., Schutz R.W. (1980); Children's Attitudes Towards Physical Activity: A Longitudinal Analysis. *Journal of Sports Psychology*, 2 (2): 137-147.

Smutok M.A., Skrinar G.S., Pandolf K.B. (1980); Exercise Intensity: Subjective Regulation by Perceived Exertion. *Archives of Physical Medical Rehabilitation*, 61: 569-574.

Stamford B.A. (1976); Validity and Reliability of Subjective Ratings of Perceived Exertion during Work. *Ergonomics*, 19: 53-60.

Stanforth D., Stanforth P., Velasquez K. (1993); Aerobic Requirement of Bench Stepping. *International Journal of Sports Medicine*. 14: 129-133.

Stern M., Haffner S. (1986); Body Fat Distribution and Hyperinsulinemia as Risk Factors for Diabetes and Cardiovascular Disease. *Arteriosclerosis*, 6: 123-130.

Stevens S.S. (1946); On the Theory of Scales of Measurement. *Science*, 103: 677-680.

Stevens S.S. (1971); Issues in Psychophysical Measurement. *Psychological Review*, 78: 426-450.

Stott P. (1999); The Role of the Primary Care Team in the Prevention and Treatment of Obesity. *Obesity in Practice*. Medical Educational Partnership. 1 (1): 12-15.

Stratton G., Armstrong N. (1994); Children's Use of RPE during Indoor Handball Lessons. *Journal of Sports Sciences*, 12 (2): 182-3.

Strazzullo P., Cappuccio F.P., Trevisan M., et al. (1988); Leisure-Time, Physical Activity and Blood Pressure in School-Children. *American Journal of Epidemiology*, 127: 726-733.

Strong W.B., Deckelbaum R.J., Gidding S.S., Kavey R.E.W., Washington R., Wilmore J.H., Perry C.L. (1992); Integrated Cardiovascular Health Promotion in Childhood. *Circulation*, 85 (4): 1638-1650.

Telama R., Viikari J., Valimaki I., et al. (1985); Atherosclerosis Precursors in Finnish Children and Adolescents. Leisure-Time Physical Activity. *Acta Paediatrica Scandinavica*, (Suppl). 318: 169-180.

The Annual Report of Her Majesty's Chief Inspector of Education and Training in Wales (2001). Estyn.

Thomas J.R., Nelson J.K. (1990); *Research Methods in Physical Activity (Second Edition).* Human Kinetics Books, Champaign, Illinois, 350-352.

Thomas S.G., Weller I.M.R., Cox M.H. (1993); Sources of Variation in Oxygen Consumption during a Stepping Task. *Medicine and Science in Sports and Exercise*, 25 (1): 139-144.

Thompson C.E., Wankle L.M. (1980); The Effect of Perceived Activity Choice upon Frequency of Exercise Behaviour. *Journal of Applied Social Psychology*, 10: 436-443.

Tipton C.M. (1991); Exercise Training and Hypertension: An Update. *Exercise and Sports Science Reviews*. 19: 447-505.

Tolfrey K., Mitchell J. (1996); Ratings of Perceived Exertion at Standard and Relative Exercise Intensities in Prepubertal Teenage and Young Adult Males. *Journal of Sports Science*. 14 (1): 101-2.

Troiano R.P., Flegal K.M., Kuczmarski R.J., Campbell S.M., Johnson C.L. (1995); Overweight Prevalence and Trends for Children and Adolescents: The National Health and Nutrition Examination Surveys, 1963 to 1991. *Archives of Pediatrics and Adolescent Medicine,* 149 (10), 1085-1091.

Ueda T., Kurokawa T. (1991); Validity of Heart Rate and Ratings of Perceived Exertion as Indices of Exercise Intensity in a Group of Children while Swimming. *European Journal of Applied Physiology*, 63: 200-204.

Unnithan V.B., Timmons J.A., Paton J.Y., Rowland T.W. (1995); Physiologic Correlates of Running Performance in Pre-pubertal Distance Runners. *International Journal of Sports Medicine*, 16: 528-533.

Updyke W., Willett M.S. (1989); Physical Fitness Trends in American Youth 1980-1989. Bloomington. In: Chrysler A.A.U., *Physical Fitness Program.*

U.S. Centres for Disease Control and Prevention (USCDC) and American College of Sports Medicine (ACSM) (1993); Summary Statement: Workshop on Physical Activity and Public Health. *Sports Medicine Bulletin*, 28 (4): 7.

Utter A.C., Robertson R.J., Nieman D.C., Kang J. (2002); Children's OMNI Scale of Perceived Exertion: Walking/Running Evaluation. *Medicine and Science in Sports and Exercise,* 34 (1): 139-44.

Van Huss W.D., Stephens K.E., Vogel P., et al. (1986); Physiological and Perceptual Responses of Elite Age Group Distance Runners during Progressive Intermittent Work to Exhaustion. In: Weiss M, Gould D (Eds). *Sport for Children and Youth.* Human Kinetics, Champaign, Illinois. 239-46.

Verschuur R., Kemper H.C.G., Besseling C.W.M. (1984); Habitual Physical Activity and Health in 13 and 14 year old Teenagers. In: Ilmarinen J., and Valimaki I. (Eds). *Children and Sport.* Springer-Verlag, New York, 255-261.

Verschuur R., Kemper H.C.G. (1985); The Pattern of Daily Physical Activity. *Medicine and Sport Science,* 20: 169-186.

Vincent W.J. (1995); *Statistics in Kinesiology.* Human Kinetics, Champaign, Illinois. 178-180.

Walberg J., Ward D. (1985); Role of Physical Activity in the Etiology and Treatment of Childhood Obesity. *Paediatrician,* 2: 82- 88.

Walker C.A.H., Lamb K.L., Marriott H.E. (1996); The Validity of Using Ratings of Perceived Exertion to Estimate and Regulate Exercise Intensity during Stepping Ergometry. *Journal of Sports Science*, 14: 102-3.

Wankel L., Kreisel P. (1985); Factors Underlying Enjoyment of Youth Sports: Sport and Age Group Comparisons. *Journal of Sport Psychology*, 7: 51-64.

Ward D.S., Blimkie C.J.R., Bar-Or O. (1986); Rating of Perceived Exertion in Obese Adolescents (abstract). *Medicine and Science in Sports and Exercise*, 18: S72.

Ward D.S., Bar-Or O. (1990); Use of the Borg Scale in Exercise Prescription for Overweight Youth. *Canadian Journal of Sport Science*, Toronto, 15 (2): 120-125.

Ward D.S., Jackman J.D., Galiano F.J. (1991); Exercise Intensity Reproduction: Children versus Adults. *Pediatric Exercise Science*, 3 (3): 209-218.

Ward D.S., Bar-Or O., Longmuir P., Smith K. (1995); Use of Ratings Of Perceived Exertion (RPE) to Prescribe Exercise Intensity for Wheelchair-bound Children and Adults. *Pediatric Exercise Science*, 7: 94-102.

Washburn R., Chin M.K., Montoye H.J. (1980); Accuracy of Pedometer in Walking and Running. *Research Quarterly for Exercise and Sport*, 51: 695-702.

Wasserman K., Whipp B.J., Koyal S.N., Beaver W.L. (1973); Anaerobic Threshold and Respiratory Gas Exchange During Exercise. *Journal of Applied Physiology*, 35, 236-43.

Watt B., Grove R. (1993); Perceived Exertion: Antecedents and Applications. *Sports Medicine*, 15 (4): 225-241.

Weiss M.R., Bredemeier B.J., Schewchuk R.M. (1985); An Intrinsic/ Extrinsic Motivational Scale for the Youth Sport Setting. A Confirmatory Analysis. *Journal of Sports Psychology*, 7 (1): 75-91.

Wenos D.L., Wallace J.P., Surburg P.R et al. (1996); Reliability and Comparison of RPE during Variable and Constant Exercise Protocols Performed by Older Women. *International Journal of Sports Medicine*, 17: 193-8.

Williams J.G., Eston R.G. (1988); Reliability of Ratings of Perceived Effort for Regulation of Exercise Intensity. *British Journal of Sports Medicine*, 22: 153-4.

Williams J.G., Eston R.G. (1989); Determination of the Intensity Dimension in Vigorous Exercise Programmes with Particular Reference to the Use of the Rating of Perceived Exertion. *Sports Medicine*, 8 (3): 177-189.

Williams J.R., Armstrong N. (1991); Relationship of Maximal Lactate Steady State to Performance at Fixed Blood Lactate Reference Values in Children. *Pediatric Exercise Science*, 3: 333-341.

Williams J.G., Eston R.G., Stretch C. (1991); Use of Rating of Perceived Exertion to Control Exercise Intensity in Children. *Pediatric Exercise Science*, 3: 21-27.

Williams T.J., Krahenbuhl G.S., Morgan D.W. (1991a); Mood State and Running Economy in Moderately Trained Male Runners. *Medicine and Science in Sports and Exercise*. 23 (6): 727- 731.

Williams J.G., Furlong B., Mackintosh C., Hockley T.J. (1993); Rating and Regulation of Exercise Intensity in Young Children. *Medicine and Science in Sports and Exercise*, 25 (5), Suppl. S8.

Williams J.G., Eston R.G., Furlong B. (1994); CERT: A Perceived Exertion Scale for Young Children. *Perceptual and Motor Skills*, 79: 1451-1458.

Williams J.G., Eston R.G. (1996); Exercise Intensity Regulation. In: *Kinanthropometry and Exercise Physiology Laboratory Manual. (First edition).* Eston R ., and Reilly T. (Eds). E and FN Spon, 221-235.

Winter E.M., MacLaren D.P. (2001); Assessment of Maximal-Intensity Exercise. In: *Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data (Second edition). Volume 2: Exercise Physiology.* (Eston R. and Reilly T., Eds). Routledge, 266.

World Health Organisation (1998); *Obesity: Preventing and Managing the Global Epidemic.* Report No. WHO/NUT/NCD, 98.1. WHO, Geneva.

Yelling M., Swaine I. (2000); *Illustrated CERT Scale. Unpublished Paper.* DeMontfort University, Bedford, U.K.

Yelling M., Lamb K., Swaine I. (In Press); The Pictorial Children's Effort Rating Table: A validation Study. *European Physical Education Review*, 8 (2).

Yorio J.M., Dishman R.K., Forbus W.R et al. (1992); Breathlessness Predicts Perceived Exertion in Young Women with Mild Asthma. *Medicine and Science in Sports and Exercise*, 24 (8): 860-867.

APPENDICES

APPENDIX A

A: Ethical Approval

Wiltshire
Health Authority

Ref: SJC App SW 54/98

18 January 1999

Miss Pamela Shepherd
Human Movement Science
Physical Education and Cell Biology
47 Tugela Road
Chippenham
Wiltshire SN15 1JF

Dear Miss Shepherd

SW54/98 ***(This number must be quoted in all correspondence)***
The Use of Effort Rating Scales to Control Exercise Intensity in Children

Your Application was considered by the Swindon Research Ethics Committee on 11 January 1999 and I will be able to give full approval to this Study on condition that the language used in the various scoring systems and assessment scales is greatly simplified for use by young children. The Committee felt that the use of phrases such as 'perceived exertion' amongst others is a barrier to the effective evaluation of these instruments.

You may find it helpful to talk to an educationalist about the appropriate level of comprehension of children of this age.

I look forward to hearing from you.

Yours sincerely

P. Hanson.

Dr Peter Hanson MA MD FRCP
Chairman - Swindon Research Ethics Committee

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Working for the health of the people of Wiltshire

Ref: SJC SW 54/98

31 March 1999

Miss Pamela Shepherd
Human Movement Science
Physical Education and Cell Biology
47 Tugela Road
Chippenham
Wiltshire SN15 1JF

Wiltshire
Health Authority

Dear Miss Shepherd

SW54/98 ***(This number must be quoted in all correspondence)***
The Use of Effort Rating Scales to Control Exercise Intensity in Children

Thank you for your letter of 15 March 199 in response to Dr Hanson's letter of 18 January.

I have spoken to a member of the Swindon Research Ethics Committee who is involved in education and she suggests you contact either:-

1. Head teachers of primary schools (or a member of the teaching staff)
2. Someone from King Alfred College Winchester

I hope this information is useful and look forward to hearing from you further..

Yours sincerely

Sally Collier (Mrs)
Administrator - Swindon Research Ethics Committee

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APPENDIX B

B: Parental Information Sheet

THE UNIVERSITY OF W ALES, BANGOR SCHOOL OF SPORT, HEALTH & EXERCISE SCIENCES

Can Children Use Effort Rating Scales to Control Exercise Intensity?

Several effort rating scales have been developed for adults, and are used to control exercise intensity in a variety of settings including gymnasiums and for rehabilitation purposes in hospitals. These scales however, are inappropriate for use with children as comprehension difficulties may exist. Recently, new scales have been developed specifically for use with children. These child-specific effort rating scales need to be tested to see if they are indeed more suitable to control exercise intensity in children.

Why Are These Scales Useful?

Studies in Japan and the United States have suggested that primary schoolchildren rarely undergo physical activity sufficient to promote cardiovascular health. By validating these scales, they may be used in a physical education / games lesson to encourage / increase physical activity. These scales may help to encourage children to stick to an appropriate level of exercise, which they find enjoyable, and thus improve health benefits. These experiences may be carried over into adulthood.

Who Will Participate In This Study?

Thirty children will be invited to participate from Walter Powell Primary School, Great Somerford, Wiltshire. All children will be anonymous in the published results, and total confidentiality throughout the study is assured.

What Sort of Exercise Will Be Involved?

Your child will participate in simple stepping and cycling tasks, which will be of a light to moderate intensity , no more strenuous than normal daily living. Each task will last no longer than thirty minutes, and will be carried out on the school premises in normal time allocated for Physical Education, supervised by a researcher.

What Measurements Will Be Taken?

All children participating in this project will have the same measurements recorded. These will be; Age, Height, Weight and Resting Heart Rate. Other measurements taken will be:

- Exercise Heart Rate. This will be recorded via a Heart Rate monitor, which your child will wear.
- Power Output. This will be recorded by the researcher directly from the cycle or calculated by the researcher from the stepping task.
- Ratings of Exercise Effort. Your child will also be asked to give the researcher feedback on their exercise experiences using various effort rating scales.

Are There Any Risks? ,

The type and amount of exercise used in this project will be no more strenuous than your child would carry out as a part of normal daily living. Ethical approval for this project has been gained from the South and West Research Medical Ethics Committee.

What Next?

If you would like your child to participate in this research project please complete the attached consent form and return the form with your child to their school teacher.

- The researcher will tell your child the nature and purpose of the study. Your child will also be required to sign the consent form.
- Your child will participate in a small group interview and will be shown the equipment that will be used.
- Scheduled dates to carry out testing have been decided between the researcher and the head teacher of the school.
- All testing will be carried out on the school premises, in normal time allocated for physical education, supervised by a researcher. Tasks will be repeated on separate occasions for reliability . **Please indicate on the consent form if you are willing to let your child participate in this project. Thank you for your interest.**

B2: Informed Consent Form

CONSENT FORM

The Use of Effort Rating Scales to Control Exercise Intensity in Children

Dear Parent / Guardian,

Please read the information sheet prior to completing this form. I would like to ask your permission for your child to participate in;

1. Light to moderate exercise involving simple stepping and cycling tasks, which will be no more strenuous than normal daily living. Heart rate will be recorded during exercise via a heart rate monitor, which your child will wear.
2. A small group interview which will be audio-taped and transcribed. Your child will be shown a number of effort rating scales, and their views recorded.

Tasks will be carried out on the school premises in normal time allocated for Physical Education, supervised by a researcher.

I do hope that you will agree for your child to take part in this important study, and I am sure that they will find it an interesting, enjoyable and educational experience. Please indicate below if you are willing to let your child participate in the project.

PLEASE TICK YES OR NO

YES ☐ **I give permission for my son/ daughter to take part in 'The Use of Effort Rating Scales to Control Exercise Intensity in Children'. I understand that I may withdraw my consent at any stage of this investigation.**

NO ☐ **I do not give permission for my son/ daughter to take part in 'The Use of Effort Rating Scales to Control Exercise Intensity in Children'.**

NAME OF SON/ DAUGHTER ______________________________

PARENT / GUARDIAN SIGNATURE ______________________________

(Children between 8 and 16 years must, in addition to a parent, also sign the consent form below).

SIGNATURE OF SON / DAUGHTER ______________________________

DATE ____________________

If you would like more information about the research please do not hesitate to contact me by writing to the University or telephone me at work on 01249 464644 ext. 342. I will be happy to answer any questions you may have. All participating individuals will be anonymous in the published results and total confidentiality throughout the study is assured.

PLEASE RETURN THIS FORM TO THE SCHOOL BY ____________________

DECLARATION BY THE INVESTIGATOR

I confirm that I have provided an information sheet and explained the nature and effect of the procedures to the volunteer and that his/ her consent has been given freely and voluntarily. SIGNED ____________________

Miss P. Shepherd BSc. (Hons).

APPENDIX C

C1: Example Instructions for Use of Perceived Exertion Scale

Children's Effort Rating Table (CERT)

When you exercise whether it is walking around the playground or running very fast in a race, it is possible to describe how the activity makes you feel. Sometimes exercise can feel hard, sometimes it can feel easy.

Scientists have developed a special scale for children, to understand how the exercise makes you feel. The scale starts at 1 (very, very easy) and goes up to 10 (so hard I am going to stop). Each number on the scale has a different 'feeling' next to it.

We would like you to practise using this scale to produce a level of exertion for which you would give a number 3, 5, and 8 on the scale.

In the exercise period that follows this short practice period, you will be asked to exercise at these levels for about 3 minutes. The order of the exercise levels may be mixed.

APPENDIX D

D1: Chapter 3 Factorial Analysis
Analysis of variance Summary Table (Heart Rate data) for CERT, BABE and CALER

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subject total	17	29323.83			
Scales.	2	690.75	345.38	0.18	0.805
Residual.	15	28633.08	1908.87		
Within subject total	144	17425.67			
Trials.	2	393.00	196.50	0.95	0.549
Scales.Trial.	4	403.50	100.88	0.49	0.580
Residual.	30	6177.92	205.93		
Sub-total	36	6974.42			
Level.	2	7110.50	3555.25	76.18	0.006
Scales.Level.	4	14.50	3.62	0.08	0.961
Residual.	30	1400.08	46.67		
Sub-total	36	8525.08			
Trials.Level.	4	105.50	26.38	0.93	0.415
Scales. Trial . Level	8	118.00	14.75	0.52	0.862
Residual.	60	1702.75	28.38		
Sub-total	72	1926.25			
Grand total	161	46749.50			

HEART RATE DATA

Source of Variation	DF	Sum of Squares	Mean Square	F-Rati
Scales. Linear trend	1	154.08	154.08	0.08
Scales. Quadratic trend	1	536.69	536.69	0.28
Trials. Linear trend	1	228.23	228.23	1.11
Trials. Quadratic trend	1	164.69	164.69	0.80
Level. Linear trend	1	7105.33	7105.33	152.25
Level. Quadratic trend	1	5.44	5.44	0.12

Analysis of Variance Summary Table (Power Output data) for CERT, BABE and CALER

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subject total	17	19178.37			
Scales.	2	2614.25	1307.12	1.18	0.351
Residual.	15	16564.12	1104.27		
Within subject total	144	816.79			
Trials.	2	0.06	0.03	0.03	0.883
Scales.Trial.	4	3.38	0.84	0.80	0.582
Residual.	30	31.59	1.05		
Sub-total	36	35.03			
Level.	2	726.97	363.48	355.95	0.000
Scales.Level.	4	8.59	2.15	2.10	0.172
Residual.	30	30.64	1.02		
Sub-total	36	766.20			
Trials.Level.	4	1.47	0.37	1.85	0.556
Scales. Trial . Level.	8	2.06	0.26	1.30	0.269
Residual.	60	11.91	0.20		
Sub-total	72	15.44			
Grand total	161	19995.16			

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio
Scales. Linear trend	1	539.13	539.13	0.49
Scales. Quadratic trend	1	2075.31	2075.31	1.88
Trials. Linear trend	1	0.16	0.16	0.15
Trials. Quadratic trend	1	0.09	0.09	0.08
Level. Linear trend	1	727.07	727.07	711.99
Level. Quadratic trend	1	0.01	0.01	0.01

Analysis of Variance Summary Table: CERT (Heart Rate) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	13189.83			
Within subject total	48	7872.67			
CERT.	2	2345.50	1172.75	28.21	0.000
Residual.	10	415.79	41.58		
Sub-total	12	2761.29			
TRIALS.	2	666.25	333.12	0.93	0.424
Residual.	10	3563.71	356.37		
Sub-total	12	4229.96			
CERT.TRIALS.	4	112.25	28.06	0.73	0.582
Residual.	20	769.12	38.46		
Sub-total	24	881.38			
Grand total	53	21062.50			
CERT. Linear trend	1	2336.11	2336.11	56.18	
CERT. Quadratic trend	1	9.48	9.48	0.23	
TRIALS. Linear trend	1	568.03	568.03	1.59	
TRIALS. Quadratic trend	1	98.23	98.23	0.28	

Analysis of Variance Summary Table: BABE (Heart Rate) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	5283.10			
Within subject total	48	4805.78			
BABE.	2	2473.12	1236.50	19.14	0.000
Residual.	10	645.96	64.60		
Sub-total	12	3119.08			
TRIALS.	2	79.12	39.56	0.33	0.680
Residual.	10	1213.29	121.33		
Sub-total	12	1292.42			
BABE.TRIALS	4	41.38	10.34	0.59	0.760
Residual.	20	352.88	17.64		
Sub-total	24	394.25			
Grand total	53	10088.88			
BABE. Linear trend	1	2466.78	2466.78	38.19	
BABE. Quadratic trend	1	6.26	6.26	0.10	
TRIALS. Linear trend	1	12.25	12.25	0.10	
TRIALS. Quadratic trend	1	66.90	66.90	0.55	

Analysis of Variance Summary Table: CALER (Heart Rate) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	10160.61			
Within subject total	48	4760.89			
CALER.	2	2325.88	1162.94	35.78	0.000
Residual.	10	325.00	32.50		
Sub-total	12	2650.88			
TRIALS.	2	51.12	25.56	0.18	0.836
Residual.	10	1400.42	140.04		
Sub-total	12	1451.54			
CALER.TRIALS.	4	60.88	15.22	0.51	0.670
Residual.	20	597.62	29.88		
Sub-total	24	658.50			
Grand total	53	14921.50			
CALER. Linear trend	1	2320.03	2320.03	71.39	
CALER. Quadratic trend	1	5.79	5.79	0.18	
TRIALS. Linear trend	1	34.03	34.03	0.24	
TRIALS. Quadratic trend	1	17.12	17.12	0.12	

Analysis of Variance Summary Table: CERT (Power Output) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	1923.86			
Within subject total	48	349.15			
CERT.	2	315.02	157.51	587.22	0.000
Residual.	10	2.68	0.27		
Sub-total	12	317.70			
TRIALS.	2	1.45	0.73	0.32	0.711
Residual.	10	22.43	2.24		
Sub-total	12	23.89			
CERT.TRIALS.	4	2.44	0.61	2.38	0.105
Residual.	20	5.12	0.26		
Sub-total	24	7.56			
Grand total	53	2273.02			
CERT. Linear trend	1	314.94	314.94	1174.16	
CERT. Quadratic trend	1	0.19	0.19	0.72	
TRIALS. Linear trend	1	0.71	0.71	0.32	
TRIALS. Quadratic trend	1	0.86	0.86	0.38	

Analysis of Variance Summary Table: BABE (Power Output) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	9340.13			
Within subject total	48	227.71			
BABE.	2	191.69	95.84	45.46	0.000
Residual.	10	21.08	2.11		
Sub-total	12	212.77			
TRIALS.	2	1.55	0.77	0.92	0.402
Residual.	10	8.43	0.84		
Sub-total	12	9.98			
BABE.TRIALS.	4	0.95	0.24	1.18	0.431
Residual.	20	4.03	0.20		
Sub-total	24	4.98			
Grand total	53	9567.84			
BABE. Linear trend	1	191.64	191.64	90.90	
BABE. Quadratic trend	1	0.16	0.16	0.07	
TRIALS. Linear trend	1	1.25	1.25	1.48	
TRIALS. Quadratic trend	1	0.42	0.42	0.49	

Analysis of Variance Summary Table: CALER (Power Output) Data

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig. F
Between subject total	5	5300.97			
Within subject total	48	239.25			
CALER.	2	227.92	113.96	155.40	0.000
Residual.	10	7.33	0.73		
Sub-total	12	235.26			
TRIALS.	2	0.12	0.06	0.52	0.512
Residual.	10	1.20	0.12		
Sub-total	12	1.33			
CALER.TRIALS.	4	0.52	0.13	1.19	0.468
Residual.	20	2.17	0.11		
Sub-total	24	2.69			
Grand total	53	5540.22			
CALER. Linear trend	1	227.96	227.96	310.85	
CALER. Quadratic trend	1	0.06	0.06	0.08	
TRIALS. Linear trend	1	0.17	0.17	1.39	
TRIALS. Quadratic trend	1	0.06	0.06	0.46	

D2: Linear Regression Analysis

SUMMARY OUPUT: CERT (Power Output)

Regression Statistics	
Multiple R	0.34147839
R Square	0.11660749
Adjusted R Square	0.06139546
Standard Error	6.38156007
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	54.0246491	4.183815034	12.91277	7.06E-10	45.15535946	62.89394	45.1553595	62.8939388
rating	1.06381579	0.732015144	1.45327	0.165481	-0.487986842	2.615618	-0.4879866	2.61561822

SUMMARY OUPUT: BABE (Power Output)

Regression Statistics	
Multiple R	0.13293199
R Square	0.01767091
Adjusted R Square	-0.0437247
Standard Error	14.224204
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	45.3770175	9.32553135	4.865891	0.000172	25.60777868	65.14626	25.6077787	65.1462564
rating	0.87535088	1.631628099	0.536489	0.599001	-2.583545395	4.334247	-2.5835454	4.33424715

SUMMARY OUPUT: CALER (Power Output)

Regression Statistics	
Multiple R	0.21307955
R Square	0.0454029
Adjusted R Square	-0.0142594
Standard Error	10.5176591
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	49.7574561	6.895483177	7.215949	2.06E-06	35.13968811	64.37522	35.1396881	64.3752242
rating	1.05245614	1.206458237	0.872352	0.395919	-1.505120491	3.610033	-1.5051205	3.61003277

SUMMARY OUPUT: CERT (Heart Rate)

Regression Statistics	
Multiple R	0.48139781
R Square	0.23174386
Adjusted R Square	0.18372785
Standard Error	14.4631167
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	129.72807	9.482164896	13.68127	3.01E-10	109.6267831	149.8294	109.626783	149.829357
rating	3.64473684	1.659033261	2.196904	0.043104	0.127744235	7.161729	0.12774423	7.16172945

SUMMARY OUPUT: BABE (Heart Rate)

Regression Statistics	
Multiple R	0.55228925
R Square	0.30502342
Adjusted R Square	0.26158738
Standard Error	11.485331
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	140.324561	7.529898861	18.63565	2.84E-12	124.3618929	156.2872	124.361893	156.28723
rating	3.49122807	1.317457824	2.649973	0.01747	0.698342878	6.284113	0.69834288	6.28411326

SUMMARY OUTPUT: CALER (Heart Rate)

Regression Statistics	
Multiple R	0.51215123
R Square	0.26229888
Adjusted R Square	0.21619256
Standard Error	11.1734359
Observations	18

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	138.807018	7.325417043	18.94868	2.2E-12	123.2778306	154.3362	123.277831	154.336204
rating	3.05701754	1.281680994	2.385163	0.029785	0.339975827	5.774059	0.33997583	5.77405926

Data from Figure 1: Williams et al. (1994)

HR (bpm) = $\frac{230-110}{10-0}$ (CERT Effort Rating) + 110

HR (bpm) = 12 (CERT) + 110

PO (W) = $\frac{100-10}{9-0}$ (CERT Effort Rating) + 10

PO (W) = 10 (CERT) + 10

APPENDIX E

E: Chapter 5 Factorial Analysis

HEART

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	29	29883.83			
Group.	1	252.00	252.00	0.24	.425
Residual	28	29631.83	1058.28		
Within subjects total	150	22997.67			
Mode.	1	1100.00	1100.00	5.50	.047
Group.Mode.	1	2.00	2.00	0.01	.911
Residual	28	5599.50	199.98		
Sub-total	30	6701.50			
Level.	2	14898.00	7449.00	1198.69	.000
Group.Level.	2	2.00	1.00	0.16	.553
Residual	56	348.00	6.21		
Sub-total	60	15248.00			
Mode.Level.	2	287.00	143.50	10.99	.009
Group.Mode.Level.	2	29.50	14.75	1.13	.492
Residual	56	731.50	13.06		
Sub-total	60	1048.00			
Grand total	179	52881.50			
Level. Linear trend	1	14896.41	14896.41	2397.12	
Level. Quadratic trend	1	1.47	1.47	0.24	

POWER

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	29	9250.79			
group.	1	693.62	693.62	2.27	.324
Residual	28	8557.17	305.61		
Within subjects total	150	28458.27			
mode.	1	7709.12	7709.12	39.97	.006
group.mode.	1	216.31	216.31	1.12	.249
Residual	28	5401.04	192.89		
Sub-total	30	13326.48			
level.	2	9629.25	4814.62	593.87	.000
group.level.	2	7.56	3.78	0.47	.705
Residual	56	454.00	8.11		
Sub-total	60	10090.81			
mode.level.	2	4591.50	2295.75	287.13	.000
group.mode.level.	2	1.75	0.88	0.11	.615
Residual	56	447.75	8.00		
Sub-total	60	5041.00			
Grand total	179	37709.06			
level. Linear trend	1	9617.66	9617.66	1186.32	
level. Quadratic trend	1	11.84	11.84	1.46	

HR3

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	29	30455.83			
Group.	1	198.00	198.00	0.18	.570
Residual	28	30257.83	1080.64		
Within subjects total	150	14759.67			
Mode.	1	98.00	98.00	0.44	.691
Group.Mode.	1	66.50	66.50	0.30	.450
Residual	28	6288.33	224.58		
Sub-total	30	6452.83			
Trial.	2	90.00	45.00	0.61	.633
Group.Trial.	2	350.00	175.00	2.37	.507
Residual	56	4131.00	73.77		
Sub-total	60	4571.00			
Mode.Trial.	2	105.50	52.75	0.87	.557
Group.Mode.Trial.	2	250.00	125.00	2.07	.402
Residual	56	3380.00	60.36		
Sub-total	60	3735.50			
Grand total	179	45215.50			Sig F.
Trial. Linear trend	1	38.53	38.53	0.52	
Trial. Quadratic trend	1	51.38	51.38	0.70	

HR5

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	29	32126.83			
Group.	1	286.00	286.00	0.25	.781
Residual	28	31840.83.	1137.17		
Within subjects total	150	13993.67			
Mode.	1	1372.50	1372.50	5.61	.048
Group.Mode.	1	11.50	11.50	0.05	.890
Residual	28	6852.83	244.74		
Sub-total	30	8236.83			
Trial.	2	209.50	104.75	2.37	.402
Group.Trial.	2	93.50	46.75	1.06	.571
Residual	56	2477.00	44.23		
Sub-total	60	2780.00			
Mode.Trial.	2	85.50	42.75	0.86	.300
Group.Mode.Trial.	2	115.50	57.75	1.17	.320
Residual	56	2775.50	49.56		
Sub-total	60	2976.50			
Grand total	179	46120.50			Sig F.
Trial. Linear trend	1	16.13	16.13	0.36	
Trial. Quadratic trend	1	193.60	193.60	4.38	

HR8

Between subjects total	29	28167.00			
Group.	1	245.00	245.00	0.25	.830
Residual	28	27922.00	997.21		
Within subjects total	150	13450.00			
Mode.	1	2660.50	2660.50	13.01	.008
Group.Mode.	1	0.50	0.50	0.00	.952
Residual	28	5724.33	204.44		
Sub-total	30	8385.33			
Trials.	2	87.00	43.50	1.21	.373
Group.Trials.	2	51.50	25.75	0.72	.740
Residual	56	2006.50	35.83		
Sub-total	60	2145.00			
Mode.Trials.	2	16.00	8.00	0.16	.610
Group.Mode.Trials.	2	153.00	76.50	1.56	.119
Residual	56	2750.50	49.12		
Sub-total	60	2919.50			
Grand total	179	41617.00			Sig F.
Trials. Linear trend	1	3.67	3.67	0.10	
Trials. Quadratic trend	1	83.14	83.14	2.32	

Analysis of Variance Summary Table

PO3

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	29	6945.06			
Group.	1	511.50	511.50	2.23	.705
Residual	28	6433.56	229.77		
Within subjects total	150	7630.88			
Mode.	1	5.62	5.62	0.03	.837
Group.Mode.	1	277.75	277.75	1.63	.119
Residual	28	4760.67	170.02		
Sub-total	30	5044.04			
Trials.	2	318.31	159.16	8.63	.009
Group.Trials.	2	60.06	30.03	1.63	.576
Residual	56	1032.25	18.43		
Sub-total	60	1410.62			
Mode.Trials.	2	216.44	108.22	6.54	.008
Group.Mode.Trials.	2	33.69	16.84	1.02	.621
Residual	56	926.06	16.54		
Sub-total	60	1176.19			
Grand total	179	14575.94			Sig F.
Trials. Linear trend	1	314.28	314.28	17.05	
Trials. Quadratic trend	1	4.31	4.31	0.23	

PO5

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	29	9541.65			
Group.	1	751.38	751.38	2.39	.621
Residual	28	8790.27	313.94		
Within subjects total	150	16691.61			
mode.	1	8580.69	8580.69	41.31	.000
Group.mode.	1	196.19	196.19	0.94	.710
Residual	28	5815.31	207.69		
Sub-total	30	14592.19			
trials.	2	120.12	60.06	3.48	.548
Group.trials.	2	24.44	12.22	0.71	.320
Residual	56	967.00	17.27		
Sub-total	60	1111.56			
mode.trials.	2	77.75	38.88	2.57	.541
Group.mode.trials.	2	61.62	30.81	2.03	.417
Residual	56	848.50	15.15		
Sub-total	60	987.88			
Grand total	179	26233.25			Sig F.
trials. Linear trend	1	115.64	115.64	6.70	
trials. Quadratic trend	1	4.58	4.58	0.27	

PO8

Between subjects total	29	12694.29			
Group.	1	854.81	854.81	2.02	.322
Residual	28	11839.48	422.84		
Within subjects total	150	37979.21			
Mode.	1	28403.12	28403.12	114.63	.000
Group.Mode.	1	184.81	184.81	0.75	.591
Residual	28	6937.79	247.78		
Sub-total	30	35525.73			
Trials.	2	12.44	6.22	0.30	.610
Group.Trials.	2	28.75	14.38	0.70	.537
Residual	56	1142.00	20.39		
Sub-total	60	1183.19			
Mode.Trials.	2	0.56	0.28	0.01	.818
Group.Mode.Trials.	2	61.75	30.88	1.43	.760
Residual	56	1208.44	21.58		
Sub-total	60	1270.75			
Grand total	179	50673.50			Sig F.
Trials. Linear trend	1	9.92	9.92	0.49	
Trials. Quadratic trend	1	2.62	2.62	0.13	

APPENDIX F

F: Coefficient of Variation

POWER OUTPUT DATA

Power.DAT	Mean	SD	υ (%)
Caler.Cycle	70.409	15.06	21.39
Caler.Step	55.129	6.92	12.55
Babe.Cycle	72.144	16.90	23.43
Babe.Step	61.247	12.01	19.61

HEART RATE DATA

Heart.DAT	Mean	SD	υ (%)
Caler.Cycle	167.800	17.77	10.59
Caler.Step	162.644	16.76	10.30
Babe.Cycle	169.956	20.59	12.11
Babe.Step	165.222	16.63	10.07

APPENDIX G

G1: Scale Preference Questionnaire

Prifysgol Cymru · University of Wales

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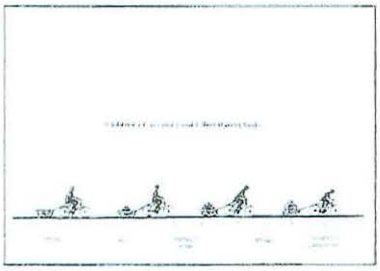
1[st] December 2000

Dear Jenna,

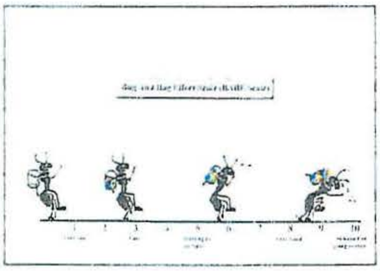
Thanks for taking part in the Cycling and Stepping exercises held at Walter Powell Primary School, Great Somerford. I hope you enjoyed it!

If you had to complete the exercises again, which Scale would you prefer to use? **Please tick 1 box below to show the Scale you would prefer to use.**



I WOULD PREFER TO USE THE CART (CYCLING) SCALE
Please tick ☐

OR



I WOULD PREFER TO USE THE BUG (STEPPING) SCALE
Please tick ☑

Thanks for your time!

P.M.Shepherd.

Pam Shepherd
PhD student.

Head of School
Pennaeth Ysgol
Dr Roger Eston, DPE, MEd, BEd

G2: Chi-squared Analysis

Cross tabulations / Chi-squared

Corrected Chi-squared = 4.171 with 1 degree of freedom

Contingency Coefficient = 0.355

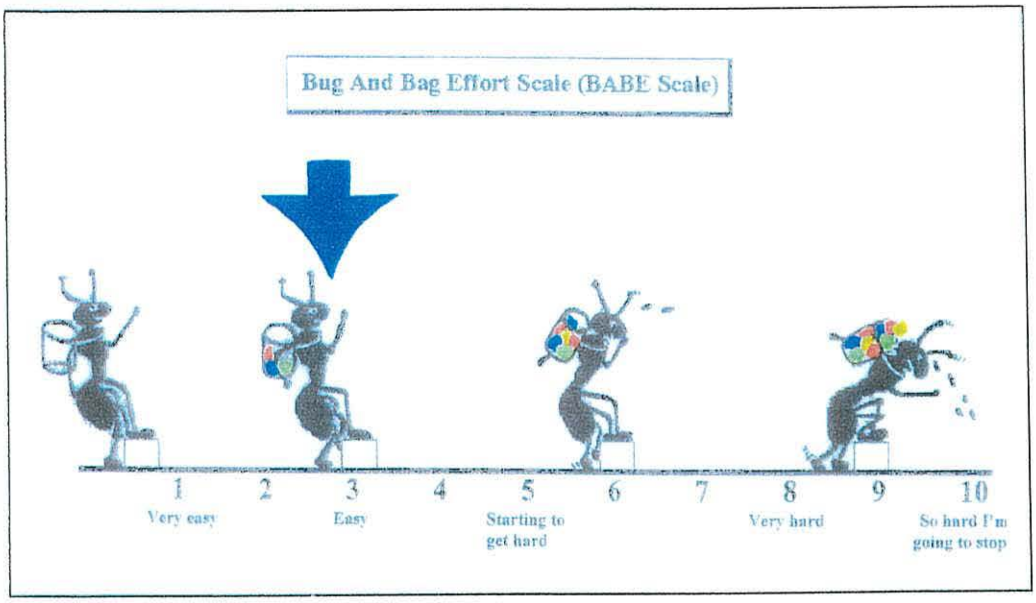
Cramer's V = 0.379

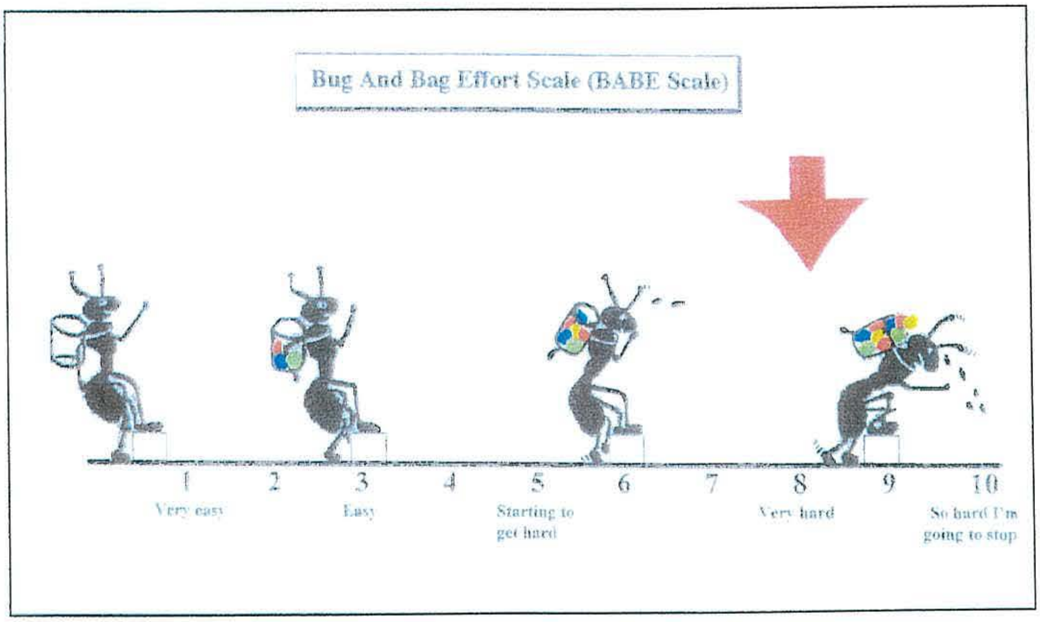
Lambda-AB = 0.38 (symmetric)

Count Row % Col % ExpVal	Used CALER	Used BABE	Totals
Change	9 75.0 64.3 5.8	3 25.0 20.0 6.2	12 41.4
Retention	5 29.4 35.7 8.2	12 70.6 80.0 8.8	17 58.6
Totals	14 48.3	15 51.7	29

APPENDIX H

H1: BABE Scales





H2: Chapter 6 Factorial Analysis

Repetitions (With BABE)

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	14	10266.88			
Within subjects total	105	95296.12			
Stat..	3	75576.28	25192.09	168.04	.000
Residual	42	6296.34	149.91		
Sub-total	45	81872.62			
Level.	1	4725.09	4725.09	40.07	.000
Residual	14	1650.78	117.91		
Sub-total	15	6375.88			
Stat..Level.	3	2169.38	723.12	6.23	.001
Residual	42	4878.25	116.15		
Sub-total	45	7047.62			
Grand total	119	105563.00			
Stat.. Linear trend	1	37209.38	37209.38	248.21	
Stat.. Quadratic trend	1	46.88	46.88	0.31	
Stat.. Cubic trend	1	38320.04	38320.04	255.62	

Pedometry (With BABE)

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	14	19338.69			
Within subjects total	105	51151.25			
Stat..	3	11099.00	3699.67	13.36	.000
Residual	42	11630.25	276.91		
Sub-total	45	22729.25			
Level.	1	12937.62	12937.62	45.09	.000
Residual	14	4016.62	286.90		
Sub-total	15	16954.25			
Stat..Level.	3	3120.94	1040.31	5.23	.004
Residual	42	8346.81	198.73		
Sub-total	45	11467.75			
Grand total	119	70489.94			
Stat.. Linear trend	1	9938.94	9938.94	35.89	
Stat.. Quadratic trend	1	572.03	572.03	2.07	
Stat.. Cubic trend	1	588.06	588.06	2.12	

Repetitions (Without BABE)

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	14	5091.12			
Within subjects total	105	95697.88			
Stat..	3	80698.81	26899.60	186.79	.000
Residual	42	6048.56	144.01		
Sub-total	45	86747.38			
Circ..	1	267.00	267.00	1.44	.250
Residual	14	2600.62	185.76		
Sub-total	15	2867.62			
Stat..Circ..	3	316.97	105.66	0.77	.518
Residual	42	5765.91	137.28		
Sub-total	45	6082.88			
Grand total	119	100789.00			Sig F
Stat.. Linear trend	1	46905.04	46905.04	325.70	
Stat.. Quadratic trend	1	715.41	715.41	4.97	
Stat.. Cubic trend	1	33078.38	33078.38	229.69	

Pedometry (Without BABE)

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	
Between subjects total	14	15460.69			
Within subjects total	105	42861.25			
Stat..	3	11806.88	3935.62	13.38	.000
Residual	42	12354.38	294.15		
Sub-total	45	24161.25			
Circ..	1	681.62	681.62	1.80	.201
Residual	14	5295.62	378.26		
Sub-total	15	5977.25			
Stat..Circ..	3	1163.31	387.77	1.41	.254
Residual	42	11559.44	275.22		
Sub-total	45	12722.75			
Grand total	119	58321.94			Sig F.
Stat.. Linear trend	1	11025.31	11025.31	37.48	
Stat.. Quadratic trend	1	270.00	270.00	0.92	
Stat.. Cubic trend	1	511.53	511.53	1.74	

H3: Factorial Analysis

Interest / Enjoyment

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	12	64.42			
Within subjects total	39	43.50			
Trial.	1	3.77	3.77	2.55	.136
Residual	12	17.73	1.48		
Sub-total	13	21.50			
Scale.	1	0.08	0.08	0.14	.711
Residual	12	6.42	0.54		
Sub-total	13	6.50			
Trial.Scale.	1	0.69	0.69	0.56	.468
Residual	12	14.81	1.23		
Sub-total	13	15.50			
Grand total	51	107.92			

Perceived Competence

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	12	35.73			
Within subjects total	39	27.25			
Trial.	1	4.33	4.33	3.87	.043
Residual	12	13.42	1.12		
Sub-total	13	17.75			
Scale.	1	1.56	1.56	4.46	.041
Residual	12	4.19	0.35		
Sub-total	13	5.75			
Trial.Scale.	1	0.94	0.94	4.03	.048
Residual	12	2.81	0.23		
Sub-total	13	3.75			
Grand total	51	62.98			

Effort-Importance

Analysis of Variance Summary Table

Source of Variation	DF	Sum of Squares	Mean Square	F-Ratio	Sig F.
Between subjects total	12	36.27			
Within subjects total	39	38.50			
Trial.	1	3.77	3.77	3.86	.043
Residual	12	11.73	0.98		
Sub-total	13	15.50			
Scale.	1	2.77	2.77	2.61	.132
Residual	12	12.73	1.06		
Sub-total	13	15.50			
Trial.Scale.	1	0.69	0.69	1.22	.291
Residual	12	6.81	0.57		
Sub-total	13	7.50			
Grand total	51	74.77			