THE DEVELOPMENT OF A RASCH MEASUREMENT PHYSICAL FITNESS SCALE FOR HONG KONG PRIMARY SCHOOL-AGED STUDENTS

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STATEMENT ON THE CONTRIBUTION OF OTHERS

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ABSTRACT

The main purpose of this study was to develop a Rasch Measurement Physical Fitness Scale (RMPFS) consisting of the physical fitness indicators routinely used in Hong Kong primary schools. Data used in this study were retrieved from the database of a Hong Kong primary school covering students' physical fitness data over academic years 2002-03 to 2006-07. The indicators of physical fitness include Body Mass Index (BMI), 6-minute Run, 9-minute Run, 1-minute Sit-ups, Sit-and-Reach, Right Handgrip, Left Handgrip, Standard Push-ups, and Modified Push-ups. Each indicator reflects one of the five usually recognized components of physical fitness: body composition, cardiorespiratory fitness, flexibility, muscular strength, and muscular endurance. After data cleaning, a total of 9,439 student records were used for the Rasch scale development.

Following a series of iterative Rasch analyses, a RMPFS integrating three key core components of physical fitness (i.e., cardiorespiratory fitness, muscular endurance, and muscular strength) was developed successfully. The RMPFS and its scale indicators showed fit to the Rasch model sufficient for the intended purposes of measuring overall fitness of children and tracking fitness levels over time. The RMPFS measures were then used to display Hong Kong primary school-aged students' overall physical fitness levels and developmental trends effectively, and the percentile distributions of overall physical fitness, measured by the RMPFS, for age, height, weight, and BMI were illustrated graphically for the sample of students in this research.

Compared to traditional approaches to measurement in physical fitness, this Rasch calibrated physical fitness scale has the following advantages. The first, the Rasch measurement logit scale provides interval measures that have consistent and stable meaning regarding the distances between persons or items, therefore, facilitating meaningful comparisons. The second, the RMPFS provides sample-distribution free and

item-distribution free measures. The third, the RMPFS developed in this study can calibrate primary school-aged students' overall fitness levels on the common scale if students had performed on any one physical fitness indicator from among those calibrated into the scale.

The successful development and application of the RMPFS provides strong evidence of the benefits derived from the techniques used in this research, so that physical fitness data can reflect students' physical fitness more objectively. Major implications for physical education practice include dividing students into groups based on fitness levels rather than sex in PE classes. Although BMI is not an appropriate indicator of overall physical fitness, height and weight are appropriate moderate correlates of overall physical fitness. Moreover, the existence of considerable individual differences in overall physical fitness at any one grade level justifies the necessity of developing appropriate fitness programmes that accommodate students' individualized requirements and reminds teachers to cater for students' individual needs in PE classes. This research also provided practical value to the partner school with regard to its PE programmes.

The findings of this study will be informative to physical education teaching practice and policy making by providing a better knowledge basis for interpreting physical fitness assessment results and giving appropriate feedback to students. The limitations of this study are related to the large measurement errors for RMPFS person estimates such that overall physical fitness estimations at the individual level have measurement errors too large to allow almost any meaningful distinctions to be made between individuals. The overall physical fitness measures and changes at the group level are more precise and, therefore, informative for depicting students' physical fitness development. Future research could attempt to find solutions to reduce the measurement error of person estimates such as developing and calibrating new physical fitness indicators into the Rasch scale.

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CHAPTER ONE

INTRODUCTION

Background

There is no doubt that children's physical fitness is an important issue for parents, educators, and the whole society. The World Health Organization (2002) officially encouraged a physically active lifestyle for children in order to enhance children's physical fitness and reduce the risk of health problems. The justification of this declaration was supported by many researchers (e.g., Biddle, Gerely, & Stensel, 2004; Hasselstrom, Hansen, Froberg, & Andersen, 2002; Janz, Dawson, & Mahoney, 2002) who claimed that good physical fitness and appropriate physical activity in children and adolescents have positive influence for their current and future health. On the other hand, good physical fitness is also beneficial to children's psychological variables. For example, Tortolero, Taylor, and Murray (2000) reported that physical fitness and physical activity in children are related to higher self-esteem, self-efficacy, and perceived physical competence and lower degree of depression and stress. A study conducted by the California Department of Education (2005) indicated that there was a strong positive relationship between physical fitness and academic achievement for grades 5, 7, and 9 students in California, the United States, although no causal evidence was found for such relationship.

Some similar evidence comes from the Hong Kong contexts. After an intensive review of existing data and research, Hui (2001) concluded that physical activity can effectively prevent and lower the risk of major diseases and health concerns such as obesity, coronary heart disease, diabetes, colon cancer, stroke, hypertension, osteoporosis, and

mental distress in Hong Kong Chinese populations. The positive relationship between physical activities and academic achievement was also found for Hong Kong children. Lindner (1997) reported that Hong Kong students with better academic performance participated in physical activities more frequently than did students with poorer academic performance.

Given the important role physical fitness might play in children's life, it is difficult to overestimate the importance of obtaining a clear and accurate profile of children's physical fitness levels so that education administrators, schools, and teachers can develop and conduct appropriate physical fitness programs for children. In order to get such a physical fitness profile, reliable assessment tools must be utilized and the measurement results much be interpreted correctly.

In the current physical education contexts, the normal practice is that different components of physical fitness, such as body composition, cardiorespiratory fitness, flexibility, muscular endurance, and muscular strength, are assessed using different indicators and children's ability in these components is reported and interpreted independently. The indicators widely used in Hong Kong primary schools include 6/9-minute Run, 1-minute Sit-ups, Push-ups, Sit-and-Reach, and so on. The same approach is also used in large-scale physical fitness research projects. For example, To (1985) administered the Asian Committee's Standardized Physical Fitness Tests to 6,000 Hong Kong school-aged children. Nine indicators were included in the physical fitness battery to assess five health-related components (anthropometric measures, cardiorespiratory endurance, muscular strength, muscular endurance, and flexibility) and one skill-related component (speed). In another study, Fu (1994) applied the ICHPER.SD-ASIA Health-related Fitness Test in Hong Kong schools and collected data from 20,304 school-aged children in 1990-91. The test battery covered four components including anthropometric measures, muscular endurance, flexibility, and cardiorespiratory endurance. In both projects, students' performances for each indicator were reported and ability in each component of physical fitness was interpreted independently.

The traditional approaches to physical fitness assessment result in, at least, two deficiencies. The first is that the interpretation of scores in physical fitness indicators is questionable. The evaluations and reports of children's physical fitness are all based on their raw scores for component-related physical fitness indicators. Since the raw scores indicate only the ordering of the children's performance, but have little inferential value about is the size of the differences between different raw scores, this method might not provide valid "measures" (Bond & Fox, 2007; Wright & Mok, 2000). For example, it is obvious that a child who completes 30 sit-ups in 1-minute Sit-ups test has better muscular endurance than a child who completes only 20 sit-ups in the same time. Unless raw data such as these are put to some other use, such as estimating VO_2max, it is difficult, even impossible, to tell the exact ability difference between these two children along the continuum of muscular endurance. The second deficiency is about the efficiency of assessment. The current method of physical fitness assessment widely used in physical education teaching and research contexts is obviously not an economical approach because students must take all the separate tests in order to get the whole picture about their abilities on different components of physical fitness. The time consuming assessment task in the physical education curriculum increases teachers' workload and occupies resources which should be put into teaching (Drewett, 1991).

Is it possible to generate "measures" based on but beyond raw scores to reflect children's physical fitness levels? These measures would locate children's positions appropriately along the physical fitness continuum and add inferential value which cannot be provided by raw scores, to children's performances on physical fitness assessment.

Is it possible to combine the separate physical fitness indicators or, at least, some of them into a single indicator which could support the calibration of children's "overall" physical fitness levels? The overall physical fitness indicator would facilitate interpretation and reporting of the results of physical fitness assessment.

This study aims to find possible solutions to these two questions by adopting a Rasch

measurement approach.

Purpose of Study

The main purpose of this study was to develop a Rasch Measurement Physical Fitness Scale (RMPFS) consisting of the physical fitness indicators routinely used in Hong Kong primary schools. The aim was to calibrate primary school-aged students' overall physical fitness levels by integrating different components of health-related physical fitness including body composition, cardiorespiratory fitness, flexibility, muscular endurance, and muscular strength. Rasch calibration of the raw scores for physical fitness indicators would transform those scores into interval measures on a logit (log odds unit) scale, so that the interval measures would have consistent meaning for both person and item estimates so that interpretation of person ability and item difficulty takes place in a single stable framework.

Furthermore, if a suitable RMPFS were developed it could be used to analyse cross-sectional and longitudinal data of different cohorts of students' to map developmental trends in overall physical fitness and the changing patterns of students' Rasch physical fitness measures.

Significance of Study

Numerous studies have been conducted on the relationship between health-related physical fitness, or the components of health-related physical fitness, and other physical or psychological variables including the relationship between cardiorespiratory fitness and metabolic syndrome (Kullo, Hensrud, & Allison, 2002), the relationship between cardiorespiratory fitness and self-reported physical function in cancer patients (Thorsen, Nystad, Stigum, Hjermstad, Oldervoll, Martinsen et al., 2006), the relationship among

cardiovascular fitness, percentage of body fat and moderate and vigorous intensities of physical activity (Gutin, Yin, Humphries, & Barbeau, 2005), the relationship between physical fitness and psychological well being (Blignaut, 1998), and the relationship between physical fitness and academic achievement for elementary and middle school students in the United States (California Department of Education, 2005) as well as for Hong Kong children and youth (Lindner, 1997). There is also research concerning the relationships among different components of health-related physical fitness. For example, Marsh and Redmayne (1994) studied the relationship between components of physical fitness and components of physical self-concept of 105 young adolescent girls aged 13 to 14 years. Five physical fitness components including endurance, balance, flexibility, static strength, and explosive strength/power were examined in that study. The findings indicated that the correlations among the five components of physical fitness varied from 0.024 to 0.437.

However, the researcher has found no attempt to combine the indicators of different components of health-related physical fitness into one overall physical fitness indicator in the current research literature. This study would be a meaningful start with the purpose of establishing a unidimensional Rasch-scaled indicator which integrates students' performances on different components of physical fitness tests to represent primary school-aged students' overall health-related physical fitness. With this scale, the health-related physical fitness level of any primary school-aged student, irrespective of sex and age, could be located in the common trait continuum in a simple and efficient way. That would be an innovative and practical way for Hong Kong schools and teachers to evaluate primary school-aged students' health-related physical fitness because their overall fitness levels could be calibrated on the common scale even if the student takes only one of physical fitness tests from among the several components.

Compared to traditional approaches to physical fitness assessment, the Rasch calibrated physical fitness scale and indicators have the following advantages.

The first, a Rasch scale provides interval measures which facilitate interpretation of physical fitness assessment results and comparisons among children. Although raw data appear as interval units, they indicate only ordering but not any proportional meaning in terms of physical fitness. For example, 2,000m. is twice as far as 1,000m from an algebraic perspective. There is no doubt that boy A who has completed 2,000 metres in a 9-minute Run test has better cardiorespiratory fitness than boy B who completed only 1,000 metres. But it is hard to know exactly the difference in physical fitness levels between these two boys. One cannot say that A is as twice physically fit as B because the difficulty of completing the second 1,000m. is much higher than running the first 1,000m in a 9-minute Run test. The Rasch-scaled indicator can solve this inferential problem because the logit scale provides linear interval measures that have consistent and stable meaning regarding the differences in physical fitness levels between persons or items.

The second, a Rasch scale provides sample distribution-free and item distribution-free measures. Measurement should be "objective" and objective measurement should be sample distribution-free and item distribution-free. A Rasch calibrated fitness scale could fulfill this requirement. With a Rasch scale, there is no need for any specific reference norm to give a student's rank or percentile. Both students and physical fitness indicators can be located on the common physical fitness scale directly, making it easy to compare students' performances on different physical fitness indicators as long as the indicator is calibrated on the scale.

The third, a Rasch scale makes it possible to construct an overall physical fitness indicator that summarizes a student's physical fitness in different components. Traditionally, different components of physical fitness have different indicators. It is very complicated and inconvenient to obtain a clear picture of a student's overall physical fitness unless a multifaceted profile which contains scores to each component of physical fitness was provided (Fleishman, 1964; Marsh, 1993). The researcher found no attempt to combine the indicators of different components into an overall physical fitness indicator in the research literature. Although the possibility of doing so could be debatable topic,

the benefits which would derive from having a single overall fitness measure suggest that it is well worth trying. If the overall physical fitness indicator works well, primary school-aged students' overall physical fitness levels could be calibrated on the common scale even if the student just takes only one of the physical fitness tests from among the five components. That will be very meaningful to physical education teaching since assessment of students' physical fitness is a time consuming task and is regarded as one of the major challenges for physical educators (Drewett, 1991). A simplified indicator and reporting system would provide a more cost efficient method and reduce teachers' workload so that they could put more time and resources into the teaching and learning that promotes children's health.

In summary, the findings of this study could be very helpful to physical education teaching and policy making by providing a better knowledge basis for interpreting physical fitness assessment results and giving appropriate feedback to students.

Research Questions

The present study aims to address the following questions related to the physical fitness indicators used with the Hong Kong primary school-aged students:

1. Is it possible to develop a RMPFS which integrates all five, or at least some, components of health-related physical fitness?

2. To what extent does the RMPFS that is developed to measure students' overall physical fitness fit to the Rasch model?

3. To what extent can the overall physical fitness indicator effectively describe the development of Hong Kong primary school-aged students' overall physical fitness over time?

4. What are the relationships among primary school-aged students' overall physical

fitness measured by the RMPFS and other factors, such as age, height, and weight?

Basic Assumptions

The present study relies on these two basic assumptions which follow:

1. The physical fitness indicators used in this study are reliable and valid to assess primary school-aged students' abilities on the components of health-related physical fitness; and

2. The data, i.e., the records of primary school-aged students' performances on physical fitness indicators, collected by physical education teachers are authentic and reliable.

CHAPTER TWO

LITERATURE REVIEW

Physical Fitness

Overview

In order to make valid measurements, a clear definition of the trait or construct under measurement must be consolidated at the first stage. Fitness is an elusive concept that has no universally accepted definition in the context of exercise and health (Bouchard, Shephard, Stephens, Sutton, & McPherson, 1990). Nevertheless, the common point shared by different conceptualizations is that it is related to, but different from, health and wellness (Corbin, Welk, Corbin, & Welk, 2006). Generally speaking, fitness is a many faceted construct which has different aspects including physical fitness, emotional fitness, social fitness, spiritual fitness, intellectual fitness, and environmental fitness (Miller, 2006; Powers, Dodd, & Noland, 2006). It is no doubt that, from the physical educators' perspective, physical fitness is of prime interest. Generally, it is accepted that physical fitness is made up of two components, namely, health-related and skill-related components (Corbin et al., 2006; Miller, 2006; Williams, Harageones, Johnson, & Smith, 2000).

Over recent decades, physical fitness has been defined from different perspectives and assessed using many methods. The conception of physical fitness based on military or athletic purpose has survived centuries since the ancient Chinese and Athenians (Sharkey, 1991). In the 20th century, the definition of physical fitness has shifted slowly towards a work- or living-related conception. For example, Clarke (1979) defined physical fitness as the ability to carry out daily tasks with enough energy and alertness without extreme

fatigue and still have energy to handle emergencies and enjoy leisure time. Clarke (1979, p.28) further pointed out the importance of physical fitness to individuals in modern society by emphasizing that "*Physical fitness affects all phases of human existence. It is vital for the whole person in order to permit total effectiveness*". In a research report provided by U.S. Department of Health and Human Services (1996), physical fitness is regarded as a set of traits that people have or obtain to take part in physical activity. Howley and Franks (1997) defined physical fitness from a health science perspective. They proposed physical fitness as a state of well-being with low risk of health problems and energy to perform a variety of physical activities. More recently, physical fitness has been viewed from a broader perspective. Corbin and his colleagues (2006) defined physical fitness as

> *... the body's ability to function efficiently and effectively. It consists of health-related physical fitness and skill-related physical fitness, which have at least eleven components, each of which contributes to total quality of life. Physical fitness also includes metabolic fitness and bone integrity. Physical fitness is associated with a person's ability to work effectively, enjoy leisure time, be healthy, resist hypokinetic diseases, and meet emergency situations.* (Corbin et al., 2006, p.7)

The Structure of Physical Fitness

In traditional opinion widely accepted among physical fitness educators and researchers, physical fitness is a multidimensional construct, and no single indicator or component adequately represents the entire construct (Fleishman, 1964; Marsh, 1993; Safrit, 1981; Sharkey, 1991). The components emphasized by skill-related physical fitness include speed, agility, balance, coordination, power, and reaction time (Corbin et al., 2006; Miller, 2006; Pate, 1983). In contrast, health-related physical fitness consists of body composition, cardiorespiratory fitness, flexibility, muscular strength, and muscular

endurance (Corbin et al., 2006; Golding, 2000; Miller, 2006; Williams et al., 2000). Although skill-related physical fitness is related to an individual's health just as is health-related physical fitness, it is more appropriately interpreted as an indicator of athletic or sporting performance rather than of health, especially from a physical education perspective. On the other hand, health-related physical fitness and its components are directly associated with good health and lower risk of health problems (Corbin et al., 2006). Recently, less importance has been paid to skill-related physical fitness by researchers and educators in determining overall physical fitness levels, while more and more importance has been attached to health-related components of physical fitness which help to ensure healthy and efficient function of organic systems of the body (Hinson, 1995; Miller, 2006; Pate, 1994; Safrit, 1990). This study also focuses on health-related physical fitness.

From the classic definition used in the majority of contemporary research (e.g., AAHPERD, 1989; Corbin et al., 2006; Council of Europe, 1988; Golding, 2000; Hinson, 1995; Miller, 2006; Williams et al., 2000), the widely accepted conception of health-related physical fitness can be summarized as a five-component concept consisting of body composition, cardiorespiratory fitness, muscular strength, muscular endurance, and flexibility. This conceptual structure was also promoted in Hong Kong by the School Physical Fitness Award Scheme (Hong Kong Education and Manpower Bureau, 2005b) which was supported by the Hong Kong Education and Manpower Bureau and Hong Kong Childhealth Foundation.

Body Composition

Body composition refers to the body fat weight and lean body weight (Miller, 2006). This two-component model is popular among physical fitness educators and researchers (Heyward, 2002; Vehrs & Hager, 2006). In this model, the body is 'divided' into a fat component and a fat-free component. The percentage of body fat is usually used to

classify the level of body composition. There are many sophisticated methods to assess percentage of body fat, such as air displacement plethysmography (e.g., BodPod), Dual Electron X-Ray Absorptiometry (DEXA), and magnetic resonance imaging (MRI). However, the widely used field indicator for body composition estimates in physical education is skinfold method. The results of measured folds give an estimate of the percentage of an individual's fat component mass in contrast to the fat-free component mass including water, muscle, and bone. When equipment-dependent body fat estimates are not available, the BMI is used to provide some information related to body composition although it is not a recommended method since it does not estimate the percentage of body fat (Miller, 2006). BMI is defined as body weight (kg) divided by height (m) squared (BMI = weight (kg) / height $(m)^2$). It can be seen from the definition and assessment methods that, distinguished from other fitness components, body composition is a non-performance indicator of health-related physical fitness.

Cardiorespiratory Fitness

Cardiorespiratory fitness, also known as aerobic fitness, is defined as the ability to perform whole body exercise involving large muscle groups at moderate to high intensity for prolonged periods (American College of Sports Medicine, 2000). Cardiorespiratory fitness is of special importance in maintaining good health for youth since good cardiorespiratory system fitness is helpful both for weight control and protection from heart disease (U.S. Department of Health and Human Services, 1996). There are many kinds of field indicators of cardiorespiratory fitness used in physical education, including 1-mile, 1.5-mile, and 3-mile run/walk, 9-minute and 12-minute run, 12-minute swimming, and so on. In western countries (e.g., U.S., Australia) the 1-mile run and 9-minute run are widely used indicators to assess cardiorespiratory fitness of children aged five or older, while other indicators are usually used for school-aged students and adults. Another popular indicator of cardiorespiratory fitness is the Progressive Aerobic Cardiovascular

Endurance Run (PACER) which provides a valid alternative to the customary distance run (The Cooper Institute, 2004). PACER is recommended for all ages, but is strongly encouraged for students of key stage 3 (grades 7 to 10).

Muscular Strength

Muscular strength refers to the ability of a muscle or muscle group to develop maximal force in a single contraction (Heyward, 2002). Muscular strength can be classified into three types: isometric strength, isotonic strength, and isokinetic strength (Baumgartner, Jackson, Mahar, & Rowe, 2007; Heyward, 2002). Laboratory tests using cable tensiometers, load cells and dynamometers are very popular in assessing muscular strength. Weight-training machines and free weights serve as alternatives in settings without those sophisticated instruments. However, in physical education contexts, the field indicators such as arm lift, leg strength, shoulder lift, torso strength, and handgrip strength are common indicators of muscular strength because those tests do not require expensive equipment and are easily administered to a large sample.

Muscular Endurance

Muscular endurance is the ability of a muscle or a muscle group to resist a sub-maximum force for extended periods (Heyward, 2002). Muscular endurance can be classified into static endurance and dynamic endurance. If the resistance is immovable, the muscle or muscle group exerts static endurance. If muscle contractions involve joint movement, the muscle or muscle group exerts dynamic endurance. Many indicators with limited equipment requirement are very popular among schools to assess students' muscular endurance. These indicators include sit-ups, curl-ups, pull-ups, and push-ups. Sit-ups and curl-ups assess abdominal endurance which is of importance not only in promoting good posture as well as correct pelvic alignment but also in maintaining lower back health. The

pull-ups and push-ups assess upper body, arm and shoulder girdle endurance which is related to maintenance of correct posture.

Flexibility

Flexibility refers to the ability to move a joint or series joints through a maximum range of motion without injury (Heyward, 2002). There is no doubt that certain levels and types of flexibility are necessary for individuals to perform physical activity, but the appropriate degree of flexibility is still a question among physical educators and researchers (Baumgartner et al., 2007). Many valid and practical field indicators are available for physical educators to assess flexibility, such as sit-and-reach, trunk and neck extension, flexed arm hang, should stretch, and shoulder-and-wrist elevation.

Physical Fitness Test Protocols

Methods of assessing physical fitness can be categorized into two types: laboratory methods and field methods. Laboratory methods are normally used in small-scale research because it requires expensive equipment and extensive training of test administrators that are not available in most of schools. The test batteries developed in most of large-scale physical fitness programme are categorized as field methods. These kinds of tests have few equipment requirements and are easily conducted in the large sample typically found in physical education settings.

Many physical fitness test protocols have been developed with the purpose of reflecting individuals' performances on different components of physical fitness. In United States, the first national physical fitness test for youth was the AAHPER Youth Fitness Test developed by the American Association for Health, Physical Education and Recreation (1958). In 1980, the American Alliance of Health, Physical Education, Recreation and

Dance (AAHPERD) Health-Related Physical Fitness Test (AAHPERD, 1980) was developed on the basis of the earlier AAHPER Youth Fitness Test for use with college students to assess health-related components of physical fitness rather than skill-related physical fitness. The AAHPERD Health-Related Physical Fitness Test assesses four components including 1) cardiorespiratory capacity and endurance; 2) body composition; 3) abdominal muscular strength and endurance; and 4) flexibility. Norms of college students on the AAHPERD test battery were also developed (Pate, 1985) so that physical fitness educators could interpret testing results in a convenient way.

In 1989, the Physical Best Physical Fitness Program was introduced by AAHPERD in order to enhance students' physical fitness by providing both program activities and a test battery (AAHPERD, 1989). The program aimed to equip students with more knowledge of physical activities and skills as well as to motivate students to be more involved in physical activities so that they might enjoy lifelong fitness and good health. The Physical Best program incorporates five health-related components: 1) aerobic endurance, 2) body composition, 3) abdominal muscular strength and endurance, 4) upper-body muscular strength and endurance, and 5) flexibility. Unlike the AAHPERD Health-Related Physical Fitness Test that is used in a norm-referenced framework, the Physical Best program utilizes criterion-referenced standards to interpret students' performances on physical fitness tests. That means children's performances are compared to a health fitness standard instead of norm-data.

The Cooper Institute for Aerobics Research (CIAR) developed the FITNESSGRAM which aimed at providing comprehensive health-related fitness assessment and a computerized reporting system. In 1993, AAHPERD endorsed and promoted the FITNESSGRAM as a replacement for the Physical Best fitness tests (Miller, 2006). The FITNESSGRAM assesses six health-related components including 1) aerobic capacity, 2) body composition, 3) abdominal strength and endurance, 4) trunk extensor strength and flexibility, 5) upper body strength and endurance, and 6) flexibility. Similar to the Physical Best program, criterion-referenced standards are used by the FITNESSGRAM in

interpreting assessment results (The Cooper Institute, 2004).

Another nationwide program for physical fitness in the United States is the YMCA Fitness Testing and Assessment Program which was developed by the Young Men's Christian Association (YMCA). The first edition of Y's Way to Physical Fitness including a standardized fitness assessment protocol was published in 1973 and revised in 1982 and again in 1989. In the fourth edition of YMCA Fitness Testing Manual published in 2000, five components of physical fitness were included in the assessment protocol: body composition, cardiovascular ability, flexibility, muscular strength, and muscular endurance (Golding, 2000).

There are also many important developments in physical fitness assessment outside United States. For example, the Manitoba Department of Education (Canada) (1977) developed the Manitoba Physical Performance Test for use with boys and girls aged 5 to 19. Indicators were designed to assess four components of health-related physical fitness including 1) cardiovascular endurance; 2) flexibility; 3) muscular endurance; and 4) body composition. A national fitness test protocol for Canadians aged 15 to 69 - the Canadian Physical Activity, Fitness & Lifestyle Appraisal Manual - was developed by the Canadian Society for Exercise Physiology (1998). This manual is a health-related physical fitness assessment protocol which covers three components including 1) body composition, 2) aerobic fitness, and 3) musculoskeletal fitness. The indicators for body composition include BMI, sum of five skinfolds (SO5S), waist girth (WG), and sum of two trunk skinfolds (SO2S). The aerobic fitness is assessed using the mCAFT - an indirect, submaximal test – which investigates heart rate response to progressively increasing, pre-determined workloads. The indicators for musculoskeletal fitness include grip strength, push-ups, sit-and-reach, partial curl-up, vertical jump, peak leg power, and back extension. In other words, the musculoskeletal fitness consists of health-related components (muscular strength, muscular endurance, flexibility) as well as a skill-related component (muscular power).

Many European countries have their own physical fitness assessment programme: the European Test of Physical Fitness (EUROFIT TEST) developed by the Council of Europe (1988). This test battery covers five health-related components including 1) anthropometric measures; 2) flexibility; 3) strength; 4) muscular endurance; and 5) cardiorespiratory endurance as well as skill-related components such as balance and speed.

Some of the indicators in the fitness batteries discussed above (e.g., the AAHPERD Health-Related Physical Fitness Test) are now commonly used in Hong Kong schools for assessing students' health profiles, as well as for talent identification (McManus, Sung, & Tsang, 2003). In order to enhance Hong Kong students' awareness of health-related physical fitness and to encourage children to be involved in more physical activities, the Hong Kong Education and Manpower Bureau and Hong Kong Childhealth Foundation promoted the School Physical Fitness Award Scheme (Hong Kong Education and Manpower Bureau, 2005b). This scheme contains fitness indicators assessing students' fitnss level on five health-related components including 1) body composition; 2) cardiorespiratory endurance; 3) muscular strength; 4) muscular endurance; and 5) flexibility. Most Hong Kong schools, both primary and secondary, adopted this scheme and used the local test battery provided to assess students' fitness levels.

In recent decades, fitness batteries specifically developed for Asian children were used in several important large scale physical fitness research projects conducted in Hong Kong. To (1985) administered the Asian Committee's Standardized Physical Fitness Tests to 6,000 Hong Kong school children. Nine indicators were included in the assessment protocol covering five health-related components including 1) anthropometric measures; 2) cardiorespiratory endurance; 3) muscular strength; 4) muscular endurance; and 5) flexibility as well as one skill-related component - speed.

Fu (1994) collected physical fitness data from 20,304 Hong Kong school children using the ICHPER.SD-ASIA Health-related Fitness Test in 1990-91. The ICHPER.SD-ASIA

Health-related Fitness Test aims to provide an alternative program for national fitness assessment programs in Asian countries, many of which still emphasize skill-related physical fitness. This test protocol covers four health-related components including anthropometric measures, muscular endurance, flexibility, and cardiorespiratory endurance.

Standards of Scores

Another important issue relating to the physical fitness assessment has to do with the score standards. When interpreting the raw data obtained from the physical fitness assessments, one cannot attach meaning to a score without a reference standard. Normally, there are two kinds of standards - norm-referenced and criterion-referenced standards - which are widely accepted among researchers. A norm-referenced standard refers to the average level of performance of members of a well-defined sample. In this approach, children's performances on physical fitness indicators are compared to those of a reference group. It is worth noting that the norm (i.e., average) level does not always mean a desirable level of physical fitness (Baumgartner et al., 2007) because the norm is based on a specific group whose average level might vary considerably from the desirable or criterion level. A criterion-referenced standard, on the other hand, refers to a standard of performance which indicates a desired level of performance that an individual should attain. Using a criterion-referenced standard, children's performance on a physical fitness indicator is compared to the standard which was established based on the relationship between scientific data and physical fitness or health rather than on others' score which might or might not reflect desired levels of health. Among the fitness batteries mentioned in above section, some are norm-referenced tests (i.e., the AAHPERD Health-Related Physical Fitness Test), and some are criterion-referenced tests (i.e., the FITNESSGRAM and the YMCA Fitness Testing and Assessment Program).

Physical Fitness Tests/Indicators in Hong Kong Primary Schools

There are many field tests/indicators which are used for the assessment of the five health-related physical fitness components which are promoted in Hong Kong by the School Physical Fitness Award Scheme. Some of the indicators that are widely used for physical fitness assessment in many countries are summarized in **Error! Reference source not found.**.

Table 2.1 Indicators for Health-Related Physical Fitness

Component Covered	Indicators	Factors Tested
Body Composition	Skinfold measurements	Body Composition
	Air displacement plethysmography (BOD POD)	Body Composition
	BMI	Body Composition
	Waist girth	Body Composition
Cardiorespiratory Fitness	1-mile run (for all students)	Cardiorespiratory Fitness
	9-minute run (for all students)	Cardiorespiratory Fitness
	1.5-mile run (for students 13 years or older)	Cardiorespiratory Fitness
	The PACER (for all ages)	Cardiorespiratory Fitness
	Step test	Cardiorespiratory Fitness
	The bicycle ergometer test	Cardiorespiratory Fitness
Muscular Strength	Handgrip	Static strength of grip muscles
	1-Repetition Maximum (RM) bench press (ages 20 or above)	Arm extension muscles
	1-Repetition Maximum (RM) leg press (ages 20 or above)	Lower leg extension muscles
	Sit-ups (strength) (ages 12 or above)	Abdominal and trunk flexion muscles
	Pull-up (strength) (ages 12 or above)	Arm and shoulder girdle strength
Muscular Endurance	1-minute Sit-ups (endurance) (ages 5 or above)	Abdominal endurance
	Curl-up (ages 5 or above)	Abdominal endurance
	Push-ups and modified push-ups (ages 10 or above)	Arm and shoulder girdle endurance

	Pull-up (endurance) (ages 9 or above)	Arm and shoulder girdle endurance
	Modified Pull-up (ages 5 or above)	Upper body muscular endurance
	Flexed-arm hang (ages 9 or above)	Arm and shoulder girdle endurance
Flexibility	Sit-and-reach (ages 5 or above)	low back and hamstring flexibility
	Back-saver sit-and-reach	hamstring flexibility
	Trunk and neck extension (ages 6 or above)	Relative flexibility of the trunk
	Shoulder and wrist elevation (ages 6 or above)	Relative flexibility of the shoulder and wrist
	Shoulder stretch	Should flexibility

The School Physical Fitness Award Scheme has adopted the following indicators to assess the five components of health-related physical fitness in Hong Kong. Two sites skinfold method (sum of triceps and calf skinfolds) is used to estimate the body composition. A 6/9-minute Run indicator is used to assess the cardiorespiratory system. The flexibility of back and the hamstring (back of the upper legs) muscles is assessed using a Sit-and-Reach indicator. Handgrip (right and left) indicator is used as the indicator to evaluate the static strength of the right and left hand flexor muscles. Two different indicators are used for primary and second students to assess their muscular endurance. A 1-minute Sit-ups indicator is used to assess primary school-aged students' endurance of the abdominal muscles. A Push-ups indicator is used to assess secondary school-aged male students' arm and shoulder girdle endurance while a modified Push-ups (bent-knee Push-ups) indicator is used for secondary school-aged female students as the alternative to the standard Push-ups indicator. It can be seen that Hong Kong practice of physical fitness assessment is consistent with that in many other countries. All the fitness indicators included in the School Physical Fitness Award Scheme are listed in Table 2.1 except the 6-minute Run.

Hong Kong primary schools adopted norm-referenced standards in interpreting students' raw scores for these physical fitness indicators. The norm-referenced standards for the

current physical fitness indicators in Hong Kong were obtained through a program carried out by the Education Department and Hong Kong Child Health Foundation in 1999 and 2000. The sample comprised 4,600 primary school-aged students aged 6 to 12 years from 23 Hong Kong primary schools (Hong Kong Education and Manpower Bureau, 2005b).

Percentile ranks transformed from raw scores were used to evaluate each student's performance in relation to that of peers of the same age and sex. For example, a performance of 19 repeats on a 1-minute Sit-ups test is at the 75^{th} percentile for a 6-year-old boy. That means 75% of the 6-year-old boys completed fewer than 19 sit-ups in the test. A 6-point ordinal score was then ascribed to the student according to her/his percentile rank in order to make the scores more understandable to students and their parents. The scale allocation is as follow:

0: < 10%

1: 10% - 25%

2: 25% - 50%

3: 50% - 75%

4: 75% - 90%

5: ≥ 90%

It is worth noting that the percentile ranks provide only a rough basis for comparison among students and could be regarded as an indicator of students' relative strengths and weaknesses (Williams et al., 2000). However, even the percentile ranks fail to provide accurate or direct information about students' ability in the latent trait under measurement. Use of numbers/counts and their allocation of norm referenced ratings do not allow for the direct assessment of the abilities against some objective standard.

Item Response Theory

Molenaar (1995) briefly summarized the history of measurement of human behavior as a step by step development from measurement by fiat, to formal measurement, to Classical Test Theory (CTT), and finally to Item Response Theory (IRT). Without strict quality control processes, measurement by fiat relied only on the domain experts' judgments and claims. Formal measurement made it possible to assess the quality of measurement by introducing some necessary assumptions and restrictions of empirical data into measurement. CTT made a further progress by dividing the total test score into a true score component and an error component. However, CTT makes so few, weak assumptions for measurement that it faces a test validity dilemma. Individual ability parameters are dependent on a given test under a given circumstance, and item difficulty parameters also rely on a given group of examinees assumed to be a representative sample of a given population. This kind of item dependence and sample dependence inherent to CTT makes it impossible to predict individuals' response to items unless those items have been previously administered to similar individuals (Lord, 1980).

IRT is a latent trait model with the purpose of measuring an unobservable, or latent, variable. The latent trait of a person cannot be observed directly and is reflected by test scores or performances. As an alternative approach to CTT, IRT is a family of mathematical descriptions of the probability of an individual's response to an item. The individual's ability parameter (usually denoted θ) and the item's difficulty parameter (usually denoted b) are estimated on the same latent trait (Wainer & Mislevy, 2000). IRT's underlying idea is that the probability of an answer of any person to a given item is a simple function of the person's position on the latent trait and the relevant item parameters (Molenaar, 1995). IRT models describe the probabilistic relationship between an individual's position on the latent trait and the position of the item that the individual encountered (Molenaar, 1995; Weiss, 1983).

Since the origin of IRT, many models have been developed. The simplest IRT model is

the one-parameter logistic model (1-PL model). It is so called because this model concerns only a single item parameter, i.e., item difficulty (b), and predicts probabilistic response based on the interaction between item difficulty and individual ability (Wainer & Mislevy, 2000). The model can be expressed as the logistic function.

$$P(\theta) = \frac{1}{1+ e^{-(\theta - b)}} \qquad (1)$$

Where $P(\theta)$ is the probability of individual with a given ability θ answering correctly to a particular item with difficulty level b. The interaction between person ability and item difficulty could be described more clearly in Item Characteristic Curves (ICC) (also termed trace lines or item response functions). Figure 2.2 presents an example of an ICC for the 1-PL model. The three curves in the figure represent three items with different difficulties. It can be seen that, for a person with given ability, the probability of getting the right answer to an item is only determined by the item difficulty.

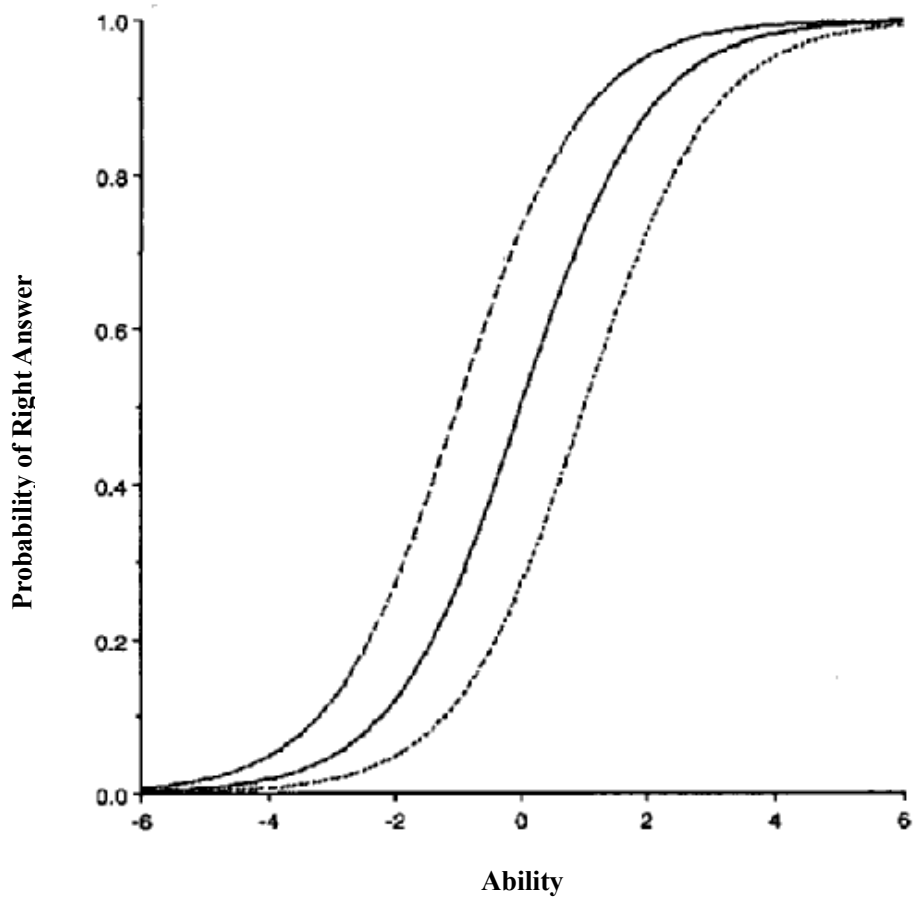


Figure 2.1 Item Characteristic Curves for 1-PL Model

In addition to item difficulty (*b*), the two-parameter logistic model (2-PL model) incorporates a second item parameter, item discrimination (usually denoted *a*), to account for the response to a particular item besides item difficulty. Item discrimination is represented by the slope of the ICC. An item with a steeper curve is more discriminating than an item with flatter curve. The equation for 2-PL model is

$$P(\theta) = \frac{1}{1+ e^{-a(\theta - b)}} \qquad (2)$$

The relevant ICCs in Figure 2.3 facilitate understanding of the 2-PL model.

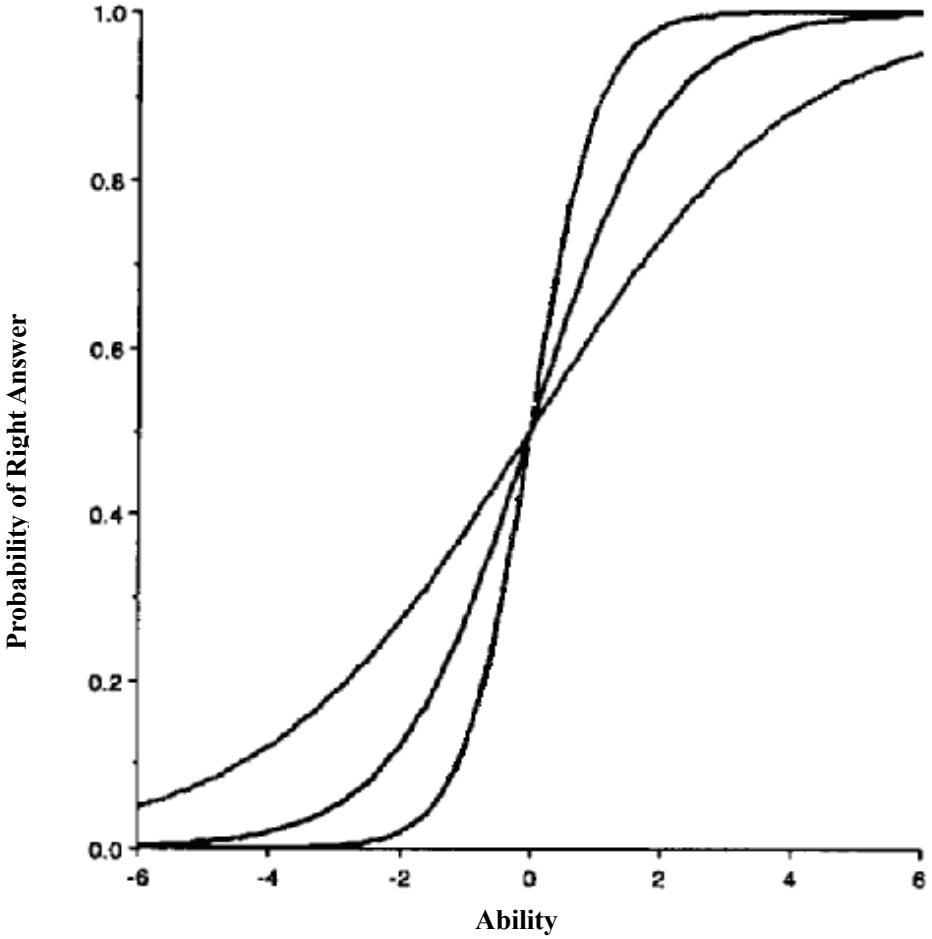


Figure 2.2 Item Characteristic Curves for 2-PL Model

The item discrimination (*a*) is characterized as the slope of the curves. It can be seen that, unlike the ICCs of the 1-PL model in which the curves have the same slope (see Figure 2.2), the curves in the 2-PL model have different slopes. Figure 2.3 presents three items

with different item discriminations. In the 2-PL model, the probability of a person with a given ability level to get the right answer is influenced by the item difficulty and item discrimination simultaneously.

The three-parameter logistic model (3-PL model) expands the 2-PL model by adding a third item parameter, a pseudo-chance parameter (also known as guessing parameter, usually denoted *c*), in the model. The *c* parameter is the low point of the ICC as it nears negative infinity on the horizontal axis, i.e., the probability of getting the item right for a person with "zero ability". The model can be expressed by the following equation.

$$P(\theta) = c + \frac{1 - c}{1 + e^{-a(\theta - b)}} \qquad (3)$$

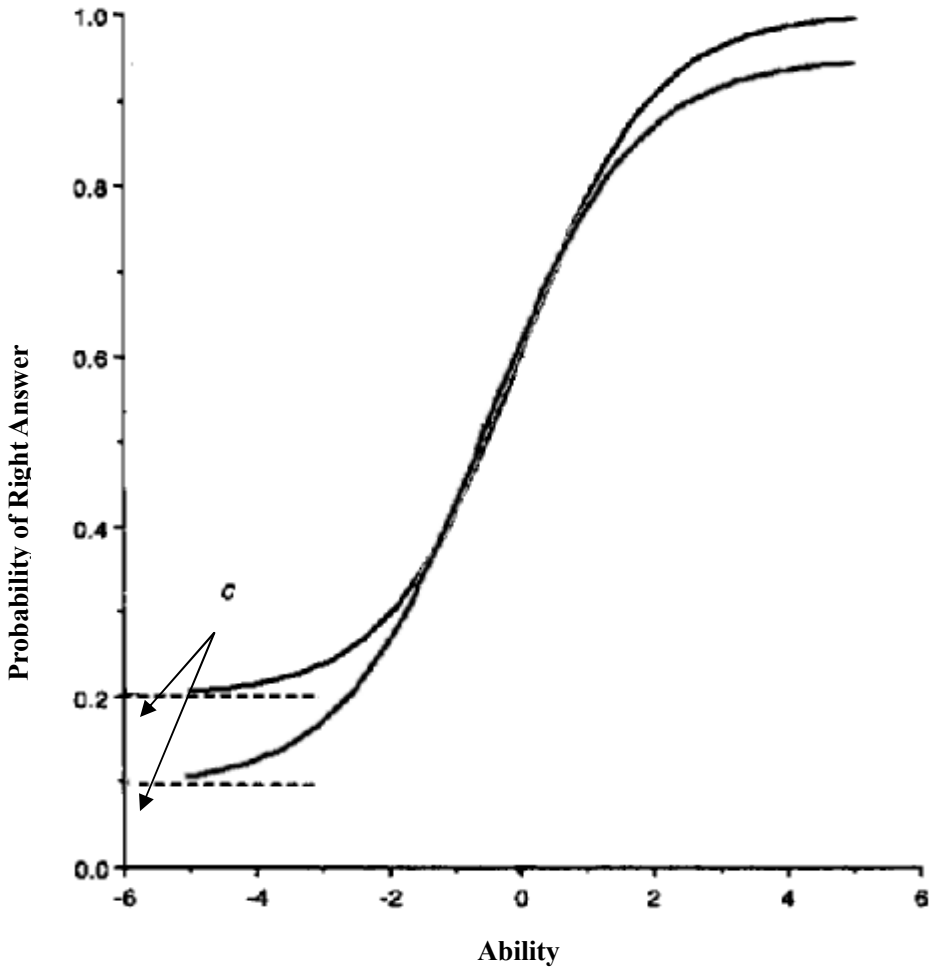


Figure 2.3 Item Characteristic Curves for 3-PL Model

Example ICCs for the 3-PL model are presented in Figure 2.4. The two curves in the figure represent two items with different pseudo-chance parameter. It can be seen that, the probabilities of getting these two items right by guessing for a person with "zero ability" are different.

Rasch Model

The Rasch model for measurement (e.g., Andrich, 1988) is a latent trait model named after the Danish mathematician and statistician Georg Rasch (1901-1980) who originally developed this model. The mathematical exposition of Rasch model is similar to that of IRT, and the Rasch model is often, somewhat misleadingly, regarded as a special case of the 1-PL model making the other two parameters - item discrimination parameter (*a*) and guessing parameter (*c*) - constant. However, Rasch model distinguished itself from other IRT models with its unique features. As pointed out by Wright (1997), variant item discrimination (*a*) indicates item bias and multidimensionality which should be rejected by objective measurement, and guessing (*c*) should not be regarded as an item parameter but an unreliable person liability. Therefore, Rasch model does not parameterized item discrimination and guessing in the measurement model, but treats variation in discrimination and guessing as sources of noises for which researchers should try to diagnose the impact on the measurement.

Although Rasch model was developed originally in educational contexts, it was expected to solve a basic measurement problem common to all social sciences (Andersen, 1995). In order to parallel the kind of objective, fundamental measurement executed successfully in the physical sciences, the Rasch Model sets up objective rules of measurement for the human sciences (Bond & Fox, 2007) so that more objective and invariant information can be provided by human science measures.

The Rasch model is a mathematical ideal which sets prior standards and structure the

collected data must meet in order to achieve objective measurement. Unlike more general IRT and multidimensional models or other statistical approaches that adopt a "the model fits data" position and use different parameters to accommodate the idiosyncrasies of the data set, the Rasch model requires that "data fit the model" (Andrich, 2004). This is one of the key differences between Rasch-based studies and other quantitative studies in the human sciences, including physical fitness studies. For example, a number of studies in physical fitness (Fleishman, 1964; Marsh, 1993; Ponthieux & Barker, 1963; Rarick & Dobbins, 1975) have conducted factor analyses on physical fitness indicators and tried to identify the structure of physical fitness. There are two general methods in the factor analytic approach - exploratory factor analyses and confirmatory factor analyses – and both of these two methods have deficiencies in building objective measurement. Exploratory factor analyses, stated by Marsh (1993), give researchers little control over the resulting factor solutions. Researchers have no way to test any *a priori* factor structure; what the data produced is the final result. As for confirmatory factor analyses, although it allows researchers to test their *a priori* factor structures and provides indices to judge the degree of match between the proposed factor structure and the empirical data, it fails to construct an objective and fundamental measurement because the data serve as a "reality" and the proposed factor model is used to account for those data only. When the proposed model cannot explain the data properly, the model has to be modified and parameters have to be redefined until the revised model fit the data well enough. Consequently, it is almost impossible to obtain a stable and unique structure of physical fitness tests because the samples change and the indicators vary among the different studies. Just imagine that scientists use a case-based developed thermometer to indicate temperature, how could the results be stable and properly communicated among researchers? In this sense, it is no wonder that there are large discrepancies among results of different studies on the same physical fitness topic because researchers have not built up an objective scale/ruler that can be used to measure physical fitness under the inevitable variety of different circumstances. In contrast, in Rasch analyses, the requirements set by Rasch model have to be met by the data set so that a scale/ruler constructed in one study could be applied

directly into other suitable situations. The measurement results under different circumstances could then be communicated in a stable framework. This feature provides a stronger basis for constructing fundamental measures from raw data.

Given the review of the quantitative approaches open for adoption in such a research project, the position taken in this research thesis is the primacy of the requirement to produce measures based on the principles espoused by Rasch measurement. As a consequence, this particular research will explicitly adopt the Rasch 'data must fit the model' requirement for the construction of fitness measures.

The Mathematical Formulation of the Rasch Model

The underlying mathematical model of Rasch analyses deals with the probabilistic relation between any item's difficulty and any person's ability (Bond & Fox, 2007). When a person's ability exceeds an item's difficulty level, the person is more likely to give the correct answer rather than the incorrect answer to that item. When an item's difficulty level exceeds a person's ability, that person is more likely to give an incorrect rather than correct answer to that item. When a person's ability is equal to an item's difficulty level, the probability of giving correct/incorrect answer is set at 50 percent.

The Rasch model estimates the person ability measure and item difficulty measure in the exactly same way. Firstly, it calculates the ratio of each person's percentage of correct answers over the percentage of incorrect answers, and then transforms that ratio into odds of a successful response. Finally, the natural logarithm of those odds are calculated as the person ability measure (or, similarly, for the item difficulty measure). Through several rounds of iteration, the raw data are transformed into interval measures of person ability and item difficulty which are independent of the particular samples of items and persons used to produce these estimates (Bond & Fox, 2007).

Wright and Stone (1979) stated that Rasch model has two expectations, i.e., (1) a person

with higher ability level should always have a greater probability of success on any item than a person with lower ability level, and (2) any person should always be more likely to do better on an easier item than on a harder one. The outcome of a person's answer to a given item is determined by the comparison of person ability and item difficulty. The relationship among probability of correct answer, person ability, and item difficulty is expressed in Equation (4) (Bond & Fox, 2007).

$$P_{mi}(x_{mi} = 1/\ \theta_m, \delta_i) = \exp(\theta_m - \delta_i) / [1 + \exp(\theta_m - \delta_i)] \qquad (4)$$

If P_{mi} is used to denote the probability of person m succeed on item i, then the probability that person m would fail on item i is $(1 - P_{mi})$. For person n, the probability of success and failure on item i is P_{ni} and $(1 - P_{ni})$ respectively.

The ability difference between person m and person n, could be inspected with the following ratio

$$\frac{P\ (m \text{ succeed on } i) \text{ AND } P\ (n \text{ fail on } i)}{P\ (m \text{ fail on } i) \text{ AND } P\ (n \text{ succeed on } i)}$$

i.e.,

$$\frac{P_{mi}(1 - P_{ni})}{(1 - P_{mi})\ P_{ni}}$$

It is reasonable to expect the above ratio would remain unchanged when we use item j instead of item i if the measurement is objective. That means

$$\frac{P_{mi}\,(1 - P_{ni})}{(1 - P_{mi})\ P_{ni}} = \frac{P_{mj}\,(1 - P_{nj})}{(1 - P_{mj})\ P_{nj}}$$

Then

$$\frac{P_{mi}}{1 - P_{mi}} = \frac{P_{mj}\,(1 - P_{nj})\ P_{ni}}{(1 - P_{mj})\ P_{nj}(1 - P_{ni})}$$

Now, let's assume person n is a "standard" person and item j is a "standard" item and the ability of person n is equal to the difficulty of item j. Then, $P_{nj} = 0.5$. We get

$$\frac{P_{mi}}{1 - P_{mi}} = \frac{P_{mj}\, P_{ni}}{(1 - P_{mj})(1 - P_{ni})}$$

If we define

$$\ln\left(\frac{P_{mj}}{1 - P_{mj}}\right) = \theta_m$$ which stands for the ability of person *m*

And

$$\ln\left(\frac{1 - P_{ni}}{P_{ni}}\right) = \delta_i$$ which stands for the difficulty of item *i*

Then

$$\ln\left(\frac{P_{mi}}{1 - P_{mi}}\right) = \theta_m - \delta_i$$

And finally

$$P_{mi} = \exp(\theta_m - \delta_i) / [1 + \exp(\theta_m - \delta_i)]$$

Given any specific θ_m and δ_i, the equation could be expressed as

$$P_{mi}(x_{mi} = 1/\, \theta_m, \delta_i) = \exp(\theta_m - \delta_i) / [1 + \exp(\theta_m - \delta_i)]$$

where $P_{ni}(x_{ni} = 1/\, \theta_m, \delta_i)$ is the probability that person with ability (θ_m) gives a correct answer ($x = 1$) to an item with item difficulty (δ_i).

When the person ability (θ_m) is equal to item difficulty (δ_i), the $\theta_m - \delta_i$ difference is equal to zero and the exp ($\theta_m - \delta_i$) is equal to one. Then the value of the equation is equal to 0.5, indicating that the probability of giving correct answer is 50 percent. When person ability (θ_m) is higher than item difficulty (δ_i), the chance of success is higher than 50 percent. Conversely, when person ability (θ_m) is lower than item difficulty (δ_i), the chance of success is lower than 50 percent. As person ability increases, the probability of correctly answering increases to an asymptote of 1. Likewise, as person ability decreases, the

chance of correctly answering decreases to an asymptote of zero.

The Main Features of Rasch Model

Linearity of Data

All observations begin as raw data and the raw data might not be the valid "measure" because they have little inferential value (Wright, 1997; Wright & Mok, 2000). Bond and Fox (2007) also stated that the inferential meaning one gets from raw data is only the ordering of the persons or the items, but not about "how much" is, say, the size of, the distance between the scores. Distances are distorted and the proportional meaning which is crucial to measurement is hidden by the superficiality of ordinal raw data. In the physical education contexts, the students' raw scores for some physical fitness indicators are recorded as interval units of distance, time or weight, but it does not mean that they are equal-interval measures of fitness because the "unit" has not constant meaning. As stated by Linacre (2000), although the units appear as linear measures, their meaning as physical fitness scores is not linear because linearity implies adding one more unit make equal-size increment. For example, students' performances on 9-minute Run are recorded with the unit "metre (m)", but "m" is not of the same meaning for different scores. The first 100 m during the running is easy but the 100 m after completing 1,000 m is very hard for primary school-aged students. Although the meaning of "m" is constant on the distance scale, it is not necessarily the same case on the fitness scale. In the same way, one cannot say that a student who completes 1,500 m in the 9-minute Run is 50 percent more physically fit than another student who only complete 1,000 m because the difficulty level of the third 500 m in the 9-minute time limit is much higher than is the first or second 500 m. Thus the raw scores recorded with the unit "m" might not be a valid measure of fitness in the assessment of students' ability on 9-minute Run.

Linearity is a basic assumption of any statistics including factor analyses (Wright &

Masters, 1982). Physical fitness data, however, are not additive or linear because they indicate only ordering but not any proportional meaning. Thus it is not appropriate to apply factor analytic approach directly to physical fitness raw data as factor analyses is properly used on interval level data. In this sense, the results of many physical fitness studies remain equivocal since statistics, such as factor analyses, are inappropriate if used on the non-linear raw data of physical fitness assessments. These non-linear raw data must be constructed into sample-distribution free and item-distribution free measures before they can be analysed using statistics requiring linear, interval data input (Wright, 1997). The Rasch model overcomes this problem by transforming non-linear raw data into logit scale measures which have constant interval meaning and provide objective, fundamental, linear measurement from ordered category responses (Linacre, 2006a). For some researchers (e.g., Fischer, 1995), the Rasch model is the only method available to transform ordinal observations into linear measures.

Parameter Separation

Traditional methods of quantification also make it difficult to compare individuals' performance in physical fitness indicators because the scores are item-dependent and the interpretation of scores is sample-dependent. This is one of the major disadvantages of CTT. Suppose a boy has completed 40 sit-ups in the 1-minute Sit-ups test; how many curl-ups could he complete in the curl-up test? Nobody knows unless the curl-up test was previously administered to him. The scores change when the items change even if the test taker remains the same. Which one of the following is better: 40 sit-ups in the 1-minute Sit-ups test or 30 curl-ups in the curl-up test? It's hard to make a decision because the raw scores provide us very limited information about these two scores' positions on the continuum of abdominal muscular endurance. A similar problem is encountered when we want to compare the cardiorespiratory fitness of primary 3 students and primary 4 students in Hong Kong. The 6-minute Run is the cardiorespiratory fitness indicator for

primary 1 to 3 students, while 9-minute Run is used for primary 4 to 6 students. It's not surprising that a primary 4 student obtained dramatically increased scores on the cardiorespiratory fitness indicator than in the previous year. The question is how can we make a judgment about whether the increment comes from the student's physical development or is just a consequence of the extra 3 minutes of running time in the test?

Instead of raw scores, standardised scores, such as *z*-scores and *t*-scores, were recommended for use in comparing different types of physical fitness scoring (Miller, 2006). However, standard scores are sample-dependent scores. That means the comparisons based on standard scores can be made only between students within the same sample from which the standard scores were computed because the means and standard deviations are expected to vary across different samples. It is a similar case for percentile ranks. For example: if a 9-year-old boy scored 15 on a 1-minute Sit-ups test, his performance is rated 5th percentile according to the norms for the Health-Related Physical Fitness Test (AAHPERD, 1980), but at 25th percentile according to the norms for Hong Kong primary school-aged students (Hong Kong Education and Manpower Bureau, 2005b).

With the purpose of solving the inherent problems of the CTT, Wright and Stone (1979) pointed out that measurement should be "objective" and listed two complementary requirements. One is that the calibration of items/indicators must be sample-distribution free, that is, independent of the particular sample used for item calibration. The other is that the measure of the latent trait must be item-distribution free, that is, independent of the particular items/indicators used for measuring the persons. This feature is referred as "parameter separation" or "invariance of parameters" (Bond & Fox, 2007; Embretson, & Reise, 2000; Wright & Masters, 1982; Wright & Mok, 2000).

It can be found that, in expression (4), the function is determined only by the ability of person m (θ_m), and the difficulty level of item (δ_i). That means the Rasch model provides the person ability and item difficulty estimates that are independent of the

distribution of the latent trait in the particular item / person calibration sample. Thus the Rasch model satisfies the requirement of objective measurement - parameter separation.

Ideally, the calibrated measures for both items and persons in a measurement scale should be invariant across any reasonable circumstance. However, it is not realistic to achieve this goal in real world when trying to solve measurement problems. The actual Rasch calibrations might vary depending upon the different combination of item difficulty and person ability (Zhu & Cole, 1996). Bond and Fox (2007) pointed out that it is the differences (i.e., the intervals) between item and person estimates (relative position of items and persons) but not the estimates themselves that should remain constant across different, but related measurement circumstances. In this sense, Rasch measurement provides interval-level, rather than ratio-level ability and difficulty measures (Stevens, 1959).

A Single Scale for Items and Persons

By the means of logarithmic transformation, Rasch analyses prevails over traditional approaches to measurement by calibrating persons and items on the same unidimensional scale (Bond & Fox, 2007; Wright & Masters, 1982). Since the person and item estimates represent the same unidimensional construct, a person who can succeed on the more difficult items on a scale should also succeed on the easier items. In other words, both persons and items can be placed on a common trait continuum one by one. The items are ordered by their difficulty levels from easy to hard, and persons are ordered by their ability levels from low to high. In such a way, direct comparisons between person abilities and item difficulties can be easily conducted based on their locations on the trait continuum.

This is a very important and distinctive feature of the Rasch model which can be applied

in physical fitness measurement in a meaningful way. From a traditional perspective for physical fitness measurement, it is hard to predict a student's performance on a physical fitness test which has not been administered to the student even if a similar test has been administered because no information about the relationship between these two tests has been provided. However, this problem could be solved through Rasch calibration. These two physical fitness tests/indicators could be calibrated on a Rasch scale and each of them has a location on the same trait (i.e., physical fitness) continuum. Their locations on the trait continuum indicate their difficulty levels. If one of these two tests was administered to a student, her/his performance on another test could be predicted through the relative position of these two tests on the trait continuum. Similarly, any other physical fitness tests/indicators could be calibrated on the same Rasch scale and the student's performance could be predicted based on the information provided by the locations of tests/indicators in relation to the student's location on the trait continuum.

Unidimensionality

Measurement should focus on one attribute or dimension at one time (Bond & Fox, 2007). Unidimensionality makes objective measurement possible and interpretation of test results more meaningful. Although human behaviors are, in many cases, multifaceted and so complicated that it is difficult to conceive them as a single indicator, carefully constructing a scale measuring one attribute at one time is still possible and will reduce the confusion caused by having many latent traits underlying the measurement scores. Traditionally, physical fitness is regarded as a multifaceted or multidimensional construct which consists of different components such as strength, endurance, flexibility, and so on. It is not likely that one unidimensional indicator would be capable of adequately representing the entire construct (Fleishman, 1964; Marsh, 1993; Safrit, 1981; Sharkey, 1991). This point of view certainly seems reasonable when looking at a fitness battery in which each indicator assesses one component, some might call it one dimension, of

physical fitness. However, the fact that indicators are component-related does not deny the possibility that there is one latent trait underlying all, or at least some, of the components. This unique latent trait determines students' performances on all component-related indicators. Through Rasch analyses, a unidimensional scale might be developed to measure that latent trait.

Local independence is another important requirement of Rasch model. Although Lord (1980) insisted that local independence was not an additional assumption, but an indispensable feature of unidimensionality, Rasch researchers (e.g., Purya, 2007; Wright, 1996; Zhu & Cole, 1996) prefer to regard local independence as another requirement of Rasch model beyond unidimensionality. Local independence refers to the requirement that the response to one item, no matter right or wrong, should have no influence on the responses to any other item within the same test. That means any two items should be mutually independent. This requirement is not a harsh one for physical fitness indicators. Each indicator of fitness battery is designed specifically for one component and has little direct linkage to other components. Empirical research (e.g., Marsh & Redmayne, 1994) also indicated that there are only low correlations among students' abilities on different components of physical fitness.

Fit to the Rasch Model

Rasch model is an ideal model and it is impossible to fulfill perfectly the model's requirements in real world measurements. For example, a test as simple as primary 1 mathematics quiz might involve students' reading comprehension ability besides the main dimension, mathematics ability, which is the latent trait the test meant to measure. Students' performances on the 1-minute Sit-ups test may be influenced by the weather, students' physical status and willingness, the severity of the rater, and many other unpredictable factors. Smith (2002) stated that unidimensionality should be viewed as a continuum rather than as a simple yes or no decision. He pointed out that the important

question is "*at what point on the continuum does multidimensionality threaten the interpretation of the item and person estimates*" (p. 206).

Although it is reasonable to admit to the complexity and imperfections in measurement, instrument developers and users should know the extent to which the data meet the requirements of the measurement model. Goodness-of-fit statistics generated from the Rasch analyses provide important indices to examine the extent to which the empirical data match the requirements of the Rasch model. An item with poor goodness-of-fit probably reflects something other than just the target latent trait or that the trait is inappropriately defined (Zhu & Cole, 1996).

Smith and Miao (1992) compared the power of Rasch fit statistics and principal component analyses in assessing unidimensionality using simulated two-factor (X and Y) data sets. A total of 50 items and a sample of 1,000 persons were used in the simulated data sets. The common variance between these two underlying factors had different values (.01, .04, .09, .16, .25, .36, .50, .64, .75), and the ratios of items in these two factors varied (45 *vs.* 5, 40 *vs.* 10, 35 *vs.* 15, 30 *vs.* 20, 25 *vs.* 25) for each data set. Thus a total of 45 different combinations of situations were generated. The results showed that principal component analyses performed well in detecting the second factor if the second factor has less than 64% common variance and 20% or more of the items load on that factor. Rasch fit statistics were sensitive in detecting the second factor if less than a specific ratio of items load on that factor in different situations. The ratio varied from 30% to 10% depending on the common variance. Finally, they suggested that if an instrument was assured to be a unidimensional measure, then factor analytic method is explicitly not appropriate because it expects more than one uncorrelated factors in the data set. If the purpose is to assess unidimensionality of existing data, it is better to use both the factor analytic method and Rasch fit statistics to complement each other.

However, Wright (1996) argued that factor analytic methods have inherent drawbacks in assessing dimensionality of empirical data sets considering they analyse the matrix of raw

responses because the both the raw responses and the residuals left after extraction of the first factor are non-linear. Therefore, he suggested implementing an improved method of factor analyses – Rasch factor analyses of the item/person residuals – instead of traditional factor analytic methods. Smith (2002) also supported the idea that linear factor analytic methods might not be appropriate tools to examine the unidimensionality requirement of Rasch model because linear factor analyses assumes a normal distribution of the data while Rasch model does not.

Many Rasch computer programs (e.g., WINSTEPS) provide two forms of chi-square fit statistics: Outfit Mean Square (Outfit MNSQ) and Infit Mean Square (Infit MNSQ). These statistics are based on the computation of residuals. A residual refers to the difference between the observed score and the model's expectation. The Outfit MNSQ is the mean of squared standardized residuals. The Infit MNSQ is the mean of squared standardized residuals, each weighted by its model variance. Outfit MNSQ is sensitive to extreme (outlier) data because of the impact of large residuals for misfitting outliers, while Infit MNSQ is more sensitive to well-targeted cases because the variance (weighting) is larger for well-targeted cases than for outliers (Bond & Fox, 2007; Smith, 2002).

Values of Outfit and Infit MNSQ values can range from 0 to positive infinity with an expected value of 1.0. A value of 1.0 means the empirical data fit the Rasch model perfectly. Values of Outfit and Infit MNSQ much higher than 1.0 (underfit) suggest that there is more variation in the empirical data than that expected by Rasch model, while values much lower than 1.0 (overfit) imply that there is less variation in the empirical data than that expected by Rasch model. In other words, the response string is too predictable (Linacre, 2006a). More emphasis should be put on underfitting (much higher than 1.0) rather than on overfitting (much lower than 1.0) performances because underfitting cases are more harmful to measurement. Underfit is caused by haphazard response strings that impair the quality of measures. On the other hand, overfit does little harm to measurement although it may result in less efficiency or overrate the quality of

measures (Bond & Fox, 2007). The criterion of acceptable range of Infit MNSQ and Outfit MNSQ depends rather on the different purposes of the research. Linacre (2006a) suggested that MNSQ falling into the range of 0.5 to 1.5 indicated a productive measurement, while many researchers adopt a stricter standard, e.g., range of 0.7 to 1.3 (e.g., Mok, Cheong, Moore, & Kennedy, 2006; Zhu & Cole, 1996) or range of 0.8 to 1.4 (Wolfe & Chiu, 1999).

Infit and Outfit statistics also have standardized forms. In WINSTEPS, the standardized form of Infit and Outfit is reported as Infit ZSTD and Outfit ZSTD. The standardized Infit and Outfit have approximately normalized *t* distribution with an expected value of 0 and an S.D. of 1.0.

However, there is reason to be suitably circumspect in the use of fit indices for the Rasch model. Wright and Panchapakesan (1969) stated that it was not recommended to delete all items with large item "misfit" value. Instead, the test designer should examine the "misfit" items carefully and find out possible effects of other factors such as discrimination and guessing in these items. Bond and Fox (2007) also suggested using fit statistics to detect problematic item and person performance but not use them as a simple criterion to delete items from a test.

Application of Rasch Model in Physical Education and Sports Science

Rasch analyses has been widely accepted and well studied in educational measurement research (e.g., Elder, McNamara, & Congdon, 2003; Merrell & Tymms 2005; Mok, 2004; Waugh, 2002, 2003; Waugh, Hii, & Islam, 2000; Weaver, 2005). There is also an abundance of Rasch applications in health and medical science (e.g., Barley & Jones, 2006; Fitzpatrick, Norquist, Dawson, & Jenkinson, 2003; Hsueh, Wang, Sheu, & Hsieh, 2004; McHorney & Monahan, 2004; Strong, Kahler, Ramsey, & Brown, 2003; Tesio, 2003).

Recently the Rasch model has been applied in sports and exercise science studies by a growing number of researchers. For example, Bowles and Ram (2006) found that Rasch analyses and the model fit statistics provided by Rasch model produce an equal-interval scale which provided more objective and consistent information about volleyball players' ability than could be obtained by traditional instruments. Coaches could utilize that information for drill and design of training sessions. Based on Rasch analyses, Zhu, Timm, and Ainsworth (2001) optimized an instrument measuring women's exercise perseverance and barriers by collapsing a five-category response scale to a three-category response scale. Heesch, Masse, and Dunn (2006) used Rasch modeling to re-validate three scales related to physical activity including the Physical Activity Enjoyment Scale, the Benefits of Physical Activity Scale, and the Barriers to Physical Activity Scale. Useful information about the validity of the three scales was provided and critical suggestions were made to improve the effectiveness of those scales based on results of Rasch analyses. In a semi-simulation study of motor function tasks, Zhu (2001) found that Rasch modeling could accurately equate different tests so that tests could be compared on a single scale, and cross-test scores could be interpreted in the same framework.

In the physical education domain, the Rasch model was also applied to develop or improve physical tests as valid instruments. Zhu and Kurz (1994) used the Rasch Partial Credit Model to assess children's gross motor competence. A total of 128 children aged from 3 to 9 years were asked to complete four different striking tasks. Partial scores were given based on their performance on the tasks and were analysed with Rasch Partial Credit Model. They concluded that the Rasch model made it possible to analyse children's motor process quantitatively. Hands and Larkin (2001) investigated the construct of a general motor ability in young children with the Rasch Extended Logistic Model. Participants consisted of 332 five- and six-year old children who were asked to perform 24 motor skills. As a result, two separate, unidimensional scales were developed for boys and for girls respectively. Zhu and Cole (1996) calibrated a gross motor instrument, which was interpreted based upon total score in a norm-referenced framework,

with the many-facets Rasch model. They demonstrated the advantages of the Rasch model over the traditional norm-referenced interpretation including parameter separation, sharing the same metric among items and examinees, and providing linear measures. More importantly, the person measures, together with S.E. and fit statistics, provided useful diagnostic information for examinees to identify their strength and weakness. They also designed a user-friendly work sheet to facilitate communication between total score and Rasch logit measures. With the work sheet, test administrators could easily transform the total scores into logit measures without any knowledge of Rasch model.

Safrit, Zhu, Costa, and Zhang (1992) used the Rasch Poisson Counts Model to investigate the difficulty levels of eighteen different Sit-ups indicators and built up a Sit-ups indicator bank for the purpose of clinical adaptive testing. In another similar study, Zhu and Safrit (1993) calibrated the 1-minute Sit-ups indicator using a national data set. Data from 8,723 children aged from 10 to 18 were analysed with the Rasch Poisson Counts Model. The result indicated that the difficulty level of the 1-minute Sit-ups indicator (-2.80 logits) was rather easy for most of children whose ability levels ranged from 0.09 to 1.39 logits. The average of boys' abilities was higher than the average of girls' abilities and the average ability increased with the children's age. However, another important finding of this study is that the model-data fit was not good as expected, especially for the low ability group. Although the Rasch Poisson Counts Model is regarded as the most suitable model for time-limited psychomotor data such as 1-minute Sit-ups indicator (Safrit et al., 1992; Zhu & Safrit, 1993), its application is still limited for several reasons. For example, Rasch Poisson Counts Model assumes examinees complete the item at a constant speed through the whole test which, unfortunately, is often not the case. The speed with which examinees complete sit-ups usually becomes slower and slower because of fatigue when examinees completed greater number of repetitions. Furthermore, the effect of dependency caused by fatigue violates the Rasch Poisson Counts Model's assumption and, therefore, reduces its appropriateness for time-limited psychomotor data.

The Rasch model has been applied to combine closely related but different scales to

assess the unidimensional construct. For example, an interesting study was conducted in the health care domain to combine two scales into one unidimensional scale (Hsueh et al., 2004). The 10-item Barthel Index (BI) assessing activities of daily living (ADL) and the 15-item Frenchay Activities Index (FAI) assessing instrumental ADL were administered to a total of 245 patients at one year after stroke. The data from these two scales were combined together and analysed with the Rasch model. The result indicated that all but 2 items of the FAI fit the unidimensional Rasch model very well, indicating that the BI and the FAI assess a single unidimensional construct. Further analyses of the 23-item unidimensional scale revealed that it had high person reliability (0.94) and the item difficulties were well targeted for the patient sample. A conversion table was offered to transform combined BI and FAI raw scores into Rasch measures. Thus a clinically useful instrument was developed by combining the BI and the FAI scales and the new scale had improved range and sensitivity for assessing comprehensive ADL function.

However, this kind of combining attempt is seldom found in physical education literature. Traditional opinions concerning physical fitness conceptualize it as a multidimensional construct, and the only possible way to present a student's overall physical fitness level is to provide a multidimensional profile which contains scores for each component of physical fitness (Fleishman, 1964; Marsh, 1993). However, a single "overall" fitness score is still necessary in many situations, especially for physical education teachers and students because a single score make it easy to summarize a student's overall physical fitness (Fleishman, 1964). In most cases, the overall fitness score is obtained by simply summing or averaging the scores for different components of physical fitness. It is not surprising, according to Fleishman (1964), this kind of overall fitness score loses rich information about specific factors and, therefore, one should be very cautious in interpreting that kind of overall score. Marsh (1993) recommended constructing, if necessary, a weighted summary score that assigns an optimal weight to each component based on theoretical and empirical research. But it will be a big challenge to get a so-called "optimal" weight for different components because the weights may need

modification according to particular criterion or particular research purposes. Given that this research has adopted the Rasch model requirement that "the data should fit the model", reviewing the possibilities of others of the family of the IRT models should be left to the possible research project mentioned in Chapter Seven.

Summary

The use and interpretation of fitness assessment have important educational and psychological consequences (Mahar & Rowe, 2008). The definition and structure of physical fitness was discussed in this chapter. It is widely accepted in the current literature that five components including body composition, cardiorespiratory fitness, flexibility, muscular strength, and muscular endurance actually contribute to health-related physical fitness.

Physical fitness components are not isolated but are interrelated. Each component contributes an essential element to physical fitness (Clarke, 1979). Although the possibility of combining all the five fitness components into a single overall fitness scale could be a debatable topic, the benefits which would derive from having a single overall measure suggest that it is well worth trying. The Rasch model is an apt tool for developing such a unidimensional scale considering its advantages over traditional test theory. The first, a Rasch scale provides equal-interval measures so as to facilitate interpretation of physical fitness assessment results and comparisons among children. The second, a Rasch scale provides sample distribution-free and item distribution-free measures. Both of students and physical fitness indicators can be located on the common physical fitness scale directly. The third, a Rasch scale makes it possible to construct an overall physical fitness indicator that summarizes a student's physical fitness in different components. With the overall physical fitness indicator, primary school-aged students' overall physical fitness levels could be calibrated on the common scale even if the student just takes only one of physical fitness tests from among the five components.

CHAPTER THREE

METHODOLOGY

As proposed in Chapter One, this study employed quantitative methods adopted from the Rasch measurement perspective to develop a physical fitness scale. This chapter outlines the important aspects of the research methodology including the sample characteristics, the instruments used to obtain students' physical fitness data, the procedures for data collection, and issues related to research ethics and data confidentiality. The methods chosen for data analyses are also justified and described in this chapter. Finally, the limitations of study design are discussed.

Sample

Data used in this study were retrieved from the assessment records database of a large, regional Hong Kong primary school. This school is a government-subsidized primary school located in the north-eastern New Territories of Hong Kong. This school routinely has five classes in each year level from primary 1 to primary 6 with over 1,000 students enrolled.

The data cover that school's students' physical fitness records over the academic years 2002-03 to 2006-07. There are two rounds of students' records for each academic year except 2002-03 for which the records for the 2nd semester were not put into the school's database. Initially, a total of 10,512 student records were included in the data pool for this study. Finally 9,439 records were kept for scale development after excluding exceptional and unreasonably extreme data. It is worth pointing out that each record does not necessarily refer to an independent student since this is a longitudinal data set over five

years and most students would have several records over time in the data set. Of the records, there are 5,149 (54.6%) male and 4,290 female (45.4%) records. The ages for all records in years range from 6 to 13 (M = 8.53, SD = 1.73). Four records did not include age information. The details of the sample used in this study are presented in Table 3.1.

Table 3.1 Details of the Sample

Academic year	2002-03		2003-04		2004-05		2005-06		2006-07		
Semester	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	Total
Male	510	0	556	551	572	574	592	590	606	598	5149
Female	458	0	472	468	492	489	488	487	468	468	4290
Total	968	0	1028	1019	1064	1063	1080	1077	1074	1066	9439

Age	6	7	8	9	10	11	12	13	Total
Male	837	900	877	845	813	779	94	4	5149
Female	666	701	727	742	717	672	61	0	4286
Total	1503	1601	1604	1587	1530	1451	155	4	9435

Instruments: Physical Fitness Indicators

Students' performances on different components of physical fitness were assessed using a variety of indicators. While there are many fitness batteries developed to assess children's physical fitness, most of the primary schools in Hong Kong, including the partner school of this study, administer the physical fitness battery recommended by the School Physical Fitness Award Scheme (Hong Kong Education and Manpower Bureau, 2005b) except that the body composition is not assessed using skinfold method but indicated by BMI because the skinfold method of body fat assessment requires special equipment which is not available in many schools including the partner school of this study.

BMI

Although the BMI does not assess the percentage of body fat and is usually used as an indicator of obesity (Vehrs & Hager, 2006), it is accepted worldwide as an alternative indicator of body composition when more direct techniques for body fat estimation are

not available. Hong Kong primary schools measure students' height and weight routinely so that the BMI could be calculated conveniently. BMI is defined as body weight (in kilograms) divided by height (in metres) squared (BMI = weight (kg) / height $(m)^2$). Teachers and students in Hong Kong schools are very familiar with the concept and calculation of BMI. A "Weight for Height Chart" developed by Leung (1993) is routinely used in Hong Kong schools to help to judge whether primary school-aged students are obese or underweight (Hong Kong Education and Manpower Bureau, 2005a).

6/9-minute Run

The 6 or 9-minute Run test is administered in most of Hong Kong primary schools to assess students' cardiorespiratory fitness. The student runs/walks around the basketball court for a 6 or 9 minute period (as appropriate) and the distance covered is recorded in metres as the score. The 6-minute Run test is administered to grades 1 to 3 students and the 9-minute Run test is administered to grades 4 to 6 students. The 9-minute Run test is commonly used in western countries and research reports it as having test-retest reliability coefficient of 0.94 and a validity coefficient of 0.90 using maximum oxygen consumption as the criterion (Miller, 2006).

1-minute Sit-ups

Generally speaking, there are two different forms of the sit-ups protocol. The sit-ups test with a weight plate or a dumbbell behind the performer's neck is designed to assess the strength of abdominal muscles (Johnson & Nelson, 1986); the other, the 1-minute Sit-ups test, aims to assess the endurance of the abdominal muscles (AAHPERD, 1980). Hong Kong primary schools adopt the 1-minute Sit-ups test to assess students' muscular endurance since it requires almost no equipment and is very convenient to administer in large-scale assessments. In the 1-minute Sit-ups test, the student lies face-up on the mat with knees bent, with arms crossed against the chest and feet pressed on the floor by a

partner. One correct repetition involves sitting-up from the mat, touching the elbows to the thighs, then lowering the upper body and returning to the original position. The number of correct sit-up repetitions the student completes in 1 minute is recorded as the score. The test-retest reliability coefficients of 1-minute Sit-ups test ranges from 0.68 to 0.94 in different studies (Miller, 2006).

Handgrip (Right and Left)

A hand-grip dynamometer can be used to test students' static strength of flexor muscles or static endurance of flexor muscles depending on the testing method used (Heyward, 2002). The grip strength test requires the performer to squeeze the dynamometer as hard as possible using one brief maximal contraction, while the grip endurance test requires the performer to squeeze the dynamometer as hard as possible and hold for 1 minute. The isometric grip strength test generally has reliability coefficients of more than 0.90, and the correlations among the arm, shoulder, torso, and leg isometric strength test range from 0.82 to 0.92 (Baumgartner et al., 2007). The handgrip test adopted in Hong Kong primary schools is the grip strength test with the purpose of assessing the static strength of flexor muscles of right and left hands. In a Handgrip test, the student stands erect, with the arm extended, and squeezes the dynamometer as hard as possible using right/ then left hand. The best score of three trials is recorded in kilograms as the final score for each hand.

Sit-and-Reach

The standard Sit-and-Reach test (AAHPERD, 1980) is used by most of Hong Kong primary schools to assess students' flexibility. This test has test-retest reliability coefficients of 0.70 or higher and concurrent validity coefficients ranging from 0.80 to 0.90 (Miller, 2006). In a standard Sit-and-Reach test, the student sits on the mat with knees extended and heels shoulder-width apart, placing soles of feet against a Sit-and-Reach box which has a scale in centimetres, keeping two hands parallel and

fingertips overlapping. Then the student reaches forward slowly and as far as possible towards the box four times and holds the position of the maximum reach for at least one second at the fourth trial. The distance the student reaches at the fourth attempt is recorded in centimeters as the score. There are many other kinds of sit-and-reach tests. Some are alternatives to the standard Sit-and-Reach test (e.g., V Sit-and-Reach test; Golding, Myers, & Sinning, 1989), and others are designed for specific purposes including back-saver Sit-and-Reach test (The Cooper Institute, 2004), the modified Sit-and-Reach test (Hoeger, 1989), and the chair Sit-and-Reach test (Jones, Rikli, Max, & Noffal, 1998). Most of these sit-and-reach tests aim to assess lower back and hamstring flexibility. However, validation studies demonstrated that the sit-and-reach test is a more valid test of hamstring flexibility than of lower back flexibility. For example, Jackson and Baker (1986) reported that the correlation between the performance on the sit-and-reach test and the criterion of hamstring flexibility was 0.64, and the correlation between the performance on the sit-and-reach test and the criterion of low back flexibility was 0.28.

Push-ups (Standard Push-ups and Modified Push-ups)

Although the push-ups test is used more often in Hong Kong secondary schools than primary schools, the partner school administered the push-ups test in some semesters, as a supplementary fitness test, to assess students' arm and shoulder girdle endurance. There are two kinds of push-ups tests: the Standard Push-ups test is administered to grades 3 to 6 boys and the Modified Push-ups test administered to grades 1 to 2 boys and grades 1 to 6 girls. In Standard Push-ups, the student lies face down on the mat with the body straight, arms bent, and hands shoulder-width apart on the mat. Using the toes as the pivot point and the student pushes upward to a straight-arm position, then lowers the body to the original position. This is one repetition. Below criterion push-ups should be corrected and should not be counted. The student tries to complete as many push-ups as possible without rest. The test should be terminated if the tester corrects the action of the student

twice. The Modified Push-ups test is similar to the Standard Push-ups except that the knees are bent and the student uses the knees as the pivot point to complete the push-ups. The number of correct push-ups completed by the student is recorded as the score. The Modified Push-ups test has a reported reliability coefficient of 0.93 (Miller, 2006).

The physical fitness test protocols adopted by the partner schools of this study are summarized in Table 3.2.

Table 3.2 Physical Fitness Test Used in the Partner School

Test	Administration	Object	Scoring
BMI	BMI = weight (kg) / height $(m)^2$	Body Composition	-
6/9-minute Run	The student runs/walks around the basketball court for a 6-minute period (children aged eight or below) or for a 9-minute period (children aged nine or above).	The cardiorespiratory fitness	The distance (m.) covered in 6/9 minutes
1-minute Sit-ups	The student lies on her/his back on the mat with knees bent, crossing her/his arms against the chest and having her/his feet pressed on the floor by her/his partner. The student sits-up, touching the elbows to the thighs, then lower the upper body and return to the original position. This is one repetition.	The endurance of abdominal muscles	The number of correct sit-ups in one minute
Handgrip (R & L)	Adjust the handgrip dynamometer to a position which suits the student. The student stands erect, with the arm extended, squeezes the dynamometer as hard as possible using right/left hand. Three trials should be administered.	The static strength of grip squeezing muscles of right/left hand	The best score (k.) of the three trials for each hand

Sit-and-Reach	The student sits on the mat with knees extended and heels shoulder-width apart, placing soles of feet against the box, keeping two hands parallel and fingertips overlapping. Then the student reaches forward slowly and as far as possible along the box four times and holds the position of the maximum reach at least one second at the fourth trial.	The flexibility of the lower back the hamstring (back of the upper legs) muscles	The distance (cm.) the student reaches at the fourth trial
Push-ups (Standard Push-ups, Modified Push-ups)	As for Standard Push-ups, the student lies face down on the mat with the body straight on the toes, arms bent, and hands shoulder-width apart on the mat. Pushes upward to a straight-arm position, then lower the body to the original position. This is one repetition. The student should complete the exercise as many times as possible. The test should be terminated if the tester corrects the action of the student twice. The Modified Push-ups is similar to the Standard Push-ups except that knees bent and the student uses the knees as the pivot point to complete push-ups.	Arm and shoulder girdle muscular endurance	The count of correct push-ups

Note. Adapted from the Teacher Handbook of Hong Kong School Physical Fitness Award Schemes (Hong Kong Education and Manpower Bureau, 2005b).

Data Collection

The source of the data for this study is the existing database of a large, regional Hong Kong primary school. This source is appropriate for the main purpose of this study, i.e., constructing a Rasch measurement physical fitness scale for Hong Kong primary school-aged students. Normally, it might be expected that a very large sample be used for scale construction. However, it is not straightforward to obtain such a quality data set with as many cases / time-points as that provided by the school's database, especially for time-consuming assessment tasks as physical fitness assessments. Furthermore, even though it would not be realistic to conduct a specifically developed longitudinal study within the three-year PhD program, the existing school longitudinal data set covering

students' physical fitness data over academic years 2002-03 to 2006-07 makes it possible to track students' developmental trends in physical fitness over five years. Based on the above considerations, this study did not undertake the collection of more physical fitness data, but put the most research effort into constructing the Rasch measurement scale based on the existing school fitness assessment data.

The selected partner school is very well regarded in Hong Kong for its commitment to promotion of children's health and diverse physical education programmes. Atypically for primary schools in general and Hong Kong schools in particular, this school has invested a huge amount of manpower and other resources in physical education. For example, nine full-time PE teachers were employed by this school when the data were collected, which was most unusual for any primary school in Hong Kong. This school had three PE classes per week while other primary schools usually had two. In order to encourage a physically active life style and reduce the risk of students' health problems, this school named the first break in school days as the "dynamic break". All students and teachers would go out of classroom to take part in sports or games. A variety of facilities, such as a sport climbing wall and physical fitness room, were provided by this school for students' physical activity. This school is the only primary school in Hong Kong that owns an indoor swimming pool. Furthermore, this school played active role in cooperative physical education projects with external parties. For example, it was the first CATCH (Coordinated Approach Towards Children's Health) school in Hong Kong. From academic year 2005-06 on, it participated in a three-year project on physical fitness assessment conducted by a local institute.

In the partner school, the physical education teachers administered the fitness battery, once each semester, during their regular PE classes and recorded students' performances for these indicators according to the guidelines provided by Hong Kong government. The students' scores then were input manually into the school's database. Normally, the physical fitness battery was administered each January for the 1st semester, and each June for the 2nd semester.

Although the physical fitness battery was administered routinely twice a year to all students, some tests were administered only once a year in particular academic years (e.g., the Handgrip test in academic year 2003-04 and 2004-05) due to shortage of manpower or other reasons. The details of each indicator having students' performances recorded are listed in Table 3.3.

Table 3.3 Data Summary

Academic year	2002-03		2003-04		2004-05		2005-06		2006-07	
Semester	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Height	✓		✓	✓	✓	✓	✓	✓	✓	✓
Weight	✓		✓	✓	✓	✓	✓	✓	✓	✓
6-minute Run			✓	✓	✓	✓	✓	✓	✓	✓
9-minute Run			✓	✓	✓	✓	✓	✓	✓	✓
1-minute Sit-ups			✓	✓	✓	✓	✓	✓	✓	✓
Sit-and-Reach	✓		✓	✓	✓	✓	✓	✓	✓	✓
Right Handgrip			✓		✓		✓	✓	✓	✓
Left Handgrip			✓		✓		✓	✓	✓	✓
Standard Push-ups	✓		✓	✓	✓	✓	✓			
Modified Push-ups	✓		✓	✓	✓	✓	✓			

The two approaches to timing and sampling of data for physical fitness studies are the cross-sectional approach and longitudinal approach. The data from longitudinal studies have the added advantage of investigating participants' developmental trends in physical fitness (Welsman & Armstrong, 2007). Nevertheless, the cross-sectional approach is used more often than the longitudinal approach because cross-sectional data are easier to collect (Baumgartner et al., 2007). It is a similar case in Hong Kong. There are numerous cross-sectional studies of Hong Kong students' performances on different components of physical fitness across various ages, but very few longitudinal studies tracking children's fitness development over time have been conducted (McManus et al., 2003). In this study, the data set provides both cross-sectional data – grades 1 to 6 in each semester – and longitudinal data – those same cohorts across several semesters – so that both cross-sectional comparisons and developmental track analyses of students' overall physical fitness can be undertaken.

Data Collation

A total of 10,512 records from academic year 2002-03 to 2006-07 were retrieved from the school's database. However, before the raw data could be subjected to analyses, it is necessary to make decisions about how to deal with some unsatisfactory data such as unexplainable zero values and extreme performance values. Those data are likely to introduce unnecessary noise into the analyses and probably distort the analyses results and, therefore, impair the utility of the Rasch measurement scale.

Among the 10,512 records available for use, there were 1,058 records (987 of them were records of the second semester in 2002-03) which provided no information on any of physical fitness indicator except Height and Weight. These were excluded from the analyses of the present study.

For the remaining 9,454 records, the "zero" value appeared in one or more fitness indicators for some records. The counts and frequencies of "zero" values for each fitness indicator are presented as in Table 3.4.

Table 3.4 Frequency of Zero Value

Item	Valid N	Missing	Zero value (N)	Zero value (%)
Height	9376	78	63	0.7%
Weight	9377	77	61	0.7%
6-minute Run	4219	5213	13	0.3%
9-minute Run	4091	5327	6	0.1%
1-minute Sit-ups	8466	963	33	0.4%
Right Handgrip	6391	3051	177	2.8%
Left Handgrip	6391	3051	180	2.8%
Sit-and-reach	9287	118	34	0.4%
Standard Push-ups	1362	8074	-	-
Modified Push-ups	1909	7523	-	-

It is obvious that zero values for height and weight were meaningless and might be due to data entry errors. For zero values in other indicators, it is hard to tell whether the zero value represents students' "zero" performance on some specific physical fitness indicators, or just another version of missing value caused by any of a number of unknown reasons.

For example, in 1-minute Sit-ups, students might complete many sit-ups but still be scored zero because those sit-ups did not meet the basic performance criteria (e.g., non-standard or part-completed). Considering that records with zero values are relatively rare in the sample, the most conservative method of handling those records is to exclude them, i.e., treat the individual data points as missing values while retaining the rest of the student record.

Another batch of records, although just a tiny proportion of the data set, needs special attention. Those are the extreme scores, e.g., the height of a 7-year old girl recorded as 1.90m., or a child recorded as running only 10 metres in a 6-minute period. It seems to make no sense to include such meaningless data in the analyses and scale construction in the present study. Therefore, those records with apparently unjustifiable extreme scores were excluded listwise in order to reduce the noise as much as possible. The details of records with extreme scores are presented in Table 3.5.

Table 3.5 Frequency of Extreme Score

	Extreme Score	Frequency
Height	190	1
6-minute Run	10	1
	7200	1
9-minute Run	15	1
	17	1
	18	1
1-minute Sit-ups	141	1
	180	1
	210	1
	220	1
Right Handgrip	70	1
	80	1
	90	2
Left Handgrip	80	1
	100	1
	189	1
Sit-and-Reach	140	1
	200	1
	320	1

A total of 20 apparently unjustifiable extreme scores appeared in 15 records. Excluding those 15 student records produces a total of 9,439 records to be used for the analyses in this study.

The descriptive summary of scores for all physical fitness indicators utilized in this study is presented in Table 3.6.

Table 3.6 Descriptive Statistics of the Data

	Unit	Subjects	Mean	SD	Min.	Max.	Valid N
BMI		All	16.8	2.9	10.1	38.2	9286
6-minute Run	Metre	Grades 1 - 3	836	169.8	360	1520	4204
9-minute Run	Metre	Grades 4 - 6	1319	271.3	560	2240	4082
1-minute Sit-ups	Count	All	25	10.2	1	63	8429
Right Handgrip	Kilogram	All	12	5.3	1	41	6211
Left Handgrip	Kilogram	All	12	5.1	1	37	6208
Sit-and-Reach	Centimetre	All	28	7.0	2	51	9250
Standard Push-ups	Count	Grades 3-6 boys	29	15.3	1	75	1362
Modified Push-ups	Count	Grades 1-2 boys & Grades 1-6 girls	35	16.9	3	82	1909

Data Analyses

Model

The Rasch Poisson Counts Model has been used to measure physical fitness in a number of studies (e.g., Safrit et al., 1992; Zhu & Safrit, 1993). Nevertheless, the appropriateness of the Rasch Poisson Counts Model in time-limited psychomotor performances such as 1-minute Sit-ups test scores is dubious because some of the model's assumptions are not satisfied by such data: the Rasch Poisson Counts Model assumes that examinees should complete the repetitions at a constant speed through the whole performance. However, the effect caused by fatigue in the 1-minute Sit-ups test violates this assumption; repetition speed is usually slower and slower as examinees complete greater numbers of sit-ups during the one minute period.

In contrast, the Partial Credit Model is possibly the best option for Rasch analyses with the physical fitness data in this study considering that definition of the rating scale for physical fitness indicators is unique for each fitness item. The Partial Credit Model is different from the dichotomous model in which all items have only correct or incorrect response options, in that it provides for "partially correct response(s)" between completely correct and incorrect responses. It also allows for more than one gradation from one ordered category to the next. Although the rating scale model also provides for partially correct responses and more than one gradation per item, it requires that all items share the same rating scale structure. In contrast, the Partial Credit Model allows the number and structure of the rating scale categories to vary from item to item (Masters, 1982).

Software

The software package used for Rasch analyses in the present study is WINSTEPS 3.0 programme (Linacre, 2006a). WINSTEPS dates from 1983 when Ben Wright and Mike Linacre developed the first Rasch program with the ability of handling missing data – MSCALE. WINSTEPS is now widely used in Rasch model application studies in a variety of fields such as educational and psychological assessment, medical research, and attitude surveys. WINSTEPS can handle maximally 30,000 items with up to 255 categories per item for 10,000,000 persons. The Rasch models implemented in WINSTEPS include the Rasch "dichotomous", Andrich "rating scale", Masters "partial credit", Bradley-Terry "paired comparison", Glas "success", Linacre "failure" models and most combinations of these models. Other models such as binomial trials and Poisson can also be analysed by anchoring (fixing) the response structure to accord with the response model.

Iterative Sequence of Analytical Steps

The intention was that the RMPFS in this study would be developed from a Rasch measurement perspective and the fitness indicators that violated Rasch measurement requirements would be excluded from the scale. More specifically, this study took the strong "data fit the model" position in developing the physical fitness scale. The physical fitness indicators that were retained would then comprise the RMPFS which would be used to measure primary school-aged students' overall physical fitness and track their developmental trends in physical fitness. It is necessary to explain and to justify the iterative sequence of analytical steps used to investigate the quality of the indicators and to decide whether an indicator should be retained or excluded. This section summarizes nine criteria used in the procedure for scale development.

1. *Investigations from practical perspective*. Practical considerations before undertaking data analyses could uncover some factors detrimental to scale development but which would not be detected by statistical approaches. For example, unwanted errors occurred during the procedure for data collection and data entry could damage the quality of data and, therefore, make the data analyses less meaningful. Furthermore, some indicators might have special features that could make it inappropriate for inclusion into the development of the Rasch measurement scale.
2. *Response category structure*. Successful implementation of polytomous Rasch measurement requires well functioning categories for each indicator in the scale. Four diagnostic indicators including category frequencies, average measures, threshold calibrations, and category probability curves could be used to control the quality of response category structure.
3. *Fit statistics for indicators*. WINSTEPS program provides both MNSQ and ZSTD for Infit and Outfit statistics. Considering the huge sample size ($n > 9,000$) in this study, MNSQ is used as a criterion for scale quality assurance instead of ZSTD because ZSTD was highly sensitive to sample size, while MNSQ was relatively

stable (Smith, Rush, Fallowfield, Velikova, & Sharpe, 2008). A huge sample size makes ZSTD so powerful that it probably magnifies the misfit between the model and the data (Mok, Cheong, Moore, & Kennedy, 2006). Wu (as cited in Bond & Fox, 2007, p. 241) also pointed out that most items are likely to be rejected if ZSTD is used to detect misfit when the sample is large enough.

4. *Point-measure correlations for indicators*. The point-measure correlation coefficient of an indicator refers to the correlation between measure of the indicator and the overall measure of the trait under measurement (Linacre, 2006b). Theoretically, the value of a point-measure correlation coefficient should fall into the range between –1 and +1. The higher the value of the point-measure coefficient is, the higher the relationship between the item measure and the overall measure. Normally, a point-measure correlation coefficient higher than 0.4 indicates acceptable consistency among indicators' polarity in the scale.
5. *Rasch reliability*. Rasch measurement provides both person reliability and item reliability. The Rasch person reliability refers to the consistency of person ordering along the trait continuum measured by the scale (Smith, 2001; Wright & Masters, 1982). The Rasch person reliability is influenced by the spread of item difficulties and the number of items that are targeted at the sample of persons. Appropriate spread of item difficulties should separate persons into distinctive ability groups. Sufficient numbers of targeted items should reduce the error of person ability estimates by providing enough information about person ability and, therefore, enhance person reliability. The Rasch item reliability indicates replicability of item placements along the trait continuum if the same set of items were administered to another similar sample of persons (Bond & Fox, 2007). High item reliabilities require the sample of persons to have a wide range of abilities. At the same time, large enough numbers of persons with appropriate ability levels to estimate the item difficulties should enhance the item reliability.
6. *Variance explained by measures*. The Rasch model describes the variance of observations as comprising a predictable component generated by the Rasch

measures and a random component (Linacre, 2006a). Variance explained by the measures refers to the proportion of variance of observations that could be explained by the item difficulties, person abilities and rating scale structures in Rasch analyses (Linacre, 2006a). A higher proportion of variance explained by Rasch measures means that the Rasch model has better capacity for predicting performances of the items and persons.

7. *Local independence*. Local independence refers to the requirement that the response to any one item, whether right or wrong, should have no influence on the responses to any other item within the test. That means that the responses to any two items should be mutually independent.
8. *Influence of underfitting persons*. The influence of extremely misfitting persons, especially underfitting persons (MNSQ fit statistics are much higher than 1.0), on scale quality would be investigated. The noise introduced by misfit would be reduced as much as possible.
9. *Consideration of sex Differential Item Functioning (DIF)*. DIF is a criterion regularly used to describe an item's quality in a scale. For an item with DIF, different groups of students of the same ability level would have different item scores (American Education Research Association, American Psychological Association, and National Council on Measurement in Education, 1999). It is obviously not productive to include items with DIF in a measurement scale.

Ethics and Confidentiality

The objects of this study are the children's physical fitness data retrieved from the existing database of a Hong Kong primary school. There was no data collection procedure in this study, such as testing and interviewing, which might involve direct contact between the researcher and students. Therefore, no physical or psychological risks to participants could be raised by this analytical study.

Prior consent for using the school's data by the researcher was obtained from the partner school at the beginning of this study. A written agreement (Appendix A) about data availability, use and confidentiality was co-signed by the principal of the school and the researcher in September 2007.

The researcher guaranteed that the data would be used only for research purposes and that the confidentiality of students' name or any other personally identifying details in the data set was assured. However, it is worth noting that third parties - other than the school and the researcher - could access the data set due to the ownership the school has of the data.

Limitations of Study Design

Since it is difficult to obtain comprehensive physical fitness data sets as that provided by the partner school from other Hong Kong primary schools due to the availability of data and schools' willingness to release internal information, this study relied exclusively on the data from the partner school. That brings limitations to the study which prevents the immediate generalization of the physical fitness scale developed in this study to other Hong Kong primary schools.

Thus this study's core value remains in trying a new approach to physical fitness measurement and building up a good model practice - rather than providing a ready-for-use instrument for physical fitness assessment.

Sequencing of Research

The researcher was enrolled in the PhD program through the School of Education at JCU over three years, from May 2006 to May 2009, to conduct this study. This study focused on the construction of RMPFS and the implementation of this scale to track students' physical fitness development. Therefore, most time and resources have been spent on

these two tasks. The idea of constructing an overall Rasch measurement physical fitness scale was initiated by the researcher and was proposed at the Pacific Rim Objective Measurement Symposium (PROMS) in July 2007 in Taiwan and the preliminary results were presented at PROMS in August 2008 in Tokyo. Just as expected, most of the specialist audience showed great interest in such a debatable topic. Nobody, from either the PE domain or Rasch field, challenged the benefits which would derive from having a single overall physical fitness measure although some of them had doubts as to whether that goal could actually be achieved. Invaluable feedback and comments from PE and Rasch colleagues at the conference and thereafter through emails provided guidance during the procedure for scale development.

CHAPTER FOUR

DEVELOPMENT OF THE RMPFS

Introduction

This chapter describes the procedures for development of the RMPFS. Nine physical fitness indicators including BMI, 6-minute Run, 9-minute Run, 1-minute Sit-ups, Standard Push-ups, Modified Push-ups, Sit-and-Reach, Right Handgrip, and Left Handgrip were investigated thoroughly from a Rasch measurement perspective. It was necessary to use a logarithmic transformation of the raw data and to create a 7-category response structure obtained through category collapsing to obtain optimal category functioning for the rating scales of the RMPFS indicators.

Consideration of BMI

Before the physical fitness indicators were submitted together into WINSTEPS to construct the Rasch measurement scale, each indicator was examined carefully to judge its appropriateness for inclusion into the RMPFS. BMI was excluded at this stage for the following two reasons: The first, BMI is a rough index appropriate for reporting adiposity at the population level but not optimal for use with individuals because of the unacceptable prediction error (Heyward, 2002; Stratton & Williams, 2007). BMI provides information related to body composition. Although not a perfect predictor, BMI has been shown to be a valid predictor for percentage of body fat. However, it does not directly estimate the percentage of body fat which is used to classify the level of body composition.

The second, BMI is a trait with an inverted U-shaped - rather than a linear - distribution. According to a report on obesity published by the World Health Organization (1998), the range between 18.5 and 24.9 is the optimal BMI zone in terms of physical fitness, a BMI ranging from 25.0 to 29.9 is regarded as overweight, and a BMI higher than 29.9 indicates levels of obesity often associated with high risk of health problems. On the other hand, a BMI less than 18.5 is regarded as underweight which is normally caused by dystrophy and is associated with other health problems as well. Thus, a higher BMI score does not necessarily stand for a better level of physical fitness; nor does a lower BMI score necessarily stand for a better physical fitness level. This is a distinctive feature which sets BMI apart from other physical fitness indicators. For example, a student who covers 1,000m. in a 9-minute Run test has better cardiorespiratory fitness than a student who covers 800m. or 600m. Similarly, a higher score on a 1-minute Sit-ups test indicates a higher level of muscular endurance than a lower score in the same test. Combining BMI together with other physical fitness indicators in the Rasch measurement scale would contradict one of the requirements of Rasch model: all items in the same scale should function in the same (linear) direction along the underlying latent trait under measure.

Rasch Analyses Based on Raw Scores

Among the remaining eight indicators, 1-minute Sit-ups, Standard Push-ups, Modified Push-ups, Sit-and-Reach, Right Handgrip, and Left Handgrip are ready for Rasch analyses using WINSTEPS software because the raw scores for these indicators have fewer than 255 categories that can be accommodated by WINSTEPS. However, the raw data for 6-minute Run and 9-minute Run are inappropriate for use with WINSTEPS directly because there are far more than 255 categories in the raw data. Therefore, it is necessary to transform the raw scores of the 6-minute Run and 9-minute Run into an appropriate number of categories which are amenable for Rasch analyses using WINSTEPS software.

The raw scores of 6-minute Run in the sample range from 360m to 1,520m. The range (1,140) was divided by 100, and the rounded value "12" was used as a step for the algebraic transformation. For 9-minute Run, the raw scores range from 560m to 2,240m. Similarly, the range (1,680) was divided by 100, and the rounded value "17" was used as a step for the algebraic transformation. By such means, the raw scores for 6-minute Run were transformed into interval records with a range from 1 to 97, and those for 9-minute Run were transformed into interval records with a range from 1 to 99. The details are presented in Table 4.1.

Table 4.1 Categories for 6-minute Run and 9-minute Run

6-minute Run		9-minute Run	
Raw score	Category	Raw score	Category
[360, 360+12*1)	1	[560, 560+17*1)	1
[360+12*1, 360+12*2)	2	[560+17*1, 560+17*2)	2
[360+12*2, 360+12*3)	3	[560+17*2, 560+17*3)	3
…	…	…	…

Finally, all the raw data (9,439 students' responses on 8 indicators) were submitted to the WINSTEPS programme except that the scores for the 6-minute Run were re-coded as 97 categories and the scores for 9-minute Run were re-coded as 99 categories using above-mentioned transformation method. The Rasch Partial Credit Model was specified in the WINSTEPS control file. The details of scores finally used in WINSTEPS are presented in Table 4.2.

Table 4.2 Raw Scores in Rasch Analyses

Indicator	Valid N	Number of Categories
6-minute Run	4204	97
9-minute Run	4082	99
1-minute Sit-ups	8429	63
Right Handgrip	6211	41
Left Handgrip	6208	37
Sit-and-Reach	9250	51
Standard Push-ups	1362	75
Modified Push-ups	1909	82

The Rasch model provides a number of indices that can be used to check the quality of a measurement scale (Wright & Masters, 1982). These indices widely used in literature include the Outfit and Infit statistics, the point-measure correlation coefficient, the Rasch reliability for both person and item, and the variance explained by the measures.

The psychometric properties of the Rasch scale constructed based these data are presented in Table 4.3. It can be seen that the Infit and Outfit MNSQ for most of the indicators - except Sit-and-Reach and Modified Push-ups - range from 0.87 to 1.03. The Infit and Outfit MNSQ for Sit-and-Reach and Modified Push-ups are higher than 1.20, indicating underfit to the Rasch model's requirements. The point-measure correlations for all indicators fall in the productive range of 0.45 to 0.76. That indicates all indicators are of the same polarity along the latent trait. The Rasch item reliability is 1.00, while the Rasch person reliability of the scale is much lower at 0.55. This is not surprising considering there are nearly 10,000 person records used to calibrate the indicator estimates, but only 8 indicators are used to estimate the person abilities. In other words, there is more than enough information provided for each indicator, but, for each person, the information provided is rather limited, such that the errors of indicator estimates are very small but the errors of the person estimates are fairly large. The variance explained by the underlying measure is 58.2%. In summary, these indices of scale quality suggest that it might be productive to investigate the possibilities for scale improvement.

Table 4.3 Scale Property (1)

Indicator	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measure
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		

There are a number of factors that probably lead to the poor performance of the scale. In the case of this study, the item category structure should be investigated carefully in the first step. Although WINSTEPS has very generous limits to items' response category structure, the analyses results would make no sense if the response categories function poorly. The 6-minute Run can be used as an example to demonstrate the salient features of the response category structure of the data. Table 4.4 and Figure 4.1 present the category structure and category probability curves for the 6-minute Run.

Due to the space limit, Table 4.4 presents just part of the response categories as examples. Three columns in Table 4.4 are worthy of discussion, namely, observed count, observed average, and structure calibration. The column "observed count" provides information about frequencies of categories observed in the data set. The column "observed average" is the average measure for each category. The column "structure calibration" presents threshold calibrations or threshold difficulties. Threshold calibrations refer to the position on the latent trait where the probability of being observed in category n and category n-1 is the same (i.e., 50%).

As indicated in Table 4.4, the frequencies in categories are very uneven. Some categories (e.g., categories 24 and 31) have a frequency counts of over 400, while many categories have zero frequency which means those values were not observed meaningfully. It is expected that the average measures of categories and threshold calibrations should advance monotonically if the data fit to the Rasch model. The results presented in this table show that the average measures of categories barely advanced and there were some reversed average measures (marked by * in the table) as well as reversed threshold calibrations.

Table 4.4 Category Structure for the 6-minute Run Data

SUMMARY OF CATEGORY STRUCTURE. Model="R"
FOR GROUPING "0" ITEM NUMBER: 1 R6 6-minute Run
ITEM ITEM DIFFICULTY MEASURE OF -.10 ADDED TO MEASURES

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	STRUCTURE CALIBRATN	CATEGORY MEASURE	
1	1	3	0	-.34	-.36	1.06	1.03	NONE	(-1.77)	1
2	2	0	0			.00	.00	NULL	-1.20	2
3	3	0	0			.00	.00	NULL	-.86	3
4	4	19	0	-.35*	-.34	.95	.96	-2.61	-.72	4
5	5	0	0			.00	.00	NULL	-.65	5
6	6	0	0			.00	.00	NULL	-.61	6
7	7	0	0			.00	.00	NULL	-.57	7
8	8	0	0			.00	.00	NULL	-.55	8
9	9	0	0			.00	.00	NULL	-.53	9
10	10	0	0			.00	.00	NULL	-.51	10
11	11	42	0	-.32	-.29	.76	.77	-2.30	-.49	11
12	12	0	0			.00	.00	NULL	-.47	12
13	13	0	0			.00	.00	NULL	-.46	13
14	14	3	0	-.30	-.27	.66	.68	2.10	-.44	14
15	15	0	0			.00	.00	NULL	-.43	15
16	16	2	0	-.32*	-.25	.30	.30	.08	-.42	16
17	17	167	2	-.25	-.25	1.03	1.01	-4.58	-.40	17
18	18	0	0			.00	.00	NULL	-.39	18
19	19	0	0			.00	.00	NULL	-.38	19
20	20	0	0			.00	.00	NULL	-.37	20
21	21	9	0	-.21	-.22	1.28	1.26	2.36	-.35	21
22	22	0	0			.00	.00	NULL	-.34	22
23	23	0	0			.00	.00	NULL	-.33	23
24	24	426	5	-.21	-.21	1.02	1.00	-4.21	-.31	24
25	25	0	0			.00	.00	NULL	-.30	25
26	26	0	0			.00	.00	NULL	-.29	26
27	27	30	0	-.19	-.19	.95	.99	2.35	-.28	27
28	28	0	0			.00	.00	NULL	-.26	28
29	29	0	0			.00	.00	NULL	-.25	29
30	30	0	0			.00	.00	NULL	-.24	30
31	31	684	7	-.17	-.17	.80	.81	-3.46	-.22	31
32	32	0	0			.00	.00	NULL	-.21	32
33	33	0	0			.00	.00	NULL	-.20	33
34	34	56	1	-.16	-.15	.79	.71	2.31	-.18	34
35	35	0	0			.00	.00	NULL	-.17	35
...										
...										
96	96	0	0			.00	.00	NULL	.53	
97	97	7	0	.13	.11	.78	.75	2.04	(.77)	97
MISSING		5235	55	-.03						

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.
Unobserved category. Consider: STKEEP=NO

Figure 4.1 presents the category probability curves which show the probability of choosing a specific category for every combination of person ability and item difficulty. In the probability curve graph, the x-axis stands for the difference between person ability and item difficulty, the y-axis stands for the probability of choosing a given category. It can be seen from Figure 4.1 that many categories have no distinct peak in the graph, i.e., they are totally submerged by others. That means they were performed rarely by the children in this sample.

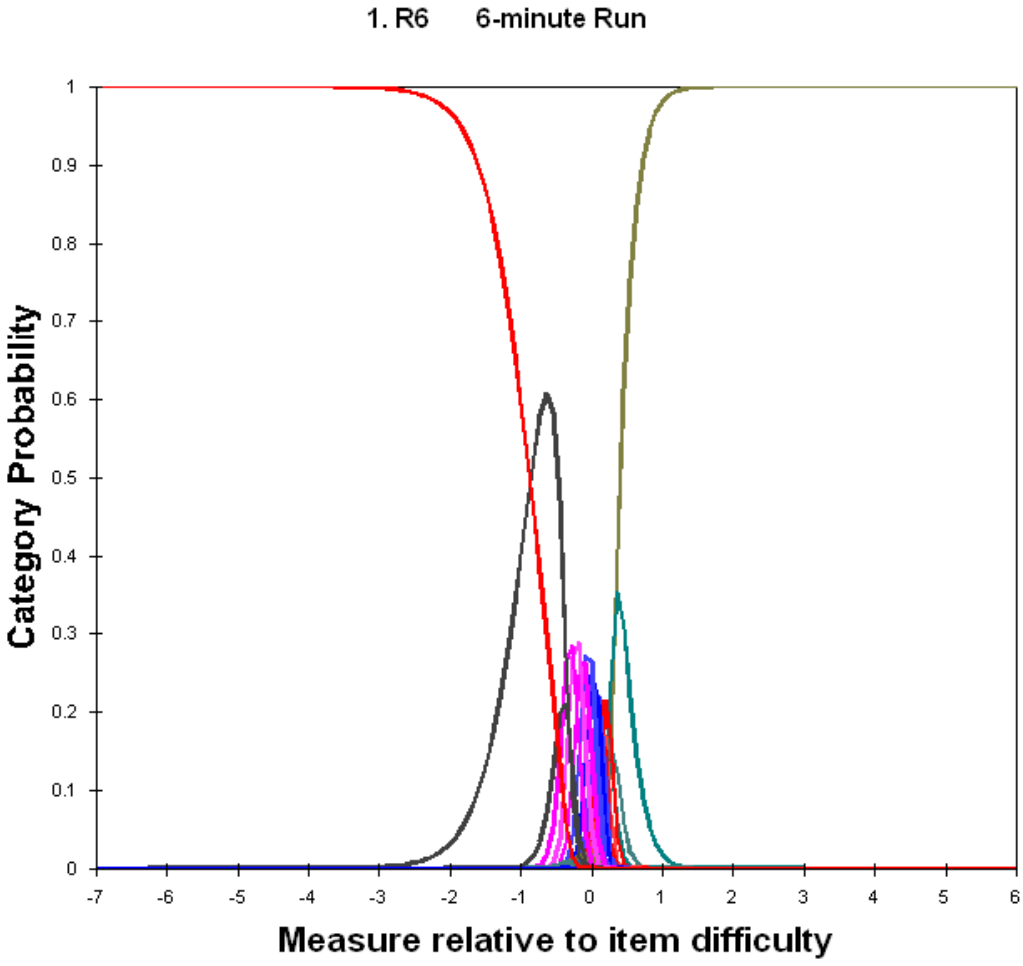


Figure 4.1 Category Probability Curves for the 6-minute Run Data

Other indicators have similar features in their category structure for the raw data. The results imply that there are many redundant categories which were not actually selected by even one single respondent. Therefore, it is necessary to collapse some adjacent categories in order to produce a better category structure and make meaningful analyses

and interpretation possible.

Logarithmic Transformation of Raw Scores

As shown in the above sections, there is no problem for the Rasch analyses software (e.g., WINSTEPS can analyse up to 255 category levels per item) to handle data with a huge number of categories, but many more than the necessary category levels probably introduces challenges to interpretation of the analyses results. In the above analyses, the number of category levels for indicators ranges from 37 to 99. From a practical perspective, it is unlikely that students' performances for physical fitness indicators have so many qualitatively different levels. Ten metres in a 6-minute Run test or one centimetre in a Sit-and-Reach test are not likely to indicate a meaningful difference in physical fitness level, even if that small difference did move a child's fitness estimate from a higher to a lower category. Thus it makes little sense to undertake analyses based on the raw scores with so many unnecessary category levels.

The results of Rasch analyses with recoded scores on 6/9-minute Run and raw scores on other fitness indicators show that the response category structure has at least four weaknesses: 1) uneven distribution of respondents among categories; 2) barely advancing average measures for categories and threshold calibrations; 3) rarely observed category probability curves for many response categories; and 4) some reversed average measures and threshold calibrations meaning higher test scores do not necessarily indicate higher levels of physical fitness. Those deficiencies indicate the necessity of recoding raw scores into qualitatively different levels to make meaningful category structure for each indicator. Furthermore, re-expressing raw data into ordered categories would help to interpret the analyses results easily and detect departures from fit more clearly (Linacre, 2000; Mosteller & Tukey, 1977).

The Poisson logarithmic transformation was used to transform the raw scores into a data

set with more even distribution and more meaningful category structure. The transformation can be expressed as

$$\text{Scored category} = 1 + 8 * \frac{\log(\text{observation}+1) - \log(L+1)}{\log(H+1) - \log(L+1)} \qquad (5)$$

Where L is the lowest value of the observations, and H is the highest value of the observations. The number "8" was chosen just because a 9-category structure was the intended transformation target.

This Poisson logarithmic transformation broke the observations into intervals such that all observations in the interval are classified into the same category level. After the transformation, students' performances for each fitness indicator were divided into 9 category levels.

Rasch Analyses of 9-Category Data (8 Indicators)

The 9-cateogry data were put into WINSTEPS programme and Rasch analyses was undertaken again. Figure 4.2 shows that the 9-category response scale has much better functioning than did the raw observations. Although there are some categories still totally submerged by others (e.g., categories 2 and 4), this graph provides a clearer picture of response categories' functioning and would facilitate the interpretation of the results.

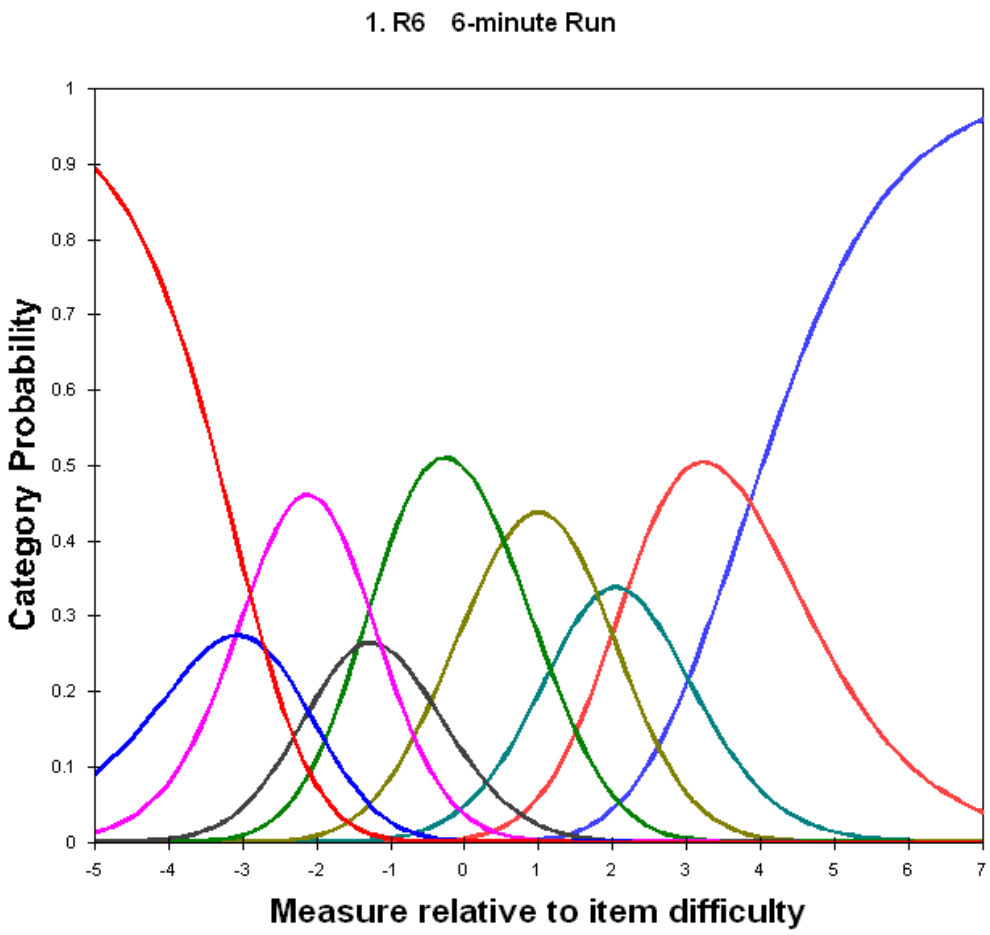


Figure 4.2 Category Probability Curves for the 6-minute Run Adopting 9-category Structure

Table 4.5 shows the psychometric properties of the Rasch measurement scale adopting 9-category response structure (Scale 2). The properties of the Rasch measurement scale with raw data (Scale 1) are also presented in this table to facilitate comparison. It can be seen that the individual item properties (Infit MNSQ, Outfit MNSQ, and point-measure correlation) did not improve much from Scale 1 to Scale 2. The Rasch item reliability is 1.00 and the Rasch person reliability of the scale is still low (0.52) and the variance explained by measures is raised slightly to 62.1%. In summary, further improvement is needed for this scale.

Table 4.5 Scale Property (2)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		

Rasch Analyses of 9-Category Data (7 Indicators)

Careful investigations of all the indicators showed that, among the eight indicators, Sit-and-Reach, which is used to assess flexibility, is distinct from others in some important ways. For example, students' performances for other physical fitness indicators increase monotonically with students' age, but it is not the case for Sit-and-Reach. Furthermore, the flexibility component has relatively small correlations with other components of physical fitness. For example, the Marsh and Redmayne (1994) study of correlations among components of physical fitness (endurance, balance, flexibility, static strength, and explosive strength/power) found that the correlations involving the endurance component are larger than the correlations involving the flexibility component. This is consistent with the findings of this study. Table 4.6 presents the correlations among students' performances on the 8 physical fitness indicators. It can be seen that the

lowest inter-correlations involved Sit-and-Reach and Modified Push-ups.

Table 4.6 Correlations among Fitness Indicators

	6-minute Run	9-minute Run	1-minute Sit-ups	Right Handgrip	Left Handgrip	Sit-and-Reach	Standard Push-ups	Modified Push-ups
6-minute Run	-							
9-minute Run	-[a]	-						
1-minute Sit-ups	.197**	.319**	-					
Right Handgrip	.098**	.144**	.268**	-				
Left Handgrip	.126**	.141**	.272**	.818**	-			
Sit-and-Reach	.049**	.119**	.168**	.039**	.042**	-		
Standard Push-ups	.242**	.420**	.399**	.153**	.134**	.211**	-	
Modified Push-ups	.035	.296**	.097**	-.204**	-.190**	.068**	-[a]	-

Note. [a] Cannot be computed because at least one of the variables is constant.
** Correlation is significant at the 0.01 level (2-tailed).

The low correlation between the flexibility component and other components of physical fitness can be supported by empirical observations. For example, it is not surprising to see that a marathon champion who has excellent cardiorespiratory fitness but cannot touch his toes.

Therefore, Sit-and-Reach was excluded from the Rasch analyses to see if there was any subsequent scale improvement. The properties of the 7-indicator scale without Sit-and-Reach (Scale 3) are presented in Table 4.7. It might be argued that exclusion of one indicator from the scale reduce the raw score range of the scale so might reduce the Rasch reliability of the scale. However, the results in Table 4.7 show that the Rasch person reliability increased appreciably from 0.52 to 0.66. This progress in scale property along with the qualitative considerations above, justified the exclusion of Sit-and-Reach from the scale. The Rasch item reliability was 1.00. The point-measure correlations for all indicators range from 0.51 to 0.76 implying that all indicators are of the same polarity along the latent trait. But the variance explained by the measure changed very little from Scale 2, and the Infit and Outfit MNSQ of indicators in Scale 3 are not yet satisfactory, for three indicators including Right Handgrip, Left Handgrip, and Modified Push-ups. Right Handgrip and Left Handgrip are overfitting and Modified Push-ups is extremely underfitting.

Table 4.7 Scale Property (3)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		

Rasch factor analysis of residuals is more appropriate for examination on the unidimensionality of data set compared with traditional factor analyses (Smith, 2002; Smith & Miao, 1992; Wright, 1996). WINSTEPS provides results of Rasch factor analyses in tables and figures. Table 4.8 presents the 1st unexplained contrast. It can be seen that indicators 4 (Right Handgrip) and 5 (Left Handgrip) have rather high loadings on the 1st contrast factor. That suggests there is probably a separate sub-dimension comprising of Right Handgrip and Left Handgrip.

Table 4.8 1st Contrast Plot for Scale 3

```
        STANDARDIZED RESIDUAL CONTRAST 1 PLOT
Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                          Empirical       Modeled
Total variance in observations     =         17.8 100.0%          100.0%
Variance explained by measures     =         10.8  60.6%           60.7%
Unexplained variance (total)       =          7.0  39.4% 100.0%    39.3%
Unexplned variance in 1st contrast =          2.1  12.1%  30.7%
```

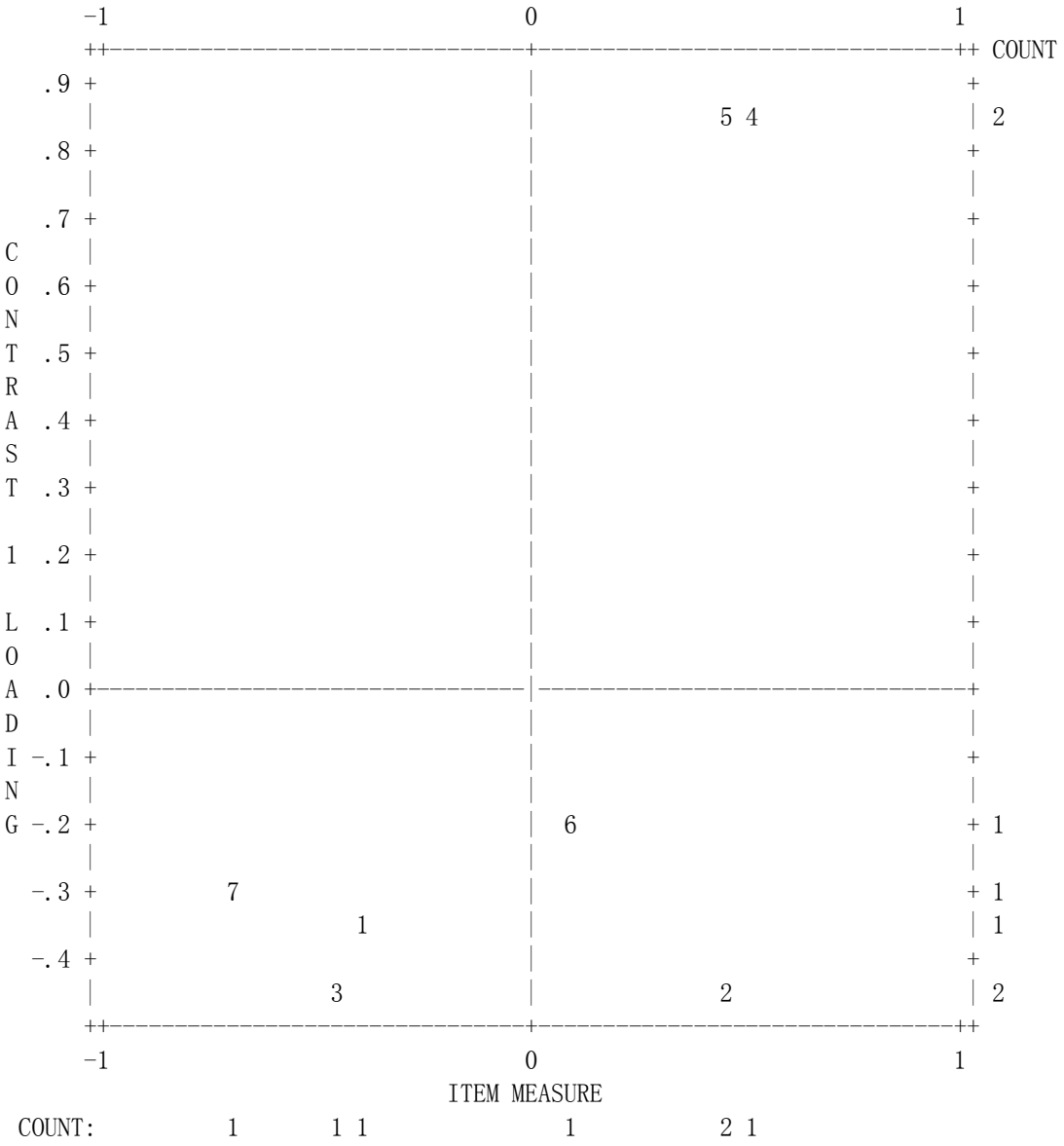


Table 4.9 further shows that the correlation between Right Handgrip and Left Handgrip residuals is 0.52, i.e., they share about 27% of their variance in common. These results are very likely to indicate local dependency between these two items. In this case, there seems no doubt that students' performances on Right Handgrip or Left Handgrip have

reciprocal influences on each other.

Table 4.9 Largest Standardized Residual Correlations for Scale 3

LARGEST STANDARDIZED RESIDUAL CORRELATIONS
USED TO IDENTIFY DEPENDENT ITEMS

RESIDUL CORRELN	ENTRY NUMBER	ITEM		ENTRY NUMBER	ITEM	
.52	4	RH	Right Handgrip	5	LH	Left Handgrip
-.39	3	SU	Sit-ups	5	LH	Left Handgrip
-.38	3	SU	Sit-ups	4	RH	Right Handgrip
-.36	2	R9	9-minute Run	5	LH	Left Handgrip
-.36	2	R9	9-minute Run	4	RH	Right Handgrip
-.31	1	R6	6-minute Run	4	RH	Right Handgrip
-.30	1	R6	6-minute Run	5	LH	Left Handgrip
-.28	4	RH	Right Handgrip	7	MPU	Modified Push-ups
-.26	5	LH	Left Handgrip	7	MPU	Modified Push-ups
-.19	5	LH	Left Handgrip	6	SPU	Standard Push-ups

In order to meet the Rasch model requirement for local independence of all indicators and to improve the measurement scale, it is necessary and reasonable to use only one grip indicator rather than two. One of the promising choices is to use Dominant Handgrip instead of Right Handgrip and Left Handgrip. In this case, the higher score of right handgrip and left handgrip was chosen as the Dominant Handgrip result for each student.

Besides Right Handgrip and Left Handgrip, local dependence is also likely to occur between 6-minute Run and 9-minute Run considering their very similar nature. However, this is not the case in this study. Since the 6-minute Run test is administered to grades 1 to 3 students only, and 9-minute Run test is administered to grades 4 to 6 students only, there is no single case that has scores on both 6-minute Run and 9-minute Run in the data set. Therefore, there is no need to deal with these two run indicators in the manner which has been adopted for Right Handgrip and Left Handgrip.

Rasch Analyses of 9-Category Data (6 Indicators)

Using Dominant Handgrip instead of Right and Left Handgrip, Rasch analyses was conducted again on the 6-indicator data set. As expected, Table 4.10 shows that there is no longer a large standardized residual correlation among indicators and that all the indicators are locally independent.

Table 4.10 Largest Standardized Residual Correlations for Scale 4

LARGEST STANDARDIZED RESIDUAL CORRELATIONS
USED TO IDENTIFY DEPENDENT ITEMS

RESIDUL CORRELN	ENTRY NUMBER	ITEM		ENTRY NUMBER	ITEM	
-.34	1	R6	6-minute Run	3	SU	Sit-ups
-.30	2	R9	9-minute Run	3	SU	Sit-ups
-.29	3	SU	Sit-ups	4	DH	Dominant Handgrip
-.29	2	R9	9-minute Run	4	DH	Dominant Handgrip
-.27	1	R6	6-minute Run	4	DH	Dominant Handgrip
-.25	4	DH	Dominant Handgrip	6	MPU	Modified Push-ups
-.20	3	SU	Sit-ups	6	MPU	Modified Push-ups
-.18	2	R9	9-minute Run	5	SPU	Standard Push-ups
-.17	1	R6	6-minute Run	6	MPU	Modified Push-ups
-.16	2	R9	9-minute Run	6	MPU	Modified Push-ups

Table 4.11 presents the psychometric properties of scales developed to this point. It can be seen that, for Scale 4, the point-measure correlations for all indicators range from 0.60 to 0.78. The percentage of variance explained by the measure has been raised slightly to 62.6%, and the Infit and Outfit MNSQ for all indicators are considerably improved. The most underfitting indicator is the Modified Push-ups (Infit MNSQ = 1.26; Outfit MNSQ = 1.27), and the most overfitting indicator is the Standard Push-ups (Infit MNSQ = 0.88; Outfit MNSQ = 0.88). The Rasch item reliability is 1.00; however, the Rasch person reliability of Scale 4 (0.60) is not as good as that of Scale 3 (0.66).

Table 4.11 Scale Property (4)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		
6-indicator 9-category (Scale 4)					
6-minute Run	0.93	0.92	0.70	0.60/1.00	62.6%
9-minute Run	0.95	0.95	0.75		
1-minute Sit-ups	0.90	0.90	0.69		
Dominant Handgrip	1.11	1.10	0.65		
Standard Push-ups	0.88	0.88	0.78		
Modified Push-ups	1.26	1.27	0.6		

The results presented in Table 4.11 show that the Standard Push-ups and Modified Push-ups have poor fit to the Rasch model compared to the other fitness indicators. The Standard Push-ups is overfitting (both the Infit and Outfit MNSQ are 0.88), and the Modified Push-ups shows underfitting (Infit MNSQ 1.26; Outfit MNSQ 1.27).

Although deleting items with large "misfit" values is often considered, the fit statistics should act as a criterion to detect problematic items and the test designer should examine the "misfit" items carefully to uncover the possible effects of other influences (Bond & Fox, 2007; Wright & Panchapakesan, 1969). In this case, the reasons of the poor performance of Standard Push-ups and Modified Push-ups in the scale are probably related to the following points.

The first, in Hong Kong, the Standard Push-ups and Modified Push-ups are not commonly used fitness indicators for primary school-aged students. The Standard Push-ups test is normally administered to Secondary male students, and the Modified Push-ups test is normally administered to Secondary female students. The partner school of this study used these two indicators just as supplementary tests to assess the component of muscular endurance before academic year 2005-06. They were no longer administered after the second semester of academic year 2005-06. Moreover, these two tests were administered to only a small portion of students before academic year 2005-06. Among the 9,439 cases, 1,362 (14.4%) cases have Standard Push-ups records, and 1,909 (20.2%) cases have Modified Push-ups records.

The second reason is related to the nature of the Push-ups test. The test would be terminated only if the tester twice corrects the action of the student. Therefore, both the tester's leniency/severity and the student's performance might have influence on the test results. Different testers are likely to use slightly different criteria to judge whether a push-up completed by the student is a correct one or not. On the other hand, these two tests have no time limit but have an assumption about students' willingness, i.e., students were assumed to try their best to complete as many push-ups as possible until they cannot do any more. But it is not always the case. Since some students will try their best while the others will not, the testing results might not reflect only the students' actual levels of muscular endurance.

Rasch Analyses of 9-Category Data (4 Indicators)

Considering the misfit shown by The Standard Push-ups and Modified Push-ups and the possibility of measurement noise introduced by these two indicators, it is reasonable to consider excluding them from the RMPFS. Consequently, a 4-indicator scale was constructed. The analyses results are presented in Table 4.12.

Table 4.12 Scale Property (5)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		
6-indicator 9-category (Scale 4)					
6-minute Run	0.93	0.92	0.70	0.60/1.00	62.6%
9-minute Run	0.95	0.95	0.75		
1-minute Sit-ups	0.90	0.90	0.69		
Dominant Handgrip	1.11	1.10	0.65		

Standard Push-ups	0.88	0.88	0.78		
Modified Push-ups	1.26	1.27	0.60		
4-indicator 9-category (Scale 5)					
6-minute Run	0.92	0.91	0.73		
9-minute Run	0.90	0.90	0.79	0.63/1.00	66.9%
1-minute Sit-ups	0.97	0.98	0.70		
Dominant Handgrip	1.09	1.08	0.70		

As indicated in Table 4.12, the property of Scale 5 is much better than that of Scale 4. The Infit and Outfit MNSQ for all indicators range from 0.90 to 1.09. The point-measure correlations for all indicators range from 0.70 to 0.79. The Rasch person reliability increased from 0.60 to 0.63, and the Rasch item reliability remains the same. The variance explained by measures increased considerably from 62.6% to 66.9%.

The Rasch factor analyses of residuals dimensionality table for the 4-indicator scale adopting 9-category structure is shown in Table 4.13 It can be seen that 66.9% of variance is explained by the measure, and 33.1% of the total variance is attributed to other factors. The increased variance explained by the measure is evidence of the higher proportion of variance in the observations that could be explained by the item difficulties, person abilities and rating scale structures in the Rasch analyses (Linacre, 2006a). Thus this Rasch scale has better capacity for predicting performances of the items and persons.

Table 4.13 Dimensionality Table for 4-indicator Scale (Scale 5)

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		Empirical		Modeled
Total variance in observations	= 12.1	100.0%		100.0%
Variance explained by measures	= 8.1	66.9%		66.4%
Unexplained variance (total)	= 4.0	33.1%	100.0%	33.6%
Unexplned variance in 1st contrast	= 1.6	13.2%	40.0%	
Unexplned variance in 2nd contrast	= 1.4	11.5%	34.9%	
Unexplned variance in 3rd contrast	= 1.0	8.2%	24.9%	
Unexplned variance in 4th contrast	= .0	.1%	.3%	
Unexplned variance in 5th contrast	= .0	.0%	.0%	

Optimizing Category Structure

Well functioning categories for each indicator should be achieved in order to implement polytomous Rasch measurement successfully. Generally speaking, there are four diagnostic indicators to help to control the quality of category structure (i.e., category frequencies, average measures, threshold calibrations, and category probability curves) (Linacre, 2002).

Reasonable category frequencies must satisfy two aspects: a) each response category should have enough observations, i.e., there is reasonable number of respondents who choose any specific category; and b) the observations should have a regular distribution, such as uniform, normal, and bimodal distribution, across all categories.

Average measures of categories should increase monotonically in the same direction as the latent trait increase. That means the higher categories along the trait metric should have higher average measures than the lower categories on the same metric. For example, in a 6-minute Run test, the category of 1,000m. should represent higher cardiorespiratory fitness than does the category of 600m.

Threshold calibrations, conceptualized as Rasch-Thurstone thresholds in the Partial Credit Model, refer to the difficulty level at which the probability of choosing the lower category is exceeded by the probability of choosing the next higher category (Bond & Fox, 2007; p105). Obviously, threshold calibrations should increase monotonically just as do the average measures for the same reason.

Category probability curves show the probability of choosing a specific category for every combination of person ability and item difficulty. For reasonable probability curves, each category should have a peak in the graph. That means each category should be the most probable option for a given group of persons with specific level of ability.

Table 4.14 presents the category structure for 6-minute Run adopting 9-category data for that indicator.

Table 4.14 Category Structure for the 6-minute Run Adopting 9-category Data

SUMMARY OF CATEGORY STRUCTURE. Model="R"
FOR GROUPING "0" ITEM NUMBER: 1 R6 6-minute Run

ITEM ITEM DIFFICULTY MEASURE OF -.49 ADDED TO MEASURES

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	STRUCTURE CALIBRATN	CATEGORY MEASURE	
1	1	3	0	-2.21	-2.62	1.18	1.10	NONE	(-5.66)	1
2	2	19	0	-2.29*	-2.01	.81	.76	-3.62	-4.29	2
3	3	214	3	-1.71	-1.63	.91	.87	-3.74	-3.18	3
4	4	435	5	-1.14	-1.17	1.02	1.03	-1.63	-2.13	4
5	5	1640	19	-.59	-.56	.80	.82	-1.72	-.89	5
6	6	1261	15	.22	.22	.98	.94	.57	.78	6
7	7	437	5	1.16	1.07	.96	.93	2.19	2.11	7
8	8	172	2	2.13	1.99	.89	.88	2.94	3.62	8
9	9	23	0	2.81	3.07	1.15	1.14	5.00	(5.70)	9
MISSING		4261	50	1.46						

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.

As indicated in Table 4.14, the frequencies in categories are very unevenly distributed. Categories 5 and 6 have a frequency count of over 1,000, while category 1 has only 3 observations among 9,439 cases, which means category 1 cannot be observed meaningfully. The results presented in this table also show that the average measures of categories 1 and 2 are reversed (marked by * in the table).

The category probability curves presented in Figure 4.3 show that some categories (e.g., categories 2 and 4) have no distinct peak in the graph, i.e., they are totally submerged by others. That means they were performed rarely by the students in this sample.

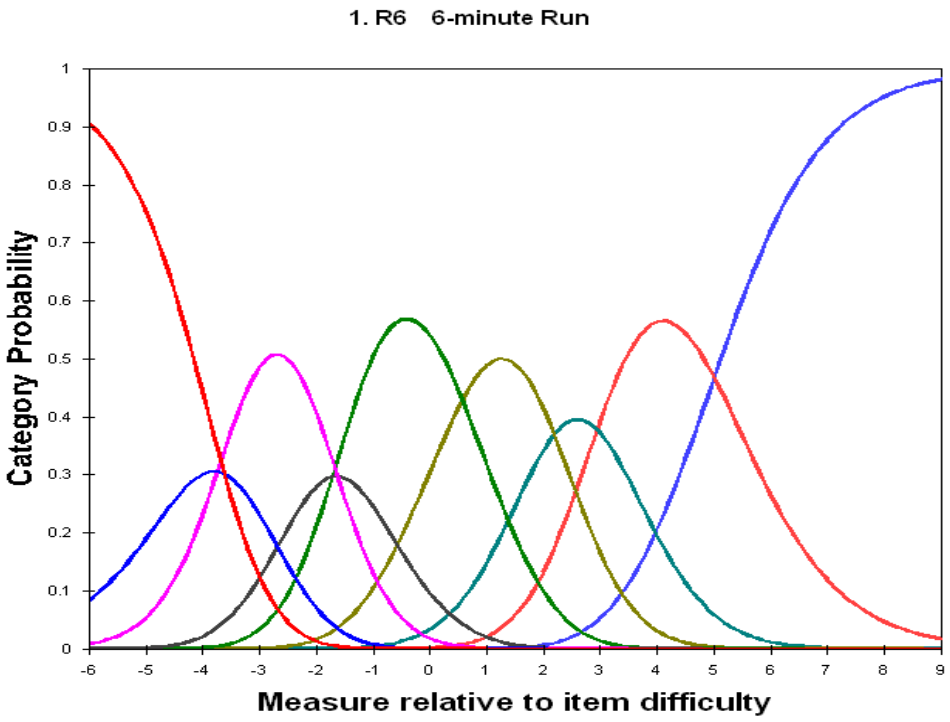


Figure 4.3 Category Probability Curves for the 6-minute Run Adopting 9-category Structure

Other indicators have similar features revealed in their category structures. The results indicate that there are some redundant categories which were not used by a meaningful number of respondents. Therefore, it is appropriate to collapse some adjacent categories in order to generate a better category structure.

Rasch Analyses of 7-Category Data

The results of Rasch analyses adopting 9-category data set showed that the response category structure was not optimal because 1) the distribution of respondents among categories was not even; 2) there were some reversed average measures and threshold calibrations; and 3) the category probability curves for some categories were submerged by others. These deficiencies indicate that further category collapsing is needed in order to obtain a meaningful and interpretable category structure for each indicator.

Two principles were followed in the process of combining adjacent categories. The first was to ensure each category had a reasonable number of respondents, and the second was to attempt to make average measures for categories and threshold difficulties increase monotonically and with reasonable increments. At the same time, for the sake of better interpretation, a 7-category structure was chosen as a suitable target for the category collapsing.

Table 4.15 summarizes the information regarding the functioning effectiveness of 7-category structure for all 4 indicators achieved by means of category collapsing.

Table 4.15 The Category Functioning of All the 4 indicators

	R6	R9	SU	DH
Point-Measure Correlation	0.72	0.79	0.73	0.71
Observations of Categories				
Category 1	21	22	46	47
Category 2	649	354	233	495
Category 3	1640	1357	663	1670
Category 4	1261	1319	2084	2313
Category 5	437	704	3496	1370
Category 6	172	272	1811	308
Category 7	23	52	92	14
Average Measures of Categories				
Category 1	-3.13	-1.86	-3.29	-2.69
Category 2	-2.17	-1.09	-2.80	-1.98
Category 3	-1.40	-0.23	-1.95	-1.13
Category 4	-0.51	0.90	-1.06	-0.04
Category 5	0.35	2.07	0.03	1.25
Category 6	1.26	3.41	1.63	2.34
Category 7	2.11	4.13	3.67	3.59
Infit MNSQ of Categories				
Category 1	0.97	1.08	1.03	1.05
Category 2	1.01	1.04	0.85	1.07
Category 3	0.79	0.84	0.97	1.04
Category 4	0.94	0.84	1.00	1.06
Category 5	0.92	0.87	0.91	1.09
Category 6	0.88	0.81	0.98	1.39
Category 7	1.11	1.30	0.96	1.44
Outfit MNSQ of Categories				
Category 1	0.98	1.08	1.03	1.05
Category 2	1.01	1.05	0.83	1.07

Category 3	0.84	0.87	1.02	1.05
Category 4	0.99	0.86	1.08	1.06
Category 5	0.93	0.86	0.92	1.09
Category 6	0.86	0.81	0.99	1.34
Category 7	1.08	1.27	0.99	1.33
Threshold Calibration				
Category 1	NONE	NONE	NONE	NONE
Category 2	-5.57	-5.24	-3.82	-5.21
Category 3	-2.21	-2.85	-2.56	-3.24
Category 4	-0.18	-0.44	-1.90	-1.37
Category 5	1.46	1.24	-0.30	0.67
Category 6	2.22	2.69	2.21	3.02
Category 7	4.28	4.59	6.37	6.13
Coherence of Categories (M → C)				
Category 1	0	0	50	0
Category 2	52	44	70	47
Category 3	54	58	43	52
Category 4	50	50	49	53
Category 5	46	58	58	51
Category 6	77	69	68	41
Category 7	50	0	45	0
Coherence of Categories (C → M)				
Category 1	0	0	2	0
Category 2	23	21	12	22
Category 3	70	60	28	55
Category 4	57	72	53	60
Category 5	32	40	73	52
Category 6	15	34	48	25
Category 7	4	0	10	0

The functioning effectiveness of response category structure could be examined in more detail according to the guidelines suggested by Linacre (2002).

Preliminary Guideline: All items oriented with latent variable

Although the 4 indicators employ different category structures as prescribed by the Partial Credit Model, it is obvious that they all share the same orientation to construct the latent variable (i.e., physical fitness). A higher score on any indicator means a higher level of physical fitness. Further support for that claim comes from the satisfactory point-measure correlations of items. In this case, the point-measure correlation coefficients of all 4

indicators range from 0.71 to 0.79. That means all indicators share the same polarity along the measured latent trait (Linacre, 2002).

Guideline #1: At least 10 observations of each category

Stable estimation of category threshold measures requires sufficient frequency of observations in each category. Linacre (2002) suggested ensuring at least 10 observations per category for a reasonable degree of stability. As indicated in Table 4.15, the data for scale development meet this requirement. The number of observations of all categories for each indicator ranges between 14 (category 7 for Dominant Handgrip) and 3496 (category 5 for 1-minute Sit-ups) with a mean of 879. Most of the categories for each indicator have more than 100 observations except categories 1 and 7.

Guideline #2: Regular observation distribution

According to Linacre's (2002) suggestions, although a uniform distribution of observations is the best choice for threshold calibrations, some other regular or substantively meaningful observation distributions including uniform distributions, unimodal distributions peaking in central or extreme categories, and bimodal distributions peaking in extreme categories are acceptable. In contrast, highly skewed distributions with long "tails" tend to be troublesome for scale construction. As shown in Table 4.15, the observation distributions across categories for all the 4 indicators are unimodal distributions peaking in a central category (category 3 for 6-minute Run and 9-minute Run, category 5 for 1-minute Sit-ups, and category 4 for Dominant Handgrip) and show smooth decreases to category 1 and category 7 respectively.

Guideline #3: Average measures advance monotonically with category

The average measures of categories indicate the levels of the measured variable held by the group of observations for that category. Therefore it naturally follows that a higher category would have a higher average measure than a lower category. That is, the average measures of categories should advance monotonically with category. As indicated in

Table 4.15, the average measures of categories for all indicators satisfied this requirement. The increase between adjacent categories ranges from 0.49 to 2.04 logits with a mean of 1.02 logits, supporting the quality of the scale by ensuring that empirical observations in higher categories correspond to higher measures of the underlying latent trait.

Guideline #4: Outfit mean-squares less than 2.0

Higher Outfit mean-squares (MNSQ) fit indices suggest that more noise than useful information is provided by the observations. It normally indicates unexpected use of the category by respondents (Linacre, 2002). The results in Table 4.15 show that the Outfit and Infit MNSQs for all of categories range from 0.79 to 1.44, and most of them are very close to 1.0.

Guideline #5: Step calibration advance

Advancing step (i.e., threshold) calibrations ensure that each category would be the most probable option for a reasonable proportion of respondents with a given amount of the underlying variable, thereby, avoiding "threshold disordering" (Bond & Fox, 2007; Linacre, 2002). Failure to fulfill this requirement often indicates that some categories have too low a probability of being observed. In the case of this scale, the threshold calibrations of categories for all indicators advance monotonically. The size of the increases between adjacent thresholds ranges between 0.66 and 4.16 logits with a mean advance of 2.06 logits. The results suggest that the responses of students with higher physical fitness levels are more likely to be observed in higher categories.

Guideline #6: Ratings imply measures, and measures imply ratings

The coherence depicted by Guideline #6 refers to the percentages of expected ratings which are actually observed in that category (i.e., M → C) and the percentages of expected measures implied by observed ratings (i.e., C → M). In this case, the measure-to-category coherence (M → C) for all categories with 5 exceptions (category 1 for 6-minute Run, 9-minute Run, and Dominant Handgrip, and category 7 for 9-minute

Run and Dominant Handgrip) ranges from 41% to 77%, which means 41% to 77% of respondents' performances placed in these categories by measures were actually located in those categories. The majority of coherence indicators are around 50% - an acceptable level of coherence in general. The category-to-measure (C → M) coherence for categories 1, 2, and 7 is 23% or less, which means fewer than 23% of respondents located in these categories were measured in these categories. For categories 3 to 6, the category-to-measure (C → M) coherence ranges from 15% to 73%, with the majority of coherences indicators around 50%. In summary, the measure-to-category coherence and category-to-measure coherence for most of the categories except categories 1 to 7 are acceptable.

Guideline #7: Step difficulties advance by at least 1.4 logits

For a 3-category scale, step(threshold) difficulties must advance by at least 1.4 logits for items with these categories, but for 4 or 5 categories, a shorter distance between the consecutive threshold calibrations (e.g., 1.0 logits) is acceptable (Linacre, 2002). As shown in Table 4.15, the distances between adjacent threshold calibrations are all larger than 1.0 with only two exceptions: for 6-minute Run, the distances between threshold 4 (intersection between categories 4 and 5) and threshold 5 (intersection between categories 5 and 6) is 0.76 logits, and for 1-minute Sit-ups, the distances between threshold 2 (intersection between categories 2 and 3) and threshold 3 (intersection between categories 3 and 4) is 0.66 logits.

Guideline #8: Step difficulties advance by less than 5.0 logits

Just like Guideline #7, Guideline #8 also concerns about the distances between two consecutive threshold calibrations and suggests that the distance between any two consecutive threshold calibrations should be less than 5.0 logits in order to make sure categories provide precise information (Linacre, 2002). This requirement is always fulfilled in the case of this scale. As shown in Table 4.15, the maximum distance between adjacent threshold calibrations is 4.16 logits.

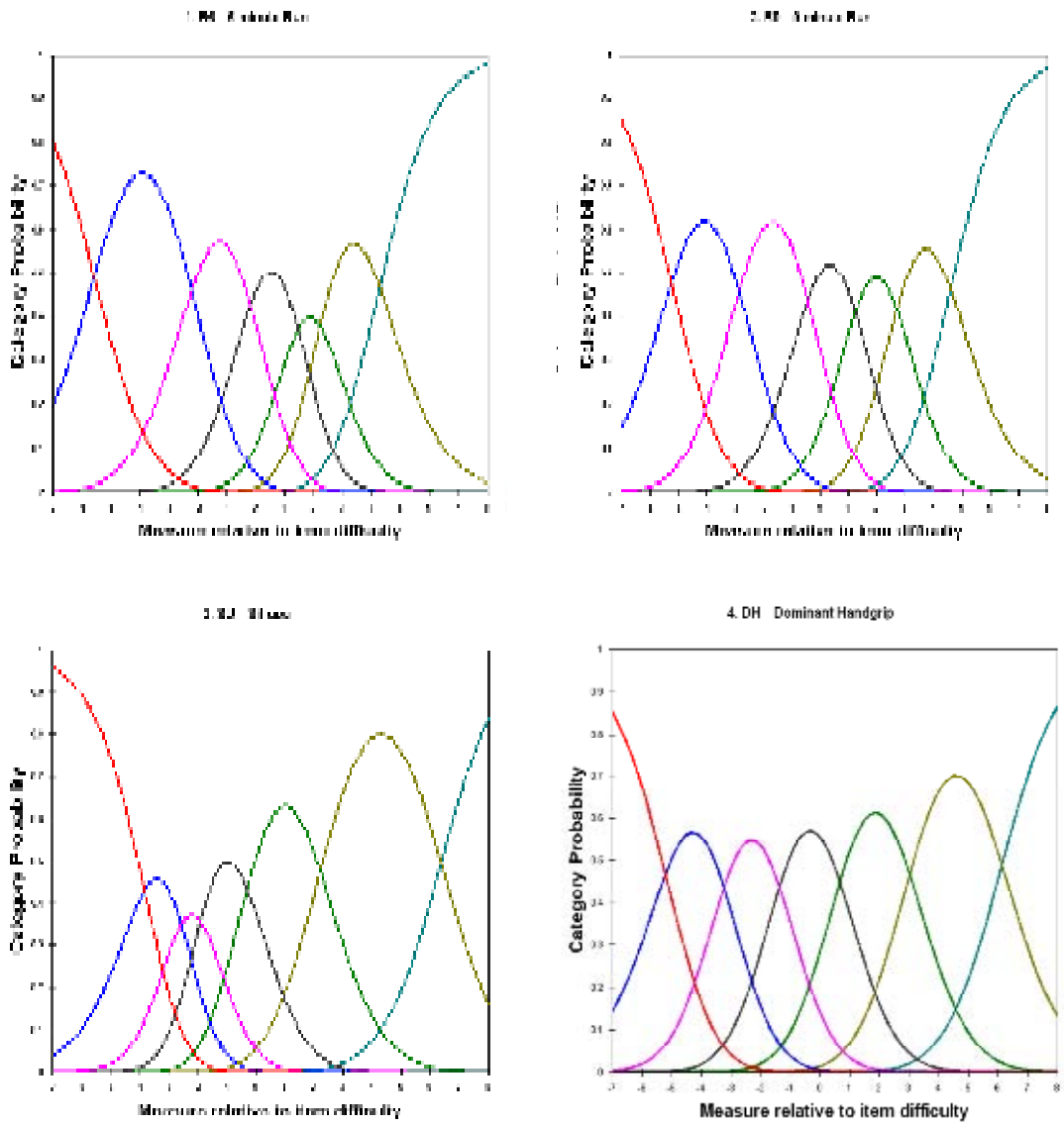


Figure 4.4 Category Probability Curves of the 4 Indicators Adopting 7-Category Structure

Figure 4.4 presents the category probability curves for each indicator. It can be seen from the graph that each category of each indicator has its own distinct peak. That means each category is most likely performed by a sample of respondents with a specific level of physical fitness.

Table 4.16 presents the property of Scale 6 (the 4-indicator scale with 7-category response structure) and compares it with the previous versions of the scale. It can be seen that the property of Scale 6 has little difference from that of Scale 5. The primary

advantage of Scale 6 is related to the optimal functioning of its response category structure.

Table 4.16 Scale Property (6)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		
6-indicator 9-category (Scale 4)					
6-minute Run	0.93	0.92	0.70	0.60/1.00	62.6%
9-minute Run	0.95	0.95	0.75		
1-minute Sit-ups	0.90	0.90	0.69		
Dominant Handgrip	1.11	1.10	0.65		
Standard Push-ups	0.88	0.88	0.78		
Modified Push-ups	1.26	1.27	0.6		
4-indicator 9-category (Scale 5)					
6-minute Run	0.92	0.91	0.73	0.63/1.00	66.9%
9-minute Run	0.90	0.90	0.79		

1-minute Sit-ups	0.97	0.98	0.70		
Dominant Handgrip	1.09	1.08	0.70		
4-indicator 7-category (Scale 6)					
6-minute Run	0.92	0.95	0.72	0.62/1.00	68.7%
9-minute Run	0.90	0.91	0.79		
1-minute Sit-ups	0.95	0.99	0.73		
Dominant Handgrip	1.10	1.10	0.71		

Rasch Analyses of 7-Category Data without Underfitting Persons

Although the results of Rasch analyses on the 7-category data show that the 4-indicator scale had acceptable fit to the Rasch model, it could be improved further. As Verhelst and Glas (1995) stated, there are two methods from which researchers could select to improve the Rasch measurement scale construction. The one is to eliminate one or more "bad" items and the other is to exclude temporarily some test takers whose performances do not fit the Rasch model. In this case, eliminating items from the scale is not the preferable option because only 4 fitness indicators are retained in the scale and all of them are "good" items from both the practical and Rasch measurement perspectives. Consequently, the alternative – eliminating misfitting persons – was carried out in an attempt to improve the measurement characteristics of the physical fitness scale. It also conforms to the basic principle of scale construction – using the best data to construct the best scale – because, by definition, misfitting persons introduce unexpected noise to the data analyses.

Bond and Fox (2007) pointed out that underfitting persons (MNSQ fit statistics are much higher than 1.0) are more detrimental to calibrating a measurement scale than are overfitting persons (MNSQ fit statistics are much lower than 1.0). Linacre (2002) further stated that Outfit MNSQ fit indices higher than 2.0 indicate more noise than useful information provided by the observations. Consequently, persons were excluded from the scale construction if either the Outfit MNSQ or Infit MNSQ was higher than 2.0 in latest round of analyses. Finally, a total of 8,469 cases which had at least one score for any of the four indicators (6-minute Run, 9-minute Run, 1-minute Sit-ups, and Dominant

Handgrip) were included, and 1,185 cases that were extremely underfitting to the Rasch model were excluded and Rasch analyses is conducted again. Detailed investigation of the performances of underfitting persons showed that there was no detectable pattern held or shared by the underfitting persons.

Table 4.17 presents the property of the 4-indicator scale without underfitting persons (Scale 7), in which the scale and the indicators show good fit to the Rasch model.

Table 4.17 Scale Property (7)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		
6-indicator 9-category (Scale 4)					
6-minute Run	0.93	0.92	0.70	0.60/1.00	62.6%
9-minute Run	0.95	0.95	0.75		

1-minute Sit-ups	0.90	0.90	0.69		
Dominant Handgrip	1.11	1.10	0.65		
Standard Push-ups	0.88	0.88	0.78		
Modified Push-ups	1.26	1.27	0.6		
4-indicator 9-category (Scale 5)					
6-minute Run	0.92	0.91	0.73	0.63/1.00	66.9%
9-minute Run	0.90	0.90	0.79		
1-minute Sit-ups	0.97	0.98	0.70		
Dominant Handgrip	1.09	1.08	0.70		
4-indicator 7-category (Scale 6)					
6-minute Run	0.92	0.95	0.72	0.62/1.00	68.7%
9-minute Run	0.90	0.91	0.79		
1-minute Sit-ups	0.95	0.99	0.73		
Dominant Handgrip	1.10	1.10	0.71		
4-indicator 7-category without Underfitting Persons (Scale 7)					
6-minute Run	0.93	0.96	0.78	0.77/1.00	81.5%
9-minute Run	0.85	0.88	0.86		
1-minute Sit-ups	0.95	1.00	0.79		
Dominant Handgrip	1.11	1.13	0.79		

It can be seen that, for Scale 7, the Infit and Outfit MNSQ for all indicators range from 0.85 (Infit MNSQ of 9-minute Run) to 1.13 (Outfit MNSQ of Dominant Handgrip). The point-measure correlations for all indicators fall in the range between 0.78 and 0.86. The Rasch item reliability is 1.00. Compared with Scale 6, Scale 7 has significant improvement in both Rasch person reliability and variance explained by measures. The Rasch person reliability of Scale 7 is 0.77 (0.62 for Scale 6), and the measures explained 81.5% of the total variance (68.7% for Scale 6).

Considerations of Sex Differential Item Functioning (DIF)

DIF occurs when different groups of students of the same level of latent trait have different scores on an item in a test (Embretson & Reise, 2000). An item with DIF displays unexpected behavior or shows bias to some specific groups of students. The Mantel-Haenszel statistic is a typical indicator which has been used in many studies to detect DIF (e.g., Clauser & Mazor, 1998; Hidalgo & LóPez-Pina, 2004; Holland &

Thayer, 1988; Kristjansson, Aylesworth, Mcdowell, & Zumbo, 2005; Narayan & Swanubatgab, 1994).

In the case of this study, sex DIF for all the 4 indicators was examined with both the *t*-test and the Mantel-Haenszel DIF test as indicators. The results are presented in Table 4.18.

Table 4.18 Sex DIF of the Four Indicators

	DIF Measure		DIF Contrast	*t*	*p*	Mantel-Haenszel
	M	F	(M-F)			prob.
6-minute Run	-0.71	-0.49	-0.22	-4.04	.000	.000
9-minute Run	1.10	1.42	-0.32	-5.17	.000	.000
1-minute Sit-ups	-1.47	-1.72	0.26	5.96	.000	.000
Dominant Handgrip	0.98	0.94	0.04	0.82	.412	.062

It is revealed that sex DIF occurs in three fitness indicators: 6-minute Run, 9-minute Run, and 1-minute Sit-ups, but not in Dominant Handgrip. Both of the *t*-test and Mantel-Haenszel statistics show that the DIF in these three indicators is statistically significant. However, it would be more cautious to interpret these results by taking the sample size into account because the very large sample size could magnify the statistical significance of the difference even though the difference has no substantively practical meaning. Bond and Fox (2007) pointed out that, in general, a difference greater than 0.5 logits might be regarded having practical, substantive meaning. The results shown in Table 4.18 indicate that the differences of item difficulties between male and female (M_{male} - M_{female}) range from -0.32 to +0.04 logits. Although the differences are statistically different, being consequence of the sample size, they are unlikely to have any practical meaning in interpreting students' performances for these fitness indicators.

Although the sex DIF in fitness indicators has no substantial practical meaning, it is worth examining the impact sex DIF might have on the physical fitness scale. Splitting the indicators with sex DIF into two separate indicators (male version and female version) generates a new scale (Scale 8, see Table 4.19). However, careful investigation of the difference of scale properties between Scale 7 and Scale 8 indicates that the properties of the (7 indicators) scale with sex-split indicators did not improve much over the

4-indicator scale. The indicators of these two scales have similar Infit and Outfit MNSQs, the person reliability remains the same (0.77), and the measures explain a similar amount of variance (81.5% and 82.7% respectively). Since the more complicated scale with sex-split indicators did not make substantial improvement to the 4-indicator scale, the more parsimonious scale (4-indicator scale) is, therefore, more effective and is the final version of the RMPFS based on the Rasch analyses of the current data set.

Table 4.19 Scale Property (8)

	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation	Rasch Reliability (Person/Item)	Variance Explained by Measures
8-indicator Raw Score (Scale 1)					
6-minute Run	0.89	0.89	0.74	0.55/1.00	58.2%
9-minute Run	1.02	1.03	0.76		
1-minute Sit-ups	0.91	0.91	0.71		
Right Handgrip	0.89	0.90	0.57		
Left Handgrip	0.87	0.88	0.58		
Sit-and-Reach	1.24	1.25	0.45		
Standard Push-ups	0.98	0.98	0.75		
Modified Push-ups	1.41	1.44	0.60		
8-indicator 9-category (Scale 2)					
6-minute Run	1.03	1.03	0.58	0.52/1.00	62.1%
9-minute Run	1.09	1.09	0.65		
1-minute Sit-ups	0.93	0.91	0.63		
Right Handgrip	0.76	0.75	0.73		
Left Handgrip	0.74	0.72	0.73		
Sit-and-Reach	1.21	1.27	0.42		
Standard Push-ups	1.01	1.01	0.70		
Modified Push-ups	1.49	1.48	0.47		
7-indicator 9-category (Scale 3)					
6-minute Run	1.10	1.10	0.61	0.66/1.00	60.6%
9-minute Run	1.15	1.15	0.68		
1-minute Sit-ups	1.07	1.05	0.64		
Right Handgrip	0.78	0.78	0.76		
Left Handgrip	0.75	0.75	0.76		
Standard Push-ups	1.01	1.02	0.74		
Modified Push-ups	1.57	1.58	0.51		
6-indicator 9-category (Scale 4)					
6-minute Run	0.93	0.92	0.70	0.60/1.00	62.6%
9-minute Run	0.95	0.95	0.75		
1-minute Sit-ups	0.90	0.90	0.69		

Dominant Handgrip	1.11	1.10	0.65		
Standard Push-ups	0.88	0.88	0.78		
Modified Push-ups	1.26	1.27	0.6		
4-indicator 9-category (Scale 5)					
6-minute Run	0.92	0.91	0.73	0.63/1.00	66.9%
9-minute Run	0.90	0.90	0.79		
1-minute Sit-ups	0.97	0.98	0.70		
Dominant Handgrip	1.09	1.08	0.70		
4-indicator 7-category (Scale 6)					
6-minute Run	0.92	0.95	0.72	0.62/1.00	68.7%
9-minute Run	0.90	0.91	0.79		
1-minute Sit-ups	0.95	0.99	0.73		
Dominant Handgrip	1.10	1.10	0.71		
4-indicator 7-category without Underfitting Persons (Scale 7)					
6-minute Run	0.93	0.96	0.78	0.77/1.00	81.5%
9-minute Run	0.85	0.88	0.86		
1-minute Sit-ups	0.95	1.00	0.79		
Dominant Handgrip	1.11	1.13	0.79		
Sex-split item 7-category without Underfitting Persons (Scale 8)					
Male 6-minute Run	0.92	0.94	0.79	0.77/1.00	82.7%
Female 6-minute Run	0.99	1.02	0.75		
Male 9-minute Run	0.83	0.85	0.87		
Female 9-minute Run	0.95	0.97	0.81		
Male 1-minute Sit-ups	0.92	0.96	0.78		
Female 1-minute Sit-ups	0.92	0.95	0.79		
Dominant Handgrip	1.13	1.15	0.78		

Properties of the RMPFS

The indicator properties of the RMPFS are presented in Table 4.20. The difficulty levels for indicators range from -1.59 logits to +1.25 logits. The Standard Error (S.E.) associated with indicator estimations is also provided in the table. S.E., an indicator of the degree of precision of the indicator estimation, refers to the "standard deviation of an imagined error distribution representing the possible distribution of observed values around their 'true' theoretical value" (Linacre, 2006a, p.324). In traditional measurement approaches, only the "average" S.E. for an sample or a test is provided, however, Rasch models

provide separate S.E. for each and every estimation of person ability and item difficulty (Linacre, 2000; Smith, 2001). Separate S.Es provide more useful information for examining the precision of estimates for individual persons and items than does the "average" S.E. for a sample or test. The results in Table 4.20 show that the S.Es for the estimations of 6-minute Run and 9-minute Run are 0.03 logits, and the S.Es for the estimations of 1-minute Sit-ups and Dominant Handgrip are 0.02 logits. These small S.Es are a consequence of large sample size and imply that the indicator difficulty estimations are quite precise.

Table 4.20 presents several important indices used to examine the quality of the resultant RMPFS from a Rasch measurement perspective. The indices include Infit and Outfit MNSQ, point-measure correlations, person separation index, Rasch person reliability, item separation index, and Rasch item reliability. As shown in Table 4.20, the Infit and Outfit MNSQ for all indicators are very close to 1.0. The minimum value is 0.85 (Infit MNSQ for 9-minute Run), and the maximum value is 1.13 (Outfit MNSQ for Dominant Handgrip). The results suggest that the indicators have sufficient fit to the Rasch model for practical measurement purposes – especially for such low-stakes decisions. The point-measure correlations for all the 4 indicators approximate 0.8. That supports the claim that all the indicators function at the same direction as a part of the latent trait under measure. The Rasch item reliability is 1.00 and the Rasch person reliability is 0.77. The Rasch person reliability is not very high but acceptable considering this is a consequence of retaining only four items in the RMPFS. Smith (2001) proposed that, in addition to Rasch reliability, researchers should use separation indices (person separation index and item separation index) to indicate the spread of person measures or item calibrations along the variable under measure in S.E. units. The separation indices can be mathematically transformed from Rasch reliability and have two advantages: 1) separation indices are linear estimations while Rasch reliability is non-linear; and 2) separation indices can range from zero to infinity while Rasch reliabilities are restricted in the range of zero to one (Smith, 2001). The higher separation indices derive from higher

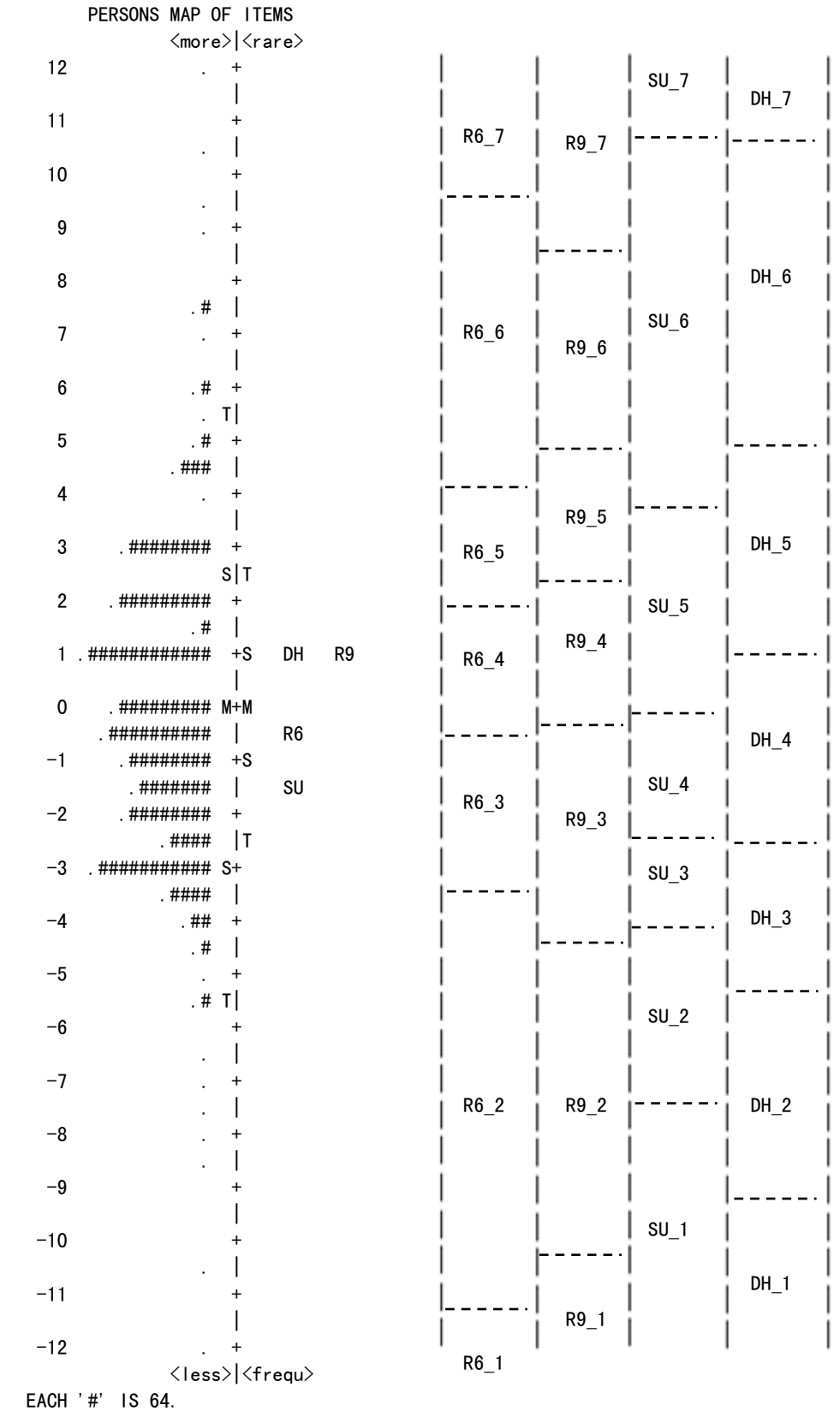
Rasch reliabilities and lower S.Es. It can be seen from Table 4.20 that the person separation index is 1.83 and the item separation index is 43.16. Both the Rasch reliabilities and separation indices imply that the consistency of person ordering along the latent trait under measure is only moderate, while the consistency of item ordering along the latent trait is very high.

Table 4.20 Scale Properties of the RMPFS

	Measure	S.E.	Infit MNSQ	Outfit MNSQ	Point-Measure Correlation
6-minute Run	-0.61	0.03	0.93	0.96	0.78
9-minute Run	1.25	0.03	0.85	0.88	0.86
1-minute Sit-ups	-1.59	0.02	0.95	1.00	0.79
Dominant Handgrip	0.96	0.02	1.11	1.13	0.79
Person	Separation:	1.83	Reliability:	0.77	
Item	Separation:	43.16	Reliability:	1.00	

Note. All measures are in logits.

Figure 4.5 presents the Wright map of the 4-indicator RMPFS. On the map both students and fitness indicators are located along a single scale. Students are placed on the left side of the scale, and fitness indicators are shown on the right side. The students with the highest fitness levels and the fitness indicators with highest difficulty level are placed at the top, while the students with the lowest fitness level and the easiest fitness indicators are placed at the bottom. The means of students' measures and indicators' calibrations are shown as the corresponding Ms on the map. The Ss and Ts represent ±1 and ±2 standard deviations of the student and item distributions respectively. Students are represented by "#" (=64 students) and "." (>31 students) on the map (since there are too many students to be displayed individually in the limited space). On the right-hand side of the map are the representations of the response categories from category 1 to category 7 for the four indicators.



R6: 6-minute Run; R9: 9-minute Run, SU: 1-mintue Sit-ups; DH: Dominant Handgrip

Figure 4.5 Item Map of the RMPFS

It can be seen that the difficulty levels of the RMPFS physical fitness indicators (M = 0.00, SD = 1.16) are appropriate for these students' fitness levels (M = -0.21, SD = 2.78). The range of indicators' difficulty (-1.59 to 1.25 logits) is much smaller than the range of students' ability (-12.86 to 11.17 logits). However, the ranges of difficulty levels of categories for each indicator, as presented on the right-hand side of the map, reveals that the indicators overall provide good coverage of the fitness of the primary school students in this sample.

The Item Characteristic Curves (ICC) and category probability curves provide further support for the valid functioning of the scale. Figure 4.6 presents the empirical and expected ICCs for the four indicators. In these graphs, the Y axes represent the students' actual scores (blue) *v.* those expected by the model (red), and X axes - measure relative to item difficulty - refers to the difference between the indicator difficulty and person ability. It can be seen that the empirical ICCs match the theoretical ICCs reasonably well, especially for students' with median fitness levels located around the middle of the curves. There are larger discrepancies between the empirical and theoretical ICCs for the most able and the least able students located at the extremes of the curves. The reason is that if person ability is close to indicator difficulty (students located at the middle of the curves, where difficulty-ability is close to zero), the indicator provides more information about the person and indicator interaction, thus reducing the error of person ability estimates and giving more precise measurement. When person ability differs considerably from (i.e., is much higher or lower than) the indicator difficulty (students located at the extremes of the curves), the indicator provides much less information about the person / indicator interaction, and the measurement is then, less precise.

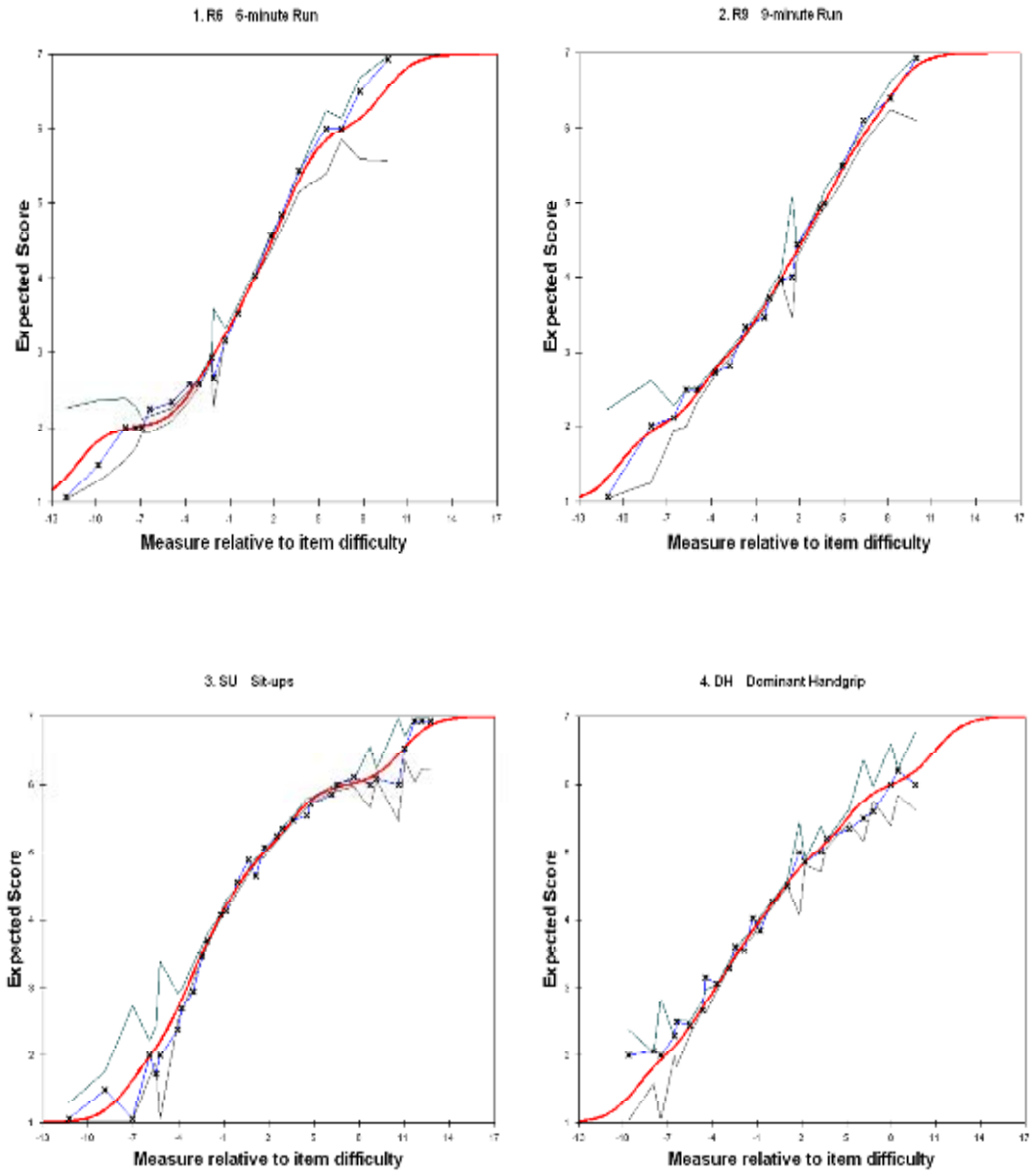


Figure 4.6 Empirical (blue) and Expected (red) Item Characteristic Curves for RMPFS Indicators

The category probability curves for each of the four indicators presented in Figure 4.7 show that each performance category has a distinct peak in the graph for all four indicators. That means each category for each indicator was the most probable performance level for given groups of persons with any specific level of physical fitness. There is no evidence of "threshold disordering" (Bond & Fox, 2007; Linacre, 2002) and threshold calibrations advance monotonically with category, indicating that higher performance categories correspond to higher measures of physical fitness.

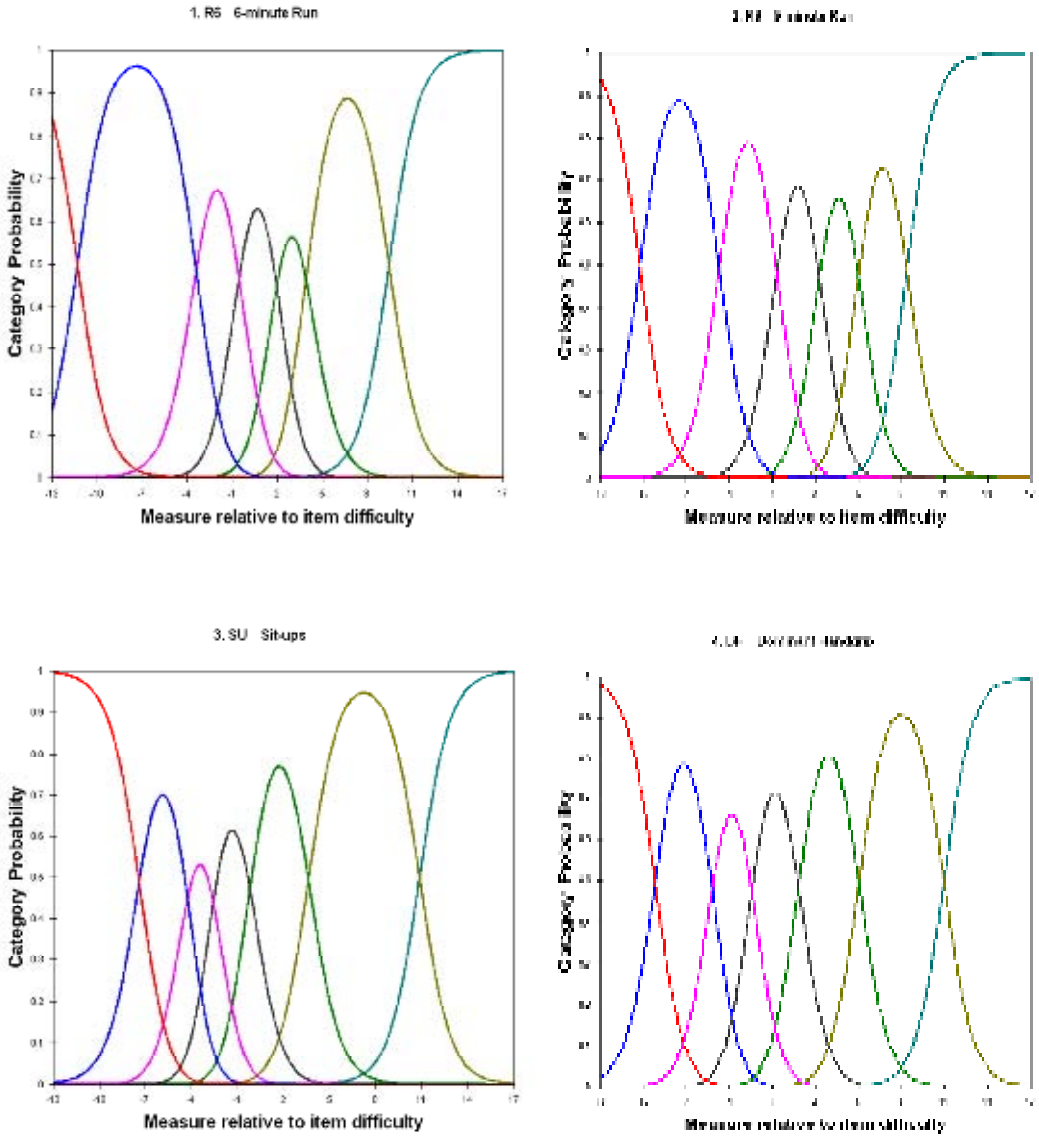


Figure 4.7 Category Probability Curves for RMPFS Indicators

Summary

Through a theory-driven development procedure guided by Rasch model principles as well as practical considerations, a physical fitness scale was developed and refined step by step and, finally, a four-indicator RMPFS which integrates and reflects three key components of health-related physical fitness: cardiorespiratory fitness, muscular endurance, and muscular strength, was established. The important steps in the development procedure for the Rasch measurement scale include the following ones:

1. BMI was excluded from the scale because BMI is not an optimal indicator for body composition and it is a trait with inverted U-shape characteristics rather than a linear one.

2. The raw scores for each indicator were transformed using logarithmic transformation into 9 category levels with meaningful differences.

3. Sit-and-Reach was excluded from the scale because its low correlation with other physical fitness indicators and its distinct feature apart from other indicators made it inappropriate for inclusion in the scale.

4. Left Handgrip and Right Handgrip were excluded (as individual indicators) from the scale because they violate one key Rasch requirement – local independence among indicators. One single indicator – Dominant Handgrip – was used instead of Left Handgrip and Right Handgrip to measure students' muscular strength.

5. Standard and Modified Push-ups were excluded from the scale. It appears that possible data collecting and reporting errors contributed to misfit of these two indicators to the Rasch model.

6. The functioning of the response category structure was examined and a more appropriate response category structure (7-category) was used instead of the earlier 9-category structure.

7. The impact of extremely underfitting persons to the 4-indicator scale was investigated and a scale with better properties was developed after excluding those extremely underfitting persons from the scale construction process.

8. Sex DIF in three of the four indicators was statistically significant, but has no practical substantive meaning. Furthermore, the comparison between 4-indicator scale and 7-indicator (including sex-split indicators) showed little difference, so the simpler efficient 4-indicator scale was regarded as the final version of the RMPFS for this investigation.

Finally, four physical fitness indicators including 6-mintue Run, 9-minute Run, 1-mintue Sit-ups and Dominant Handgrip were successfully calibrated to form the RMPFS which integrates three key components of physical fitness including cardiorespiratory fitness, muscular endurance, and muscular strength into an overall measure of health-related physical fitness suitable for use with primary school children in Hong Kong. The RMPFS and its scale indicators show fit to the Rasch model sufficient for the intended purposes.

In traditional approaches to physical fitness assessment, students' performances on each fitness indicator are recorded and interpreted separately. For example, the 6 or 9-minute Run tests students' cardiorespiratory fitness and is interpreted independently from muscular strength or endurance. Similarly, the 1-minute Sit-ups test demonstrates students' muscular endurance capacity, but does not reflect cardiorespiratory fitness levels. That approach treats components of physical fitness as independent unrelated aspects. Each aspect must be tested and interpreted separately, and students' ability in one aspect does not provide information for predicting their performances on other aspects. In contrast, a RMPFS performance score provides an overall physical fitness measure based on the student's performance on the four fitness indicators. This overall measure, obtained through Rasch calibration, is contributed by the three components, but it is not the simple or weighted "average" of the performance on the components. With the RMPFS, students' overall fitness measures can be located along the overall fitness

continuum and interpreted in a stable interpretive framework.

CHAPTER FIVE

RESULTS I

MEASUREMENT OF STUDENTS' OVERALL PHYSICAL FITNESS

Introduction

Following the development of the RMPFS, this chapter reports the application of the developed physical fitness scale to measure students' overall physical fitness. Further, it reveals age and sex differences in students' overall physical fitness development and the features of overall physical fitness development for different cohorts in the sample for the study. This chapter further depicts the unique development tracks of some individual students which were selected from the sample for the study to demonstrate the variety of students' physical fitness development.

During the development of the RMPFS, a total of 8,469 cases which had at least one score for one of the four indicators (6-minute Run, 9-minute Run, 1-minute Sit-ups, and Dominant Handgrip) were input into the Rasch analyses and, finally, 1,185 cases were excluded because they are extremely underfitting to the Rasch model's measurement requirements. In other words, the Rasch analyses identified 1,185 underfitting cases from the data set with the RMPFS if the four indicators' difficulty values were estimated. In contrast, if the calibrated item locations were anchored to the scale to measure all students, the Rasch analyses identified more underfitting cases (N=1,814). In order to provide better measurement of all students in this sample without generating too many underfitting cases, the scale with unanchored item locations (Scale 6 described in Chapter Four) is used as an instrument to measure the overall physical fitness level of students in this sample and track their development over time.

Many studies concerning students' change or development over time compare the

difference between starting point and ending point, and make inferences based on the analyses of the differences. However, in longitudinal data sets, it is possible that individuals have records at different intermediate stages or occasions in addition to the starting and the ending points. Individuals who have similar performances at the beginning or the end might show different developmental tracks over time. Focusing only on the starting and ending points and ignoring intermediate stages probably wastes much valuable information and fails to reveal the nature and the developmental trends (Endler & Bond, 2008).

In the case of this study, most students have more than two records, i.e., they have fitness records between the starting and ending points. These longitudinal data could be used to provide useful information on students' physical fitness development. Furthermore, students at different ages or year levels are located at a variety of different positions on the physical development continuum and, therefore, have quite different physical and fitness developmental characteristics (Zaichkowsky & Larson, 1995). It should be meaningful to investigate students' physical fitness features associated with developmental stages and attempt to depict the developmental trends over time.

Students' Overall Fitness Development by Age

The RMPFS overall fitness measure comprises three key components of physical fitness including cardiorespiratory fitness (indicated by the 6/9-minute Run), muscular endurance (indicated by the 1-minute Sit-ups), and muscular strength (indicated by Dominant Handgrip). Table 5.1 and Figure 5.1 present the mean overall fitness measures in logits of students by age from age 6 to age 11. Although students in the sample for this study were aged from 6 to 13 years, the sample size of 12 and 13 years old students was considerably small compared with those of other ages. There were only 142 students aged at 12 and 2 students aged at 13, while there were over 1,000 students at each of the other ages. Therefore, this section reports students' overall fitness from age 6 to 11 years only.

Table 5.1 Overall Fitness Measure by Age

Age (years)	Mean	Standard Deviation (S.D.)	Growth	Valid N
11	1.39	1.61	0.85	1317
10	0.54	1.50	0.31	1400
9	0.23	1.48	0.84	1419
8	-0.61	1.27	0.28	1429
7	-0.89	1.30	0.53	1412
6	-1.42	1.16	-	1344

Note. All measures are in logits.

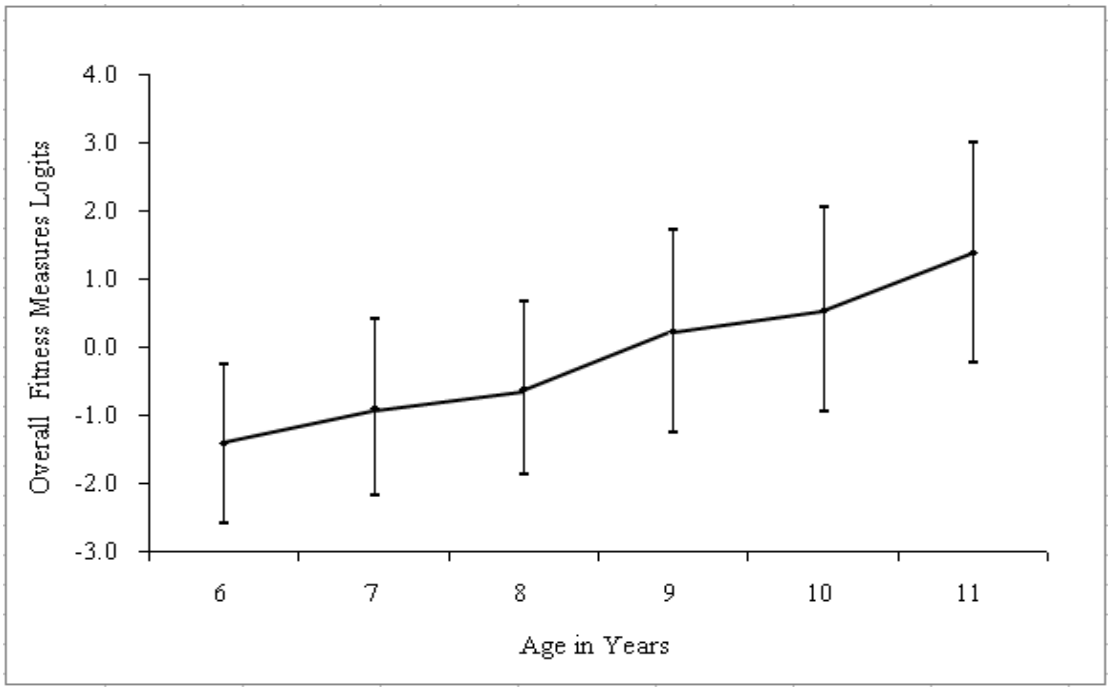


Figure 5.1 Overall Fitness Development by Age (M ± 1S.D.)

It can be seen from Table 5.1 and Figure 5.1 that students' overall fitness levels increase along with their ages. This developmental trend is similar to the results of some national fitness surveys conducted in other countries such as Australia (e.g., Pyke, 1987) and the United States (e.g., Ross & Pate, 1987). The mean overall fitness measure of 6-year old students is -1.42 logits, and 11-year old students have average measure of +1.39 logits. A total of 2.81 logits growth was demonstrated over the six years of maturing and schooling. Nevertheless, the growth of overall fitness is not even over the six years. The advance of overall fitness for any one year ranges from 0.28 logits to 0.85 logits. Less development

on average occurs when students advance from 7 to 8-years old (0.28 logits) and from 9 to 10-years old (0.31 logits). Larger average developmental progress occurs when students advance from 8 to 9-years old (0.84 logits) and from 10 to 11-years old (0.85 logits). The median amount of developmental progress occurs as students advance from 6 to 7-years old (0.53 logits).

Although students' physical fitness demonstrates a clear developmental trend with age in this sample, there are quite large individual differences (see Figure 5.1). The results indicate that students' overall fitness levels cover a wide range from -7.27 to +7.27 logits, and the S.Ds for those mean values range from 1.16 logits (6-years old) to 1.61 logits (11-years old). This implies a trend that the individual differences become more salient with age since the S.Ds for older children are larger than those for younger children.

Sex Differences in Overall Fitness Development

The term "sex differences" is used here instead of the "gender differences" that is commonly used in other literature because the comparison and interpretation of differences between boys and girls in this study are conducted on a biological basis only, while gender, according to the American Psychological Association (2009, p.28), "*refers to role, not biological sex, and is cultural*".

Sex differences in overall fitness levels are examined for each of the different age groups. Table 5.2 and Figure 5.2 present the developmental trends for boys and girls separately. The overall developmental trend line for all students is also provided in the graph for the purpose of comparison. It can be seen from Figure 5.2 that boys have higher overall fitness levels than girls, especially for the older children (age 9, 10 and 11). The results of *t*-tests show that the sex differences at all ages are statistically significant at $p<.01$ level.

Table 5.2 Sex Differences in Overall Fitness

Age	Male		Female		Difference (boys - girls)
	Mean	S.D.	Mean	S.D.	
11	1.77	1.61	0.93	1.48	0.84**
10	0.81	1.58	0.23	1.34	0.58**
9	0.43	1.59	0.01	1.31	0.42**
8	-0.45	1.32	-0.81	1.18	0.36**
7	-0.75	1.32	-1.07	1.25	0.32**
6	-1.30	1.17	-1.58	1.12	0.28**

Note. All measures are in logits.
** $p < .01$.

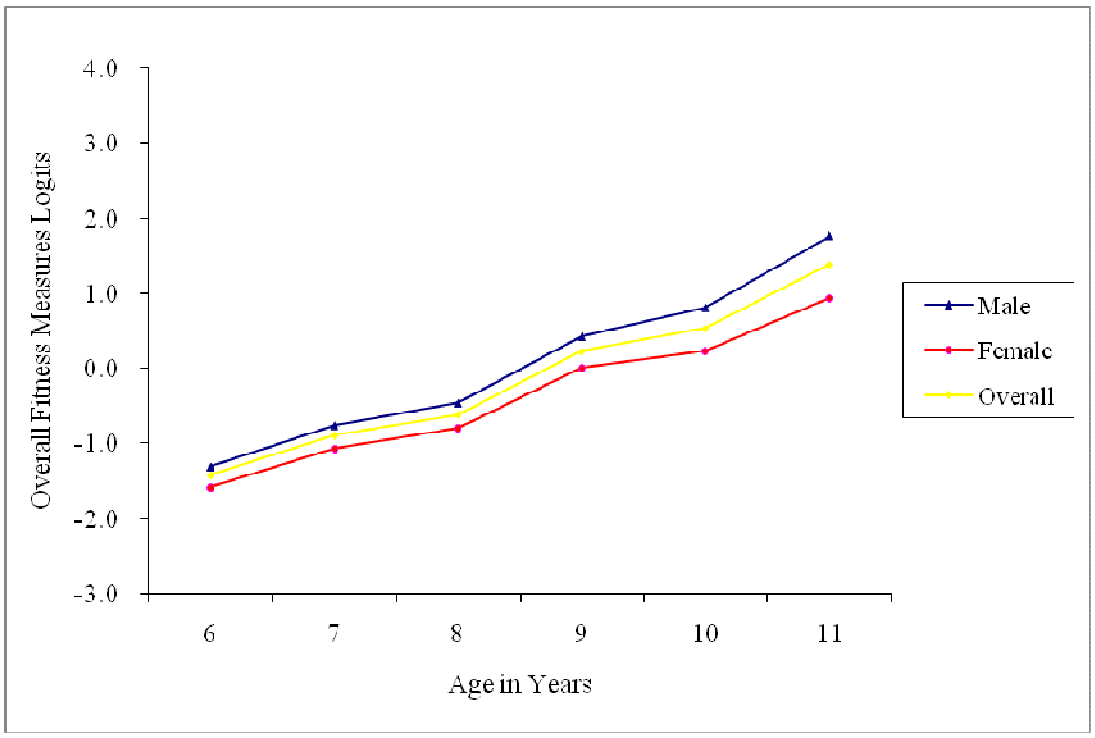


Figure 5.2 Overall Fitness Development by Age and Sex

Figure 5.3 shows the developmental trend for boys and girls with S.Ds. It can be seen that there is a very large overlap of the overall fitness estimations for boys and girls of the same age. For example, the mean estimation of overall fitness for 8-years old boys is -0.45 logits, while the mean estimation of overall fitness for 8-years old girls is -0.80 logits. Although the boys' mean value is 0.3 S.D. higher than the mean estimation for girls, approximately 38% of 8-years old girls have higher overall fitness measures than the average of boys of the same age.

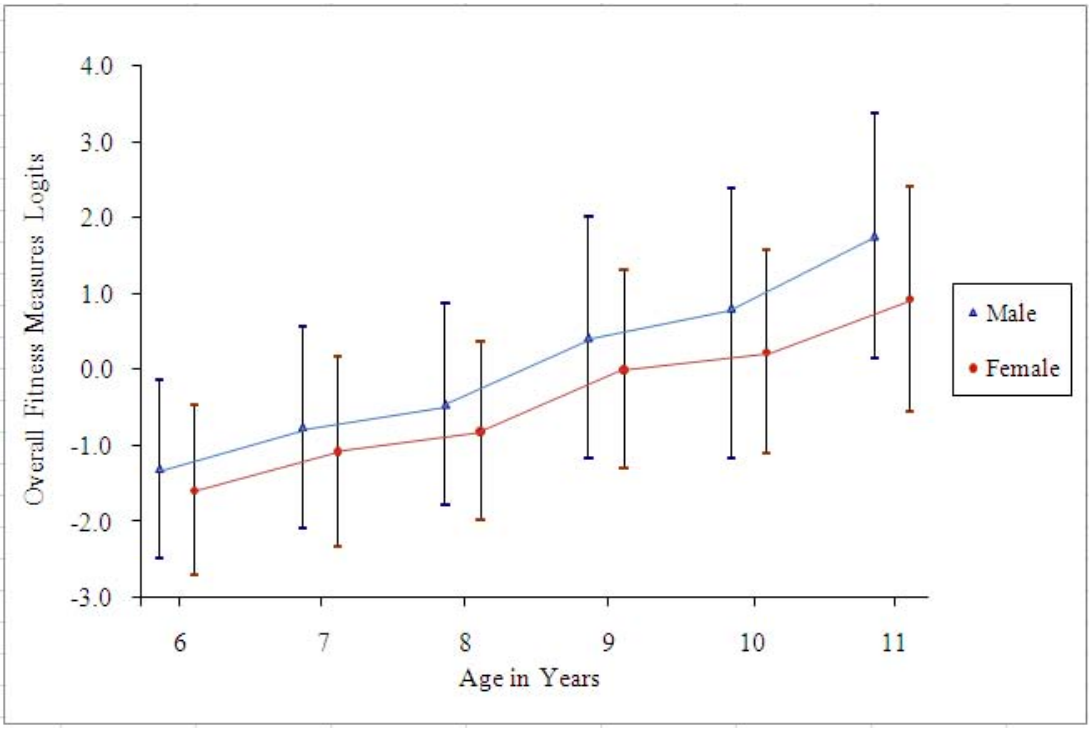


Figure 5.3 Overall Fitness Development by Age and Sex (M ± 1S.D.)

In general, the sex difference of overall fitness is statistically significant (p <.01) in favor of boys for all age groups. However, those differences are blurred when S.Ds are taken into account, just as has been shown in Figure 5.3. It is worth recalling that statistically significant difference is not necessarily the same as meaningful difference. A minute difference might be detected as statistically significant, especially with large sample, even though that difference has very little practical meaning. It is appropriate to regard a difference greater than 0.5 logits to have practical, substantive meaning (Bond & Fox, 2007). In terms of overall physical fitness, the sex differences at age 6 to 9 are less than 0.5 logits but the differences increase with students' age. For students aged 10 and 11, the sex differences are more than 0.5 logits. Therefore, it is prudent to conclude that there is no empirical fitness evidence for dividing students into sex-based groups for physical education for junior primary school-aged students at age of 6 to 9, but sex of the student could be a consideration influencing the grouping of senior primary school-aged students at age of 10 or 11, for physical fitness based activities.

Students' Overall Fitness Development by Academic Year and Level

Figure 5.4 presents students' overall fitness development by academic year. Each line with six markers in this figure represents cross-sectional students' performances of six grade groupings (P1 to P6) in each semester of any one academic year. The performance line is labeled with the semester and academic year. For example, the line "2003 1" presents students' overall fitness levels of six levels in the 1st semester of the academic year 2003-04. Note that students' overall fitness measures in the academic year 2002-03 were not included here because, in the academic year 2002-03, there were records on only four physical fitness indicators including BMI, Sit-and-Reach, Standard Push-ups, and Modified Push-ups, each of which were excluded from the RMPFS.

It can be seen from the figure that, with just four exceptions, students' overall fitness levels increase as the year level advances. The four exceptions are Primary 3 and Primary 5 for the 2nd semester of academic year 2003-04, Primary 5 for the 2nd semester of academic year 2004-05, and Primary 2 for the 2nd semester of academic year 2006-07. These four groups of students have lower overall fitness levels than do their counterparts in the lower year level.

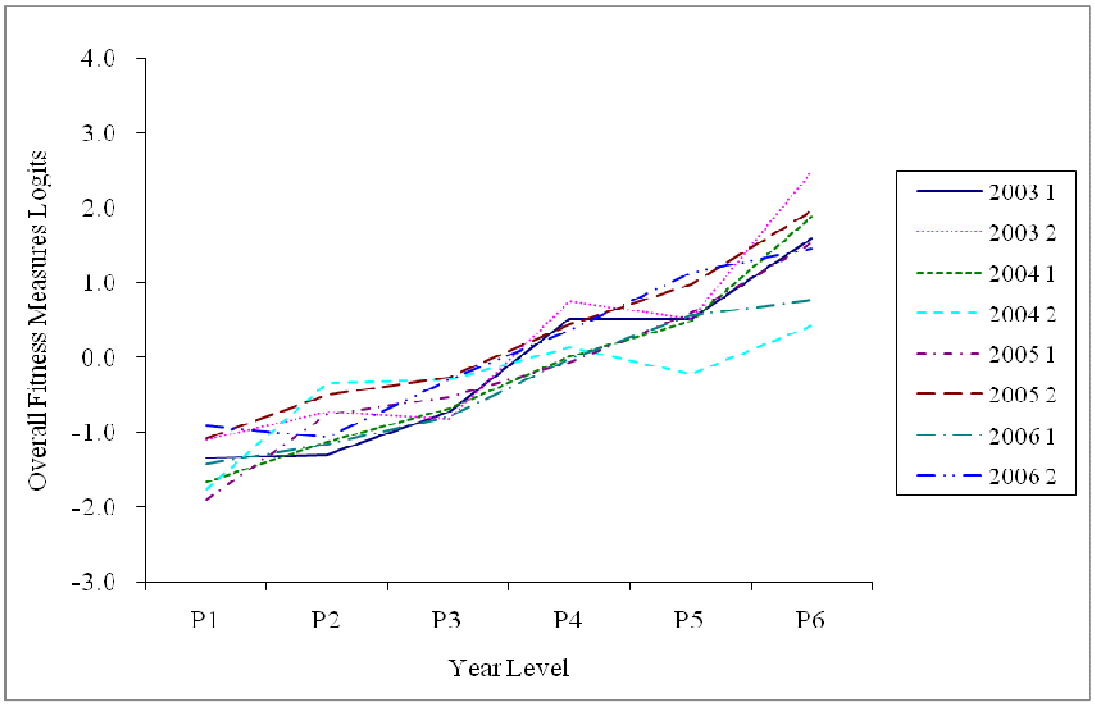


Figure 5.4 Students' Overall Fitness Development by Academic Year and Level

Figure 5.5 is a further development of Figure 5.4, in which mean fitness measures with ± 1 S.E. (the measurement errors - plotted as whiskers) are included.

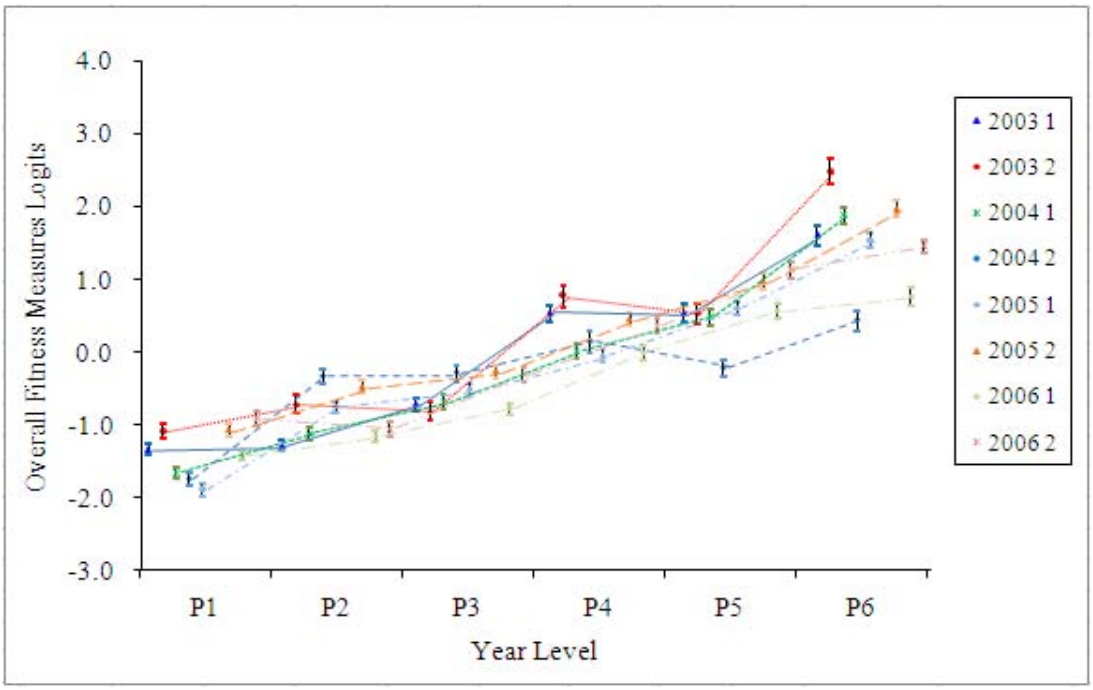


Figure 5.5 Students' Overall Fitness Development by Academic Year and Level (M ± 1S.E.)

Table 5.3 presents the differences and the conjoint measurement errors (sum of measurement errors of the consecutive year levels) of the four exceptions mentioned above.

Table 5.3 Fitness Changes and Conjoint Measurement Error for Exceptional Groups

Exception	Cohort	Decrease in Fitness Measures	Conjoint Measurement Error
1	Primary 3, 2nd Semester, 2003-04	-0.10	0.25 (0.13 + 0.12)
2	Primary 5, 2nd Semester, 2003-04	-0.23	0.27 (0.14 + 0.13)
3	Primary 5, 2nd Semester, 2004-05	-0.36	0.25 (0.14 + 0.11)
4	Primary 2, 2nd Semester, 2006-07	-0.15	0.18 (0.09 + 0.09)

Note. All measures are in logits.

The information provided in Figure 5.5 and Table 5.3 shows that the differences for three exceptions (exceptions 1, 2, and 4) have no substantial or practical meaning when conjoint measurement error is taken into account. In other words, the negative differences do not reflect "real" differences in fitness as they do not extend beyond measurement error. Only the difference between Primary 4 and Primary 5 in the 2nd semester of academic year 2004-05 (exception 3) is larger than the conjoint measurement error. That indicates in academic year 2004-05, the overall fitness level of Primary 5 students was measurably lower than the overall fitness level of Primary 4 students and the difference is related directly to the measured trait (i.e., overall fitness) rather than the measurement error.

Students' Overall Fitness Development by Cohort

Figure 5.6 presents students' overall fitness development by cohort along the academic year. Each line in the graph represents a single cohort which is labeled with the academic year and year level of students' first record. For example, if the cohort's first record was at Primary 1 in academic year 2004-05, then the cohort is labeled with 2004P1. It is

signified by a blue dashed line and continues until Semester 2, 2006-07. Similarly, the cohort is labeled with 2003P2 if the cohort's first record was at Primary 2 in academic year 2003-04. It is signified by a green dashed line and continues until Semester 2, 2006-07.

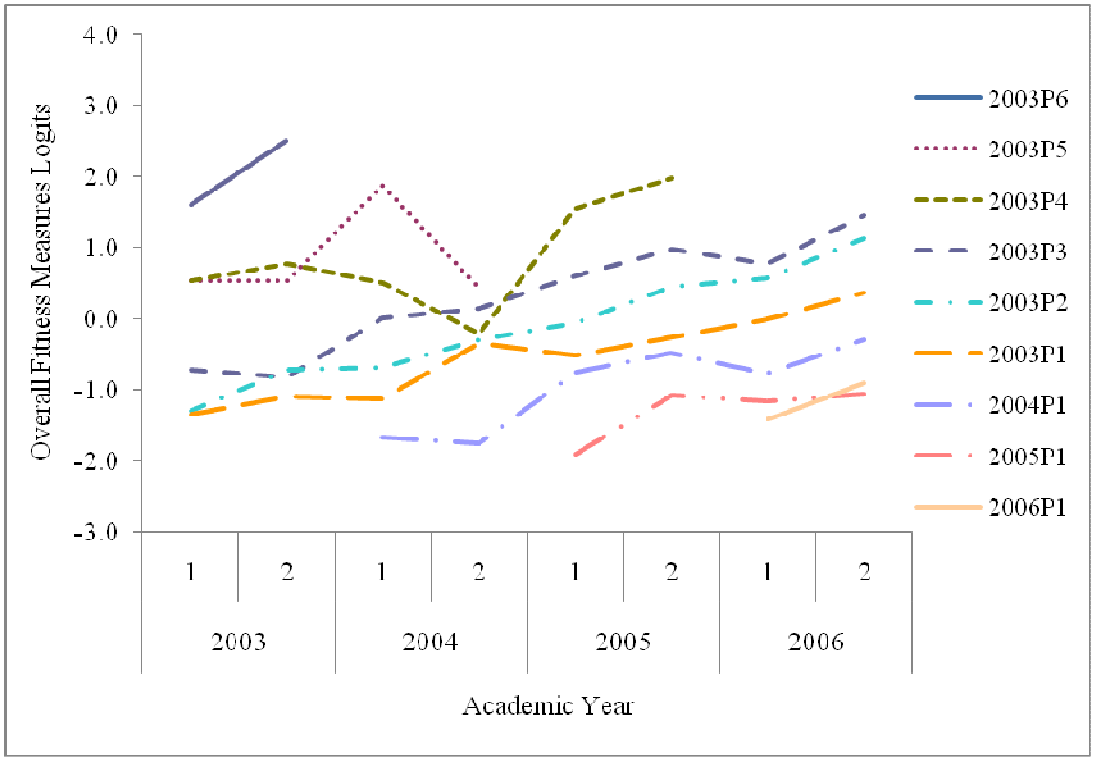


Figure 5.6 Students' Overall Fitness Development by Cohort and Academic Year

Figure 5.7 includes the S.E. for each estimate so that measurable differences for the mean levels might be more easily and meaningfully interpreted.

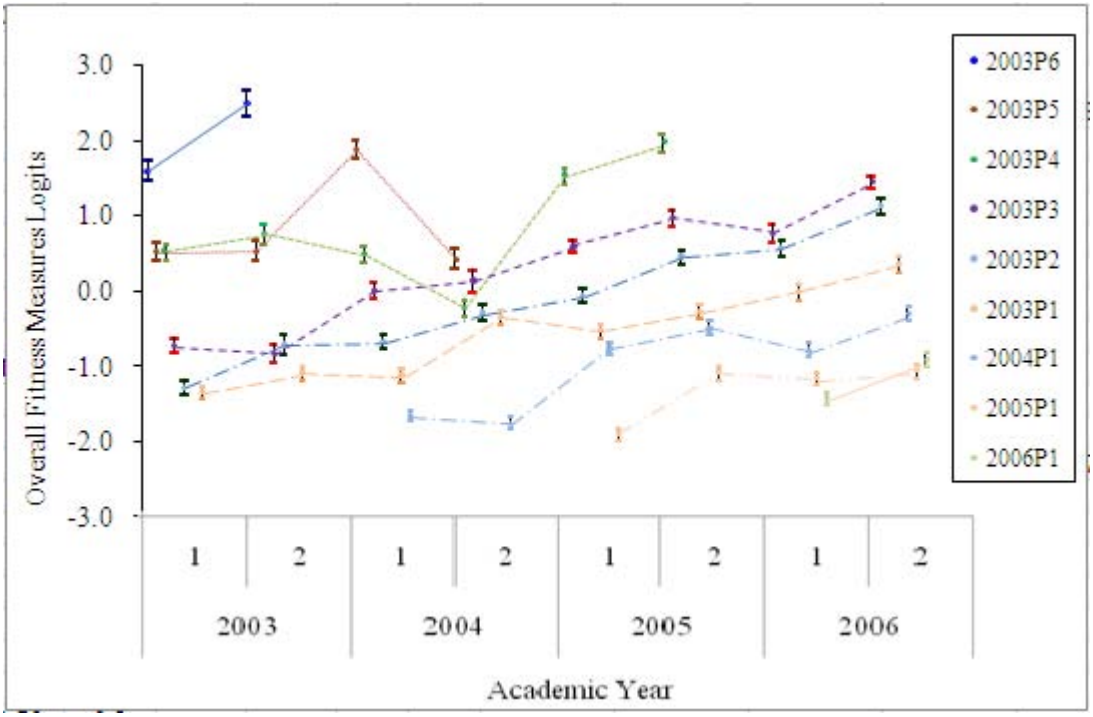


Figure 5.7 Students' Overall Fitness Development by Cohort and Academic Year (M ± 1S.E.)

It can be expected that, in general, the overall fitness level of each cohort increases with the academic year since children's age advances as well. However, there are two dramatic decreases for Primary 5 and Primary 6 in the 2nd semester of academic year 2004-05. This observation conforms to the findings mentioned in the earlier section, that Primary 5 and Primary 6 students in the 2nd semester of academic year 2004-05 demonstrated measurably lower overall fitness levels than did their counterparts in other academic years.

In order to investigate the underlying reasons for this unusual phenomenon, the performances of Primary 5 and Primary 6 students in the 2nd semester of academic year 2004-05 (focus group) and their counterparts in other cohorts (reference group) were compared. Since the focus group has scores for 9-minute Run and 1-minute Sit-ups only, the comparisons were conducted for these two fitness indicators. Table 5.4 presents the score distribution of these two fitness indicators for focus group and reference group respectively.

Table 5.4 Score Distributions in Two Indicators for Focus Group and Reference Group

Score Category	9-minute Run				1-minute Sit-ups			
	Focus Group		Reference Group		Focus Group		Reference Group	
	Freq.	Valid Percent (%)	Freq.	Valid Percent (%)	Freq.	Valid Percent (%)	Freq.	Valid Percent (%)
1			2	0.1			1	0
2	1	0.3	8	0.3			2	0.1
3	2	0.6	20	0.9			4	0.2
4	15	4.5	149	6.4	2	0.6	8	0.3
5	72	21.8	705	30.3	41	12.2	65	2.8
6	112	33.9	787	33.8	213	63.6	315	13.4
7	91	27.6	435	18.7	61	18.2	995	42.4
8	32	9.7	181	7.8	16	4.8	898	38.2
9	5	1.5	39	1.7	2	0.6	61	2.6
Total	330	100.0	2326	100.0	335	100.0	2349	100.0

It can be seen that there is no substantial difference on the performance in 9-minute Run between focus and reference groups, but quite large differences exist on the 1-minute Sit-ups performances. It is obvious that students from the reference group have much better performance than do students from the focus group on the 1-minute Sit-ups test. The majority of students (83.2%) from the reference group scored 7 or higher, while most of students (76.4%) from the focus group scored 6 or lower.

From a practical perspective, it is easy and convenient to keep the records of students' performances on fitness indicators, put the records into computer, and undertake statistical analyses with a software package. What's more important and meaningful, however, is to interpret the data analyses results appropriately, provide explanations as to what had happened, and predict what would be likely to happen next time based on the analyses results. In the case of this study, two groups of students have highly similar performance in the 9-minute Run, but substantially different performances on the 1-minute Sit-ups. It would not be conservative to conclude that students from the focus group have much lower muscular endurance ability than do students from reference group

just based on the result that they completed many fewer sit-ups. This is because the difference might not come from variation of students' abilities alone, but from other factors which might influence the data collection, e.g., rater leniency/severity. Students' performances for 1-minute Sit-ups are recorded as the number of correct sit-ups completed in one minute. However, whether any one sit-up repetition is "correct" or not is determined by the rater's subjective judgment. A severe rater might underestimate a student's ability by counting fewer repetitions as "correct", while a lenient rater might overestimate a student's ability by treating partially completed or non-standard repetitions as "correct". In the case of this study, it is quite likely that students from the focus group had severe raters at that occasion, while their counterparts in reference group were "lucky" enough to have more lenient raters. On the other hand, this kind of rater difference did not occur in the 9-minute Run because the performance in this test is objectively recorded as the distance a student runs or walks in 9 minutes. The whole scoring procedure does not involve raters' subjective judgments. The rater merely keeps record of the distance covered in the elapsed time but does not evaluate the quality of the performance, i.e., whether a student completes the task by running, walking, or even skipping and jumping.

Exemplar Cases

In addition to investigations of students' overall fitness development at the group level, it would be informative to have a closer look at some exemplar cases in order to illustrate the considerable possible variation in individual development patterns of overall fitness over time. Figure 5.8 shows the developmental profiles of 5 exemplar students selected from the cohort 2003P1 where each student has 8 records (overall RMPFS fitness measures) across four consecutive academic years. Among the five exemplar students, there are three boys (Student A, B, and C) and two girls (Student D and E). The variation

is noteworthy given that all exemplar students were 6-years old Primary 1 students at academic year 2003-04.

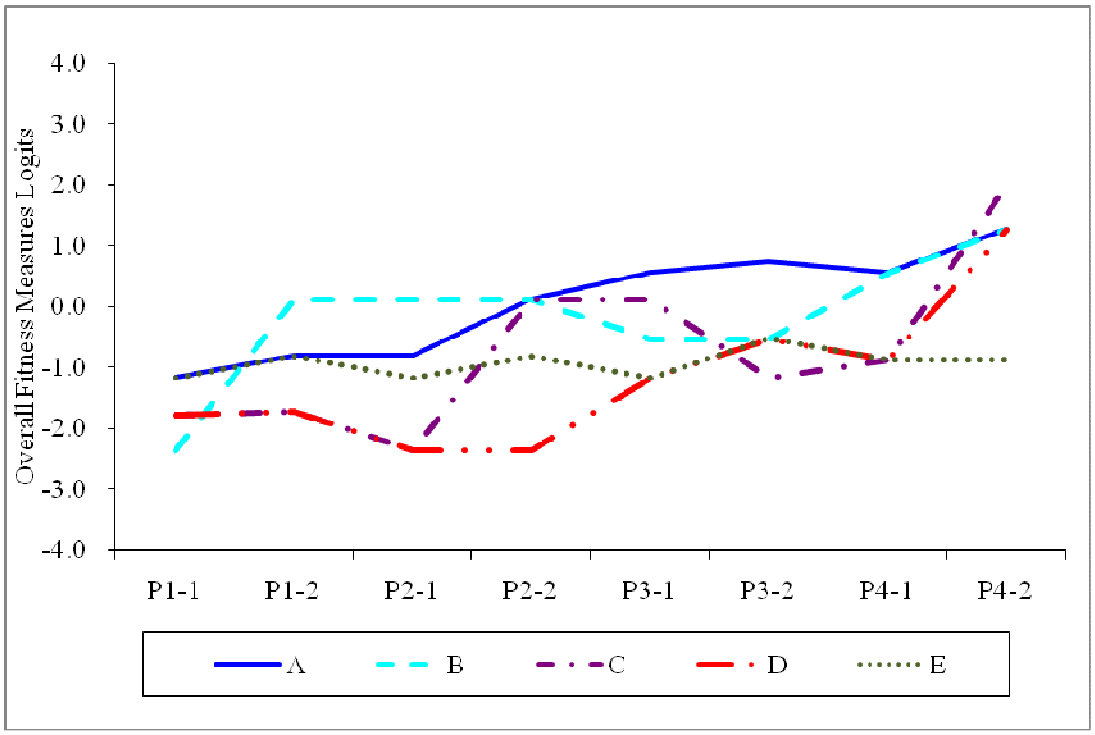


Figure 5.8 Individual Overall Fitness Developmental Profiles of Students

The individual overall physical fitness developmental profiles presented in Figure 5.8 show that there is quite apparent variation in students' overall fitness levels at any one time and in their developmental patterns over time. For example, Student A's physical fitness developed in a relatively constant rate. The physical fitness measures for Students A advanced evenly from starting point to ending point (-1.17. -0.82, -0.82, 0.12, 0.55, 0.74, 0.55, 1.27 logits). Student B's overall physical fitness had a growth spurt at the early stage and then flattens to a plateau. Student B gained 2.48 logits improvement in physical fitness from 1st to 2nd semester in Primary 1, but gained only a further 1.15 logits improvement in the next three years from Primary 2 to Primary 4. Some students' overall physical fitness, e.g., Student C, developed in a more erratic way. No specific pattern could be identified in the plotted profiles of their physical fitness development. Some students (e.g., Student D) are, apparently, late developers. Student D's overall physical

fitness showed little development across Primary 1 and Primary 2, but increased dramatically from -2.36 logits to -0.53 logits in the next year (from Primary 2 to Primary 3), and spurted to +1.27 logits by the end of Primary 4. In distinct contrast to these cases, some students seem to have made very little progress in overall physical fitness during the whole four academic years. For example, Student E had gained 0.30 logits from Primary 1 to Primary 4 and the RMPFS fitness measures remained quite flat over all that time. (-1.17, -0.82, -1.17, -0.82, -1.17, -0.53, -0.87, -0.87 logits).

Figure 5.9 presents the individual developmental profiles of the same group of students with ± 1 S.E. The S.Es for the RMPFS measures of the exemplar students at different year levels range from 0.75 to 0.97 logits. These are quite large values, representing a lack of measurement precision of about 1.5 to almost 2 logits for any individual student fitness measure. It can be seen that the individualized overall physical fitness developmental patterns over time clearly presented in Figure 5.8 are considerably blurred in Figure 5.9 when measurement error is taken into account.

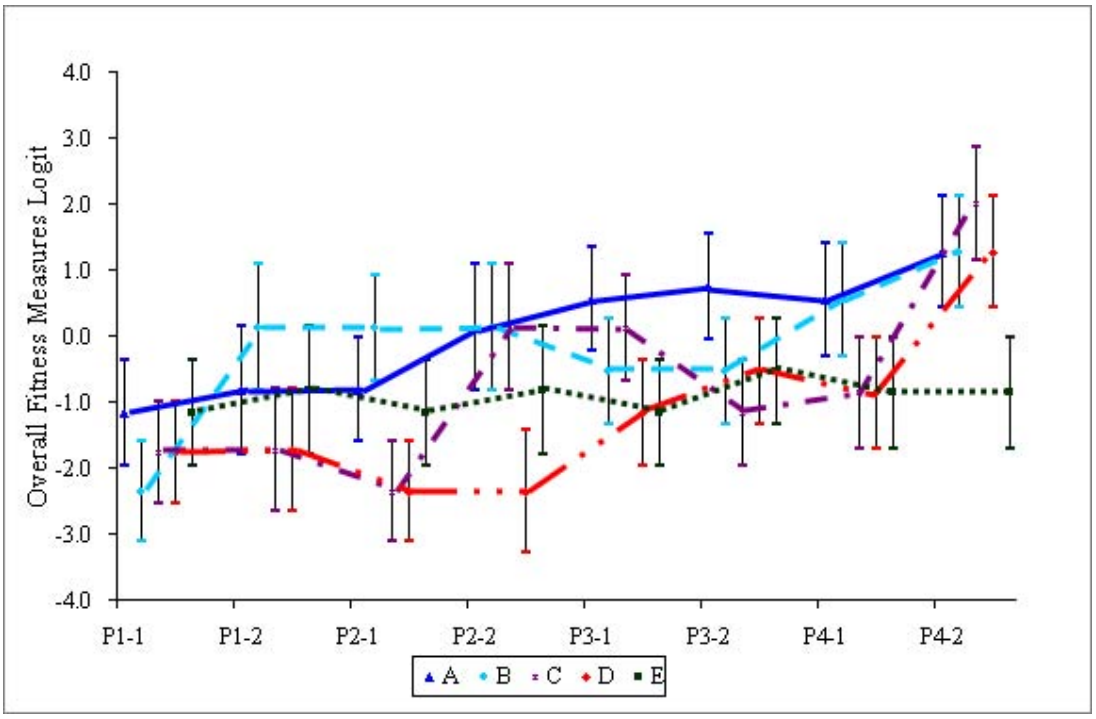


Figure 5.9 Individual Overall Fitness Developmental Profiles of Students (M ± 1S.E.)

Figure 5.10 presents two exemplar cases (Students C and E). Student C had maximum growth in physical fitness (3.78 logits) among the five exemplar students during the four years, while Student E had minimum growth (0.30 logits). However, Student C's physical fitness might grow from -1.01 logits at starting point (C1) to +1.14 logits at ending point (C2) within the measurement error range. Similarly, Student E's physical fitness might grow from -1.96 logits at starting point (E1) to -0.04 logits at ending point (E2). In this case, Student C had 2.15 logits improvement in physical fitness, and Student E had a remarkably similar 1.92 logits improvement. The difference between these two students is much smaller than the 3.78 logits *vs.* 0.30 logits when the lack of measurement precision (large S.Es) is taken into account.

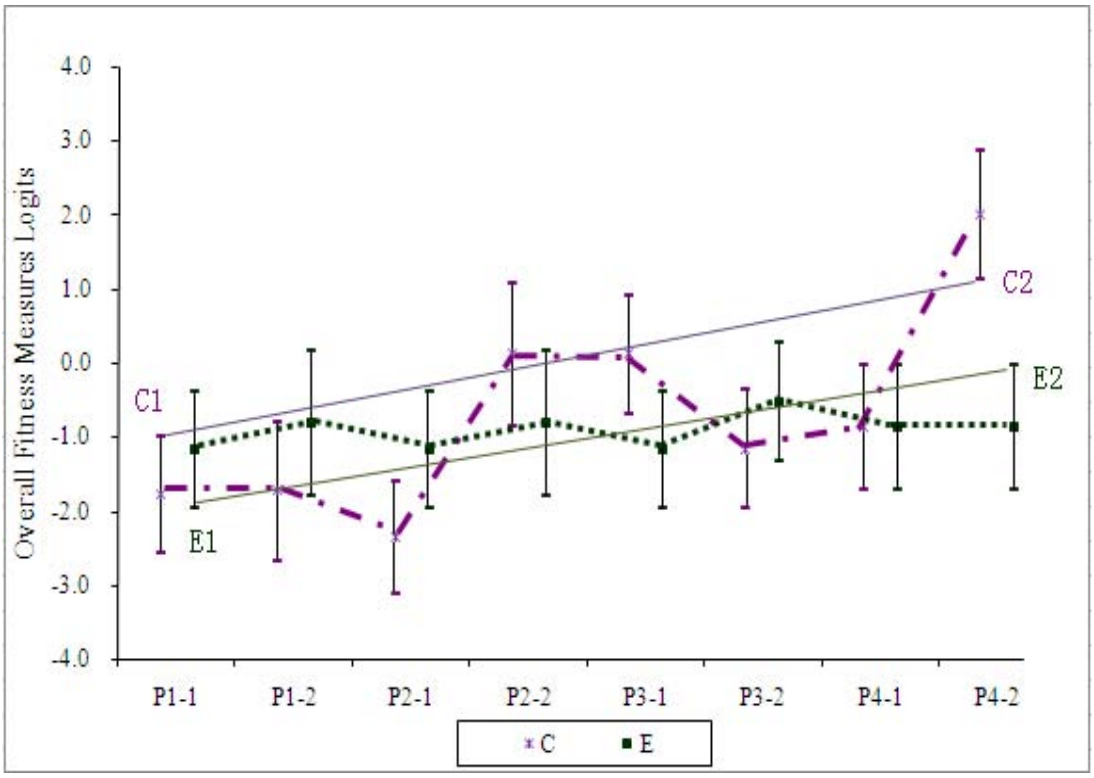


Figure 5.10 Comparison between Students C and E

In contrast, the S.Es for the overall physical fitness measures of cohorts are comparably quite small. Figure 5.11 presents the developmental profiles of the cohort 2003P1 from which the 5 exemplar cases were selected. The S.Es for the mean physical fitness

measures of different year levels in this cohort range from 0.04 to 0.06 logits. In other words, the estimates for the mean fitness of cohorts are quite precise.

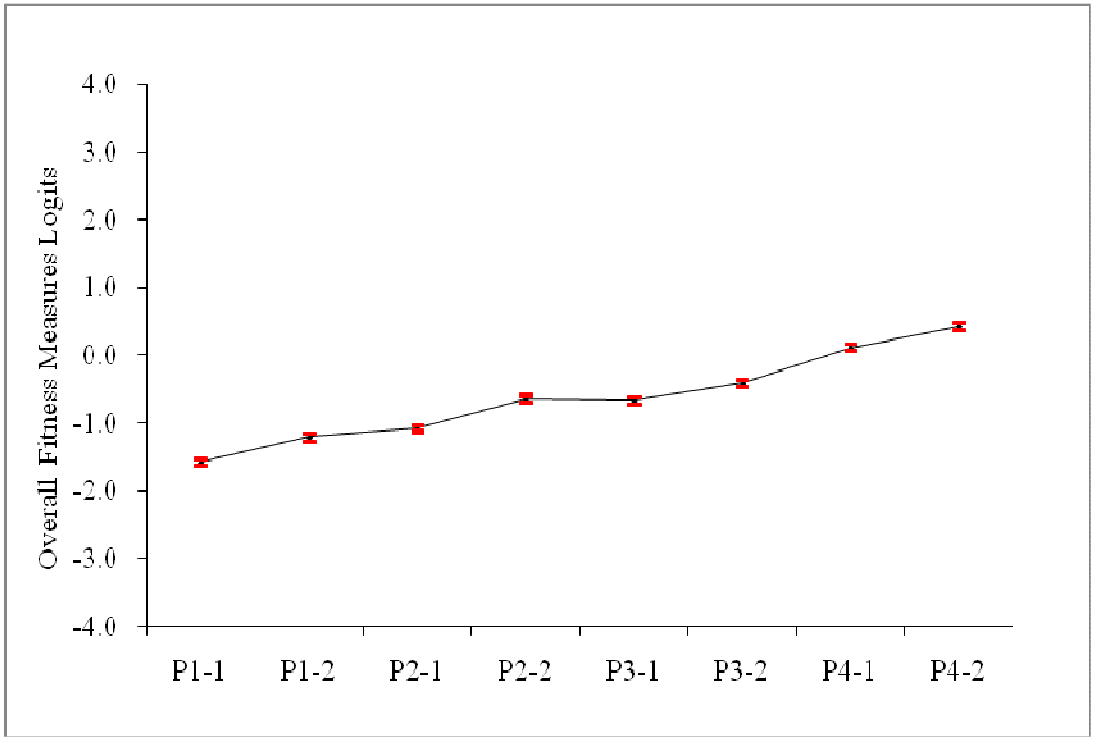


Figure 5.11 Overall Fitness Developmental Profiles of the Cohort 2003P1 (M ± 1S.E.)

In summary, it would not be cautious to make inferences about students' overall physical fitness estimations at the individual level because the measurement error is too large to allow almost any meaningful distinctions to be made between the fitness levels of individuals; not between any two students nor between any two time points for a particular student. The overall physical fitness measures and changes at the group level are more precise and, therefore, informative to depict students' physical fitness development.

Summary

This chapter used the RMPFS to measure students' overall physical fitness and track the physical fitness developmental trends in terms of Rasch-scaled measures. As described in

this chapter, students' overall fitness levels increase monotonically from 6-years old to 11-years old, although the rate of development is not even across the six years. The results also showed quite large individual differences in students' physical fitness development.

In general, boys have higher overall fitness levels than girls of the same age and the differences are statistically significant. However, the sex differences for students aged 6 to 9 years are less than 0.5 logits and have no practical importance. There is a large overlap of the overall fitness estimations for boys and girls of the same age when taking S.Ds into account. Therefore, it would not be appropriate to divide students aged 6 to 9 years into sex-based groups for physical education lessons. .

Students' overall fitness levels increase with academic year and year level since children's age advances as well except that, in the 2nd semester of academic year 2004-05, Primary 5 and Primary 6 students demonstrated measurably lower overall fitness levels than did their counterparts in other academic years and even their counterparts in lower year levels in the same academic year. Investigation of the difference between this group of students and other Primary 5 and Primary 6 students revealed that the significant difference of students' overall fitness measures is not attributable to the objectively scored 9-minute Run, but is related to the 1-minute Sit-ups indicator on which students' performance might be related to factors other than students' physical fitness, such as rater leniency/severity.

In addition to investigations of students' overall physical fitness and developmental trends at the group level, the individual overall fitness and developmental trends over time were also examined through exemplar cases. The results showed considerable apparent variation in students' overall fitness levels at any one time and their developmental patterns over time. The S.Es for the overall physical fitness measures of the exemplar students are quite large, indicating a lack of measurement precision. In contrast, the S.Es

for the overall physical fitness measures of cohorts are comparably small, suggesting that the estimates for the mean fitness of cohorts are quite precise.

CHAPTER SIX

RESULTS II

RELATIONSHIPS BETWEEN RMPFS MEASURE AND ANTHROPOMETRIC INDICATORS

The relationships between physical fitness and other aspects of human behavior have attracted considerable research interest and have been investigated in medical and health studies (e.g., Erikssen, Liestøl, Bjørnholt, Thaulow, Sandvik, & Erikssen, 1998; Katzmarzyk, Malina, & Bouchard, 1999; Kullo et al., 2002; Kyröläinen, Häkkinen, Kautiainen, Santtila, Pihlainen, & Häkkinen, 2008; Rankinen, Church, Rice, Bouchard, & Blair, 2007; Thorsen et al., 2006; Twisk, Kemper, & Van Mechelen, 2000; Williams, 2001) as well as in physical education and physical activity studies (e.g., Brunet, Chaput, & Tremblay, 2007; Gutin et al., 2005; Kamtsios & Digelidis, 2007; Rowlands, Eston, & Ingledew, 1999; Stratton, Canoy, Boddy, Taylor, Hackett, & Buchan, 2007). Those studies have contributed to a better understanding of associations between physical fitness and a variety of other aspects including BMI, body fat, nutritional habits, physical activity, and health problems such as coronary heart disease and cancer for both youths and adults. It is worth noting that physical fitness investigated in those studies is not a composite conception but indicators are treated as separate and independent components or even, in most of the medical and health studies, are seen as identical to cardiovascular fitness or maximal aerobic capacity and have nothing to do with other components.

However, the present study proposed a new conceptualization of overall physical fitness which can be measured through Rasch calibration of students' performances on different physical fitness indicators. Instead of examining the separate physical fitness components one by one as has been done in traditional physical fitness assessment, the RMPFS

measure described the overall picture of students' physical fitness and placed students in order on the linear continuum of physical fitness.

This chapter aims to detect the relationships between students' overall physical fitness, measured by the RMPFS, and anthropometric indicators including age, height, weight, and BMI for the students in this sample. The relationships are described in the form of percentile distributions. It is worth pointing out that percentile ranks, which are often used in traditional fitness assessment and reporting system, are not on an equal-interval scale so that they are not appropriate for use as direct indicators of students' physical fitness. However, this chapter is to use percentile distribution to set up a reference database for comparative interpretation of students' RMPFS measures rather than to place students on the physical fitness continuum. The percentile distributions are helpful in interpreting students' RMPFS measures in a conventional and somewhat "friendly", for some people, way, especially for the sample used in this study. Seven percentile curves (3%, 10%, 25%, 50%, 75%, 90%, 97%) are to be used in figures to describe the distributions of students' RMPFS measures in the relationship with age, height, weight, and BMI.

RMPFS Measure by Age

Chapter Five reports the average values of RMPFS measures for students aged 6 through 11 years and displays the overall fitness developmental trend for students at the group level. This section shows the percentile distribution of RMPFS measures for each age group. Although students' age ranges from 6 to 13 in the sample used in this study, the sample size of students aged 12 and 13 years is very small (142 at age of 12 and 2 at age of 13 respectively) compared to other ages. Therefore, the following analyses and discussion cover students aged 6 to 11 years only. Figure 6.1 and Figure 6.2 present the RMPFS measure for age percentiles for boys and girls respectively.

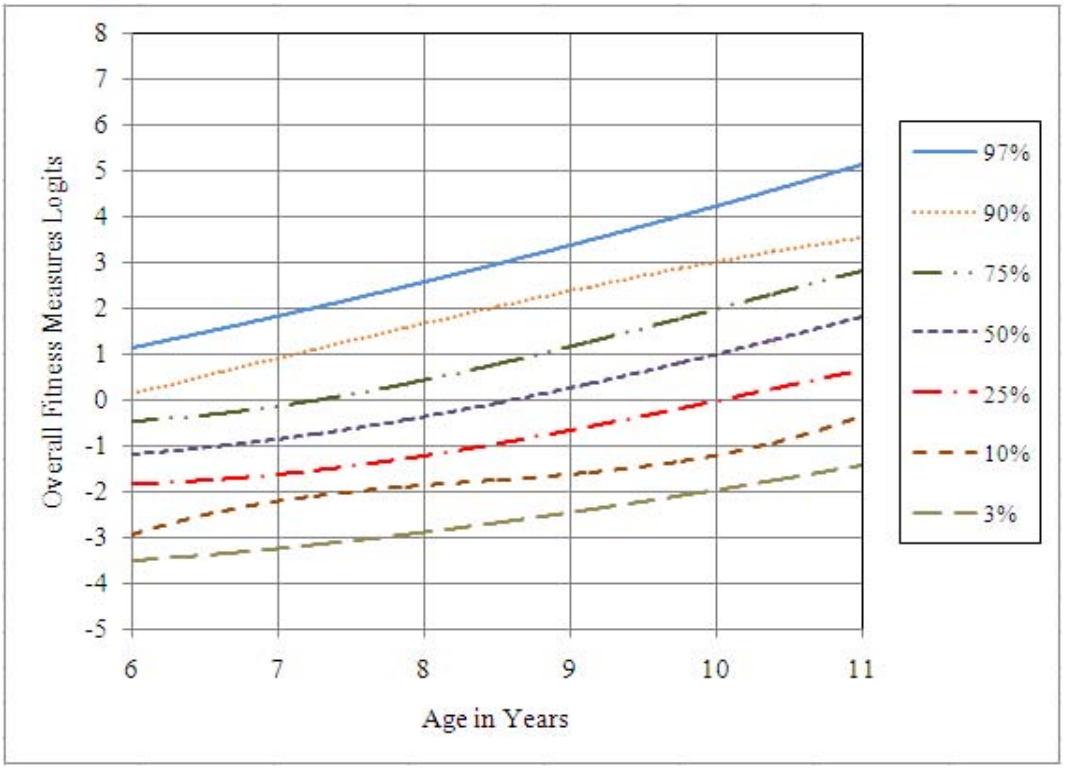


Figure 6.1 RMPFS Measure for Age Percentiles (Boys)

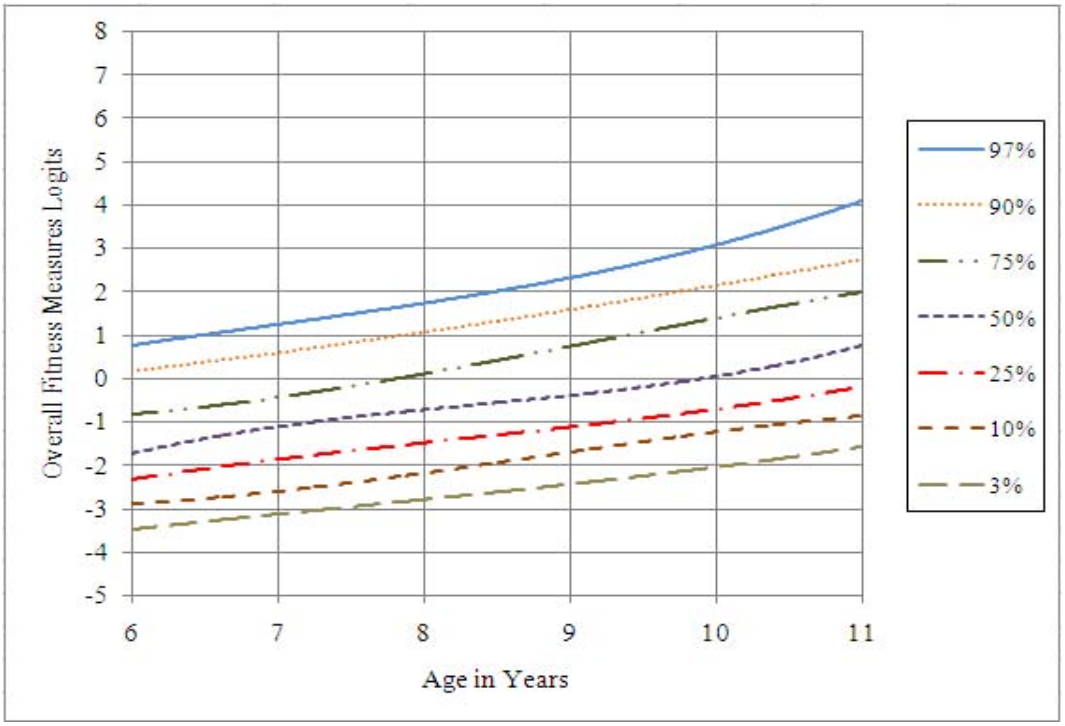


Figure 6.2 RMPFS Measure for Age Percentiles (Girls)

Smoothed percentile curves were derived for RMPFS measure by age. It is obvious that chronological age is a very important factor associated with primary school children's RMPFS measure. The seven percentile curves increase monotonically and almost in parallel with age. The slopes of most of percentile curves for boys are higher than those for girls, indicating that age has more salient influence on overall physical fitness for boys than for girls.

However, these figures provide only a rough reference database for the relationship between RMPFS measure and age since the age information was presented in years (6 to 11 years). More precise age information, e.g., age in months, might generate more comprehensive percentile distributions and provide a more precise reference database.

The Relationship among RMPFS Measure, Height, Weight, and BMI

A number of studies have investigated the relationships among physical fitness and other anthropometric indicators especially BMI. For example, Brunet et al. (2007) made use of the data of 1,140 Canadian children at age of 7 years, 8 years, and 10 years who were involved in the "Quebec en Forme (QEF)" Project to investigate the relationship between BMI and children's performances on three physical fitness indicators including standing long jump, 1-minute speed sit-ups and speed shuttle run. The results showed that BMI and children's performance in all the three physical fitness indicators have negative correlations, and that those associations increased with age; i.e., higher BMI was associated with lower levels of fitness and this relationship became more marked in older children. Stratton et al. (2007) investigated the changing pattern over time in height, weight, BMI, and cardiorespiratory fitness for 15,621 9-11-years old children in the annual school cohorts in England between 1998/9 and 2003/4. They found that cardiorespiratory fitness levels decreased within a 6-years period while BMI increased in the same period. Although they argued that the temporality of the relationship between fitness and BMI could not be tested in cross-sectional data, the change pattern did

indicate a negative correlation between cardiorespiratory fitness and BMI. In another study, Kamtsios and Digelidis (2007) examined 5th and 6th grades students with different BMIs and found that overweight and obese students had lower performances on three physical fitness indicators including long jump, 30m. speed run and 20m. shuttle run.

In the present study, the correlations among RMPFS measure, height, weight, and BMI are presented in Table 6.1 .

Table 6.1 Correlations among RMPFS Measure, Height, Weight, and BMI

	Height	Weight	BMI
RMPFS measure	.525**	.356**	.069**
R-sq	.276	.127	.005

Note. ** p <.01.

It is revealed that the correlations between RMPFS measure and height or weight are 0.525 and 0.356 respectively and these correlations reach statistical significance at .01 level. While the correlation between RMPFS measure and BMI is statistically significant (due, at least in part, to the large sample size), the amount of variance explained (.005) is remarkably low. These results do not align with the findings of some previous studies (e.g., Brunet et al., 2007; Kamtsios & Digelidis, 2007; Stratton et al., 2007). However, the discrepancy is not surprising because the conceptions of physical fitness are different between the present study and other studies mentioned above. In other studies, the physical fitness is treated in a traditional way. Components of fitness were assessed with different indicators and students' performances on each indicator were recorded and interpreted separately. The object under investigation was the association between weight/BMI and each component but not the overall physical fitness. In the present study, the physical fitness is conceptualized as an overall construct which integrates students' performances on 6-minute Run, 9-minute Run, 1-minute Sit-ups, and Dominant Handgrip. Students' traits in cardiorespiratory fitness, muscular endurance, and muscular strength function together have their own contributions to the overall physical fitness. Another possible reason leading to the discrepancy of results between this study and other studies

is that Hong Kong primary school-aged students, especially girls, have lower BMI and smaller BMI range than their counterparts in western countries. For example, the 7-years, 8-years, and 10-years old girls in this sample have a mean value of 15.8 (S.D. = 2.2), 16.1 (S.D. = 2.4), and 16.8 (S.D. = 2.6) respectively. In contrast, the girls in Brunet et al.'s (2007) sample have a mean value of 16.3 (S.D. = 2.1), 17.0 (S.D. = 2.8), and 18.5 (S.D. = 3.4) respectively. The different range and positions on the BMI continuum probably resulted in different correlations between BMI and physical fitness.

RMPFS Measure by Height

Figure 6.3 presents the RMPFS measure for height percentiles for boys and Figure 6.4 presents the same results for girls. Students' height ranges from 101 to 175 cm, but many of categories at the extremes of the height continuum have fewer than 10 observations and some categories have only 1 observation. In order to reduce the noise introduced by unexpected observations and generate meaningful percentile curves, it is suitably conservative to include only those height categories with 30 or more observations for the calculation of percentiles. Consequently, height categories ranging between 112 and 154 cm for boys and between 112 and 153 cm for girls are plotted against RMPFS measure in Figure 6.3 and Figure 6.4 respectively.

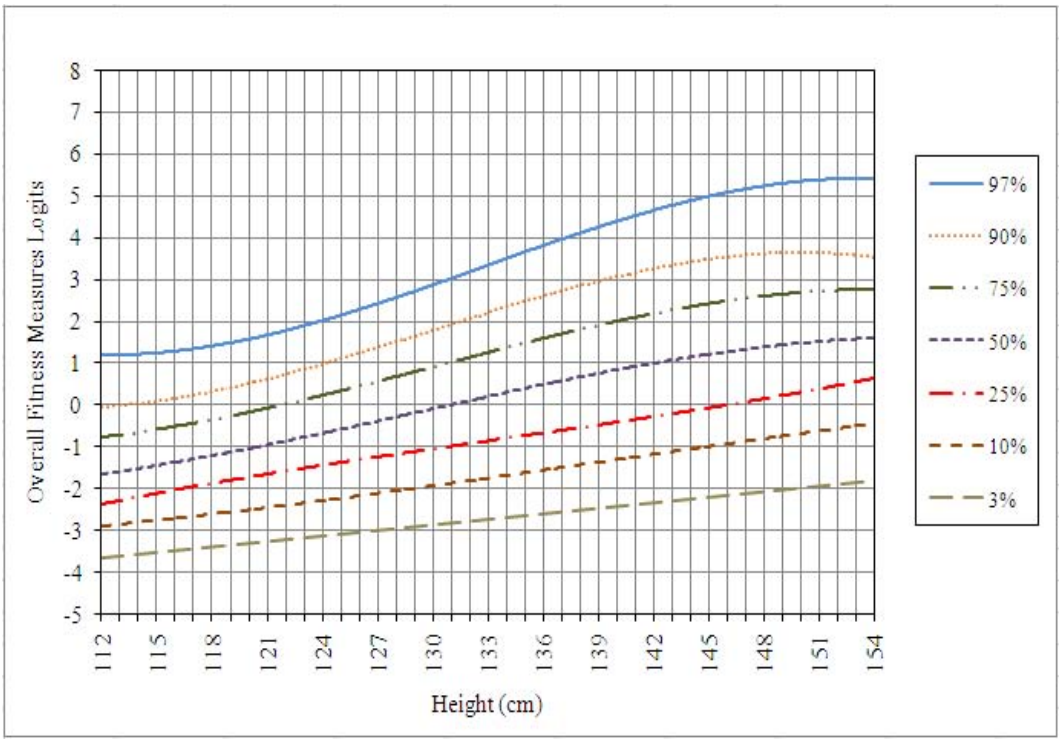


Figure 6.3 RMPFS Measure for Height Percentiles (Boys)

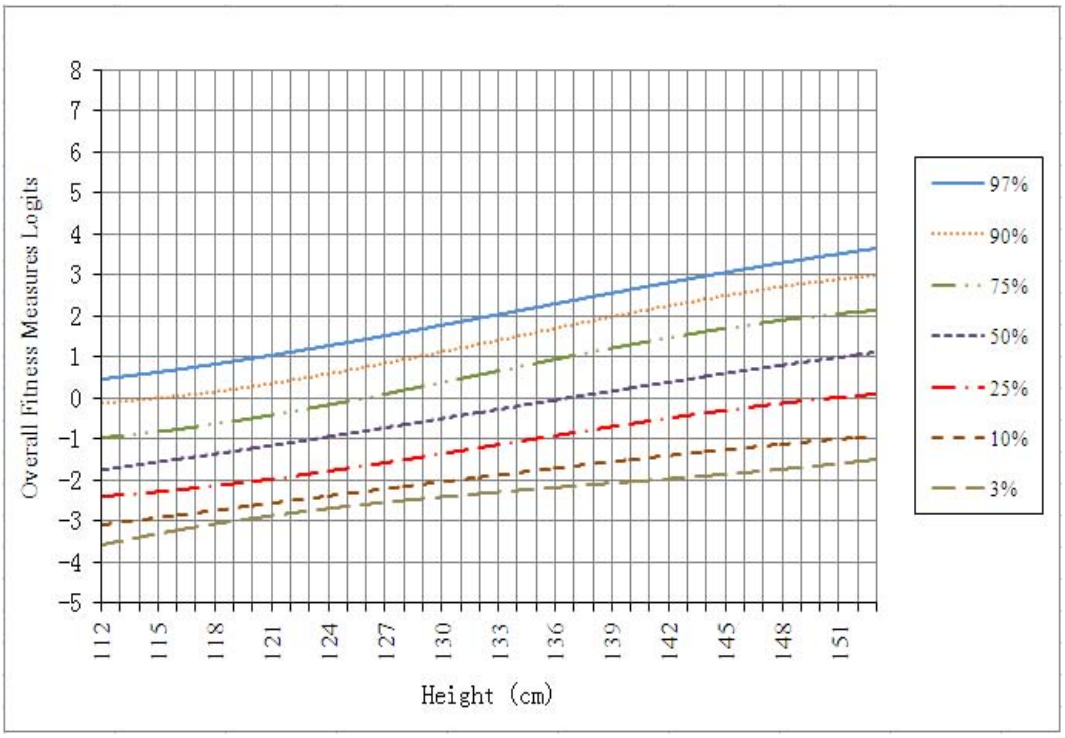


Figure 6.4 RMPFS Measure for Height Percentiles (Girls)

Smoothed percentile curves were derived for RMPFS measure by height. It can be seen that height is a factor of great influence on overall physical fitness. The high percentile curves (e.g., 75%, 90%, 95%) are steeper than low percentile curves (e.g., 3% and 10%), suggesting that there are more apparent variation of overall physical fitness for taller students than for shorter students.

The height percentile can thus be used to investigate an individual student's RMPFS measure relative to other students of the same height, but not necessarily of the same age or weight.

RMPFS Measure by Weight

Figure 6.5 and Figure 6.6 present the RMPFS measure for weight percentiles for boys and girls respectively. Students' weight ranges from 13 to 81 kg, but, again, some extreme weight categories have so few observations that it is not possible to generate meaningful percentile curves. Therefore, only weight categories with 30 or more observations are included in the figures. Consequently, the weight categories ranging between 18 and 50 kg for boys are plotted in Figure 6.5 and the weight groups ranging between 17 and 45 kg for girls are plotted in Figure 6.6 .

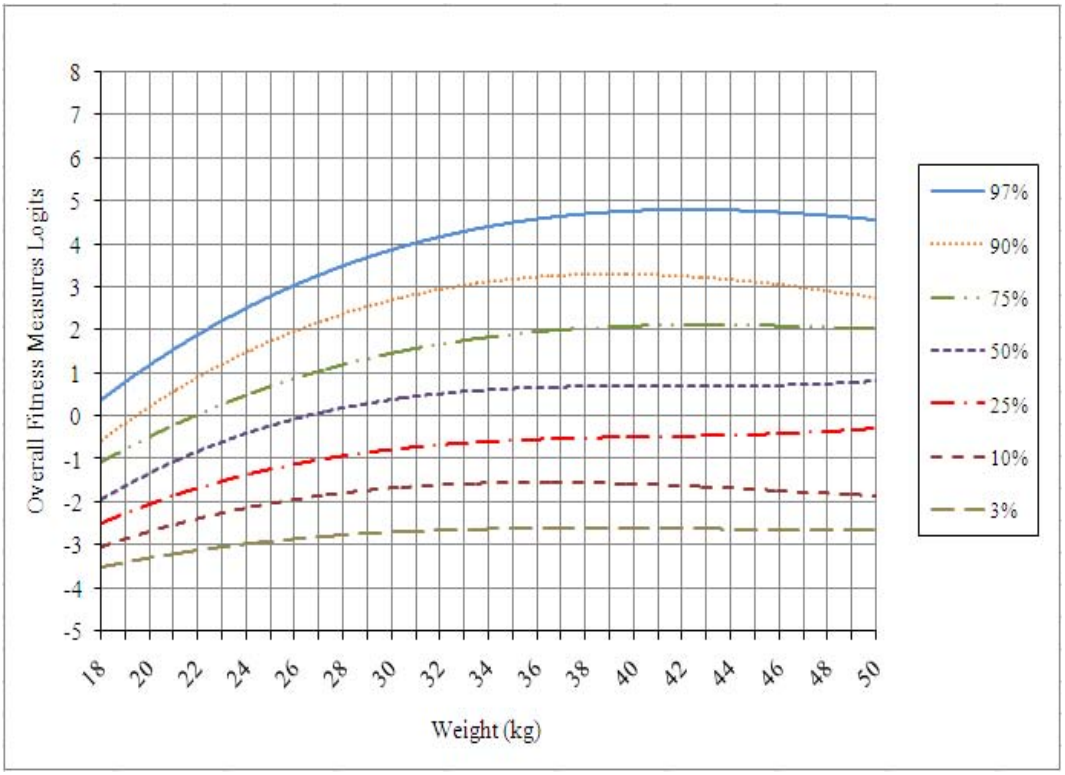


Figure 6.5 RMPFS Measure for Weight Percentiles (Boys)

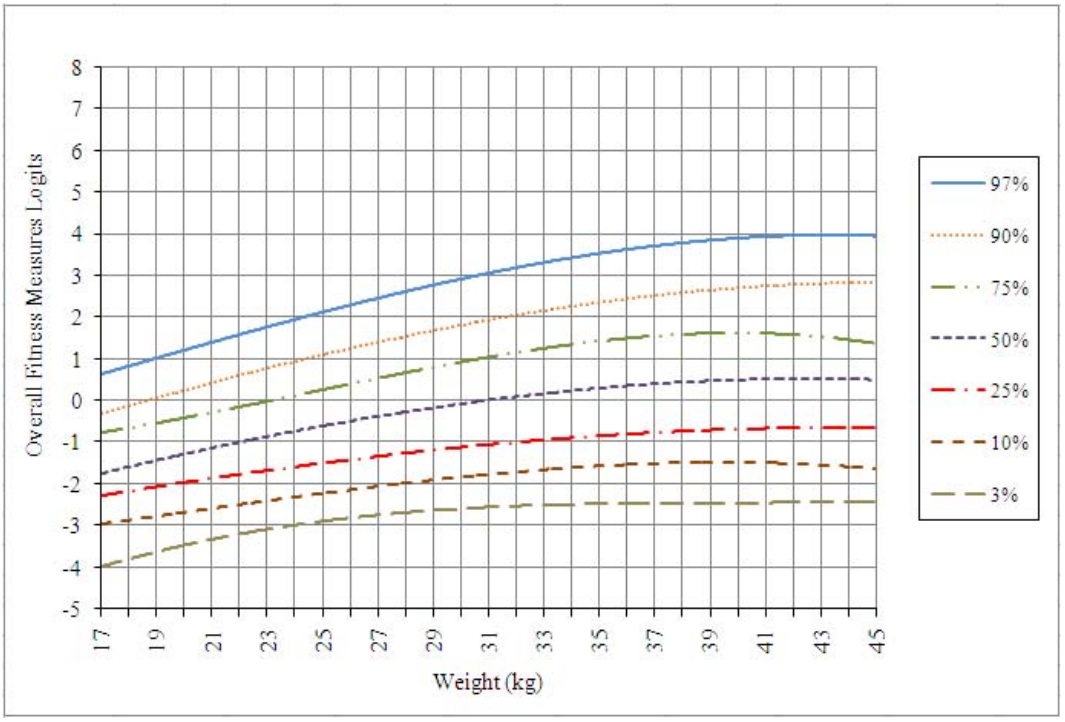


Figure 6.6 RMPFS Measure for Weight Percentiles (Girls)

It is obvious that weight has impact on overall physical fitness. The percentile curves, especially high percentiles, are quite steep from the beginning to the middle of the curve, and then become flat from the middle to the end of the curves. It implies that students' overall physical fitness increase when the weight increases from low to median, but remain unchanged when the weight increases from median to high. This pattern is more salient for boys than for girls.

The RMPFS measure-for-weight figure can be used to investigate an individual student's RMPFS measure relative to other students of the same weight, but not necessarily of the same age or height.

RMPFS Measure by BMI

There are numerous studies on the relationship between physical fitness and percentage body fat or BMI for youth (e.g., Brunet et al., 2007; Kamtsios & Digelidis, 2007; Rowlands et al., 1999; Stratton et al., 2007). Those studies investigated the relationship between percentage body fat/BMI and separate components of physical fitness. In contrast, the present study focused on the relationship between BMI and overall physical fitness, in the form of RMPFS measure, which integrates key components of physical fitness. Figure 6.7 and 6.8 present the RMPFS measure for BMI percentiles for boys and girls respectively.

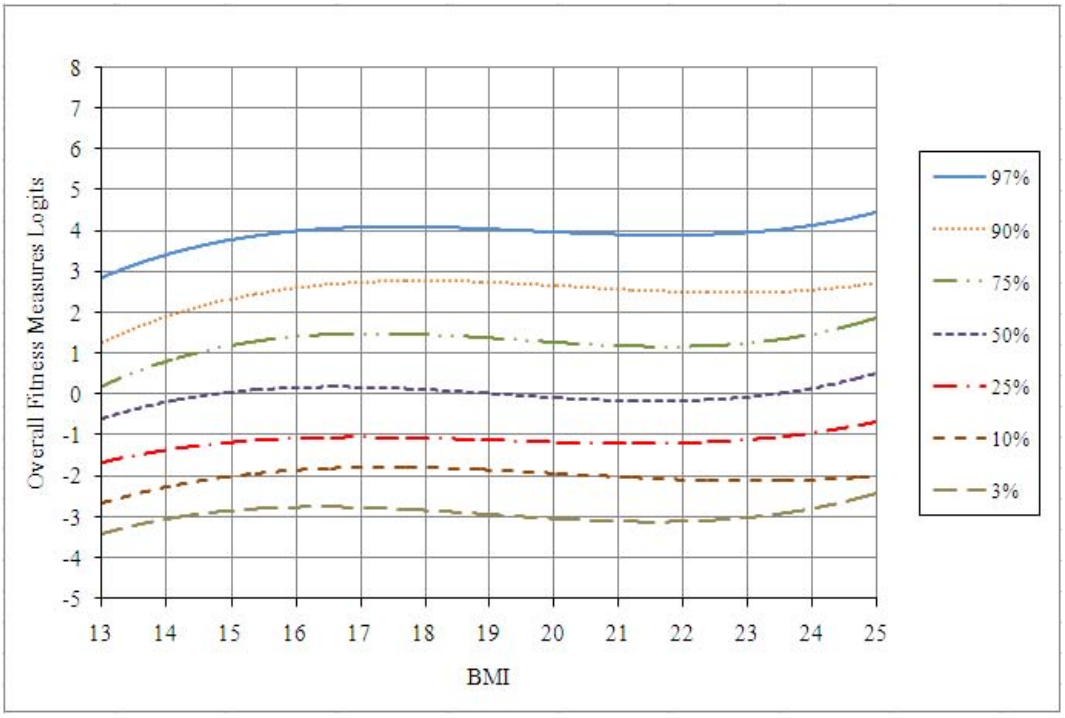


Figure 6.7 RMPFS Measure for BMI Percentiles (Boys)

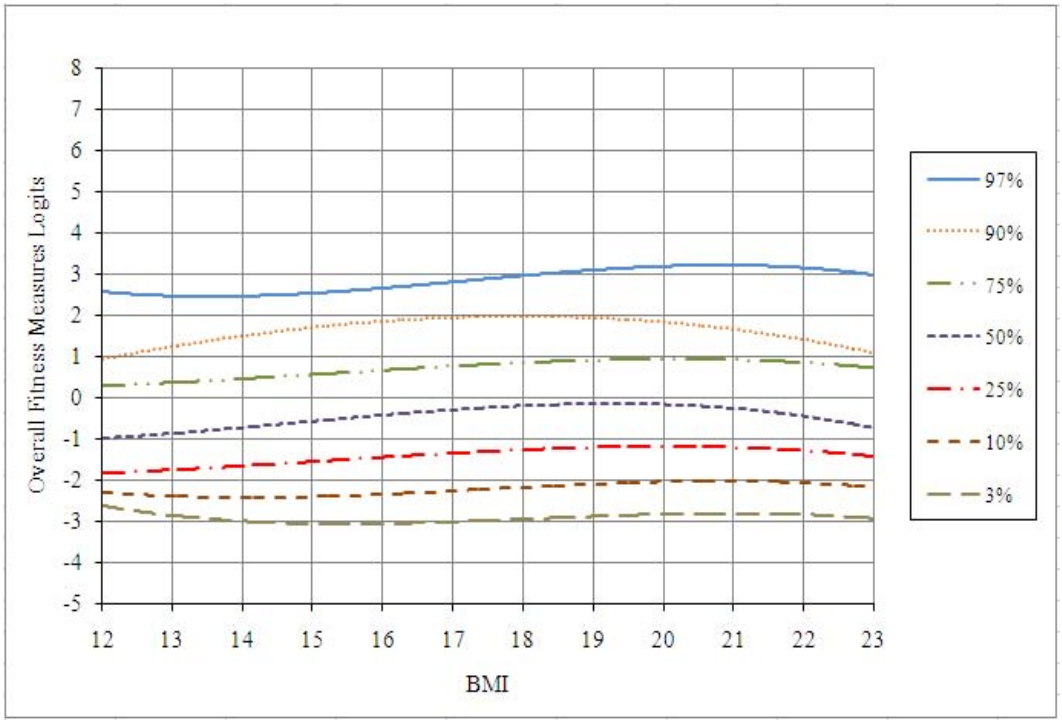


Figure 6.8 RMPFS Measure for BMI Percentiles (Girls)

Although students' BMI ranges from 10 to 38, only BMI categories with 30 or more observations are included in the percentile distributions. Consequently, the BMI categories ranging between 13 and 25 for boys and between 12 and 23 for girls are plotted in Figure 6.7 and 6.8 respectively. The percentile curves presented are quite flat, indicating that the BMI has very low correlation with students' overall physical fitness.

The RMPFS measure-for-BMI figure can be used to investigate an individual student's RMPFS measure relative to other students of the same BMI.

Summary

In this chapter, percentile distributions of overall physical fitness, in the form of RMPFS measure, were calculated from both the cross-sectional and longitudinal data. Seven smoothed percentile curves (3%, 10%, 25%, 50%, 75%, 90%, 97%) were presented in each graph to depict the relationships between RMPFS measures and age, height, weight, and BMI for male and female students in the sample used in this study.

The percentile distributions presented in this chapter can be used to monitor, cross-sectionally and longitudinally, an individual student's RMPFS measure relative to other students of the same age, height, weight, or BMI. This will provide a convenient and direct method to indicate a student's rank relative to the whole sample used in this study by plotting the student on the percentile distributions according to the particular anthropometric attribute (age, height, weight, or BMI).

Since the percentile distributions were calculated based on a particular sample, it might not be appropriate to immediately generalize the profiles to other Hong Kong primary schools or to the whole Hong Kong population due to the sampling limitation. Nevertheless, the percentile distributions provided a school-based reference for a better interpretation of students' RMPFS measures and provide further evidence of the benefits that could be derived if the techniques used in this research could be implemented

successfully in other research situations. It should also provide a highly useful empirical resource to assist physical education teachers to cater for students' developmental status and, therefore, deliver appropriate fitness programmes to accommodate individualized requirements. It would behove teachers to pay special attention to the extreme values (for example, above 97% or below 3%) and to explore the answers for several questions concerning those extreme values, such as, was the physical fitness measurement for those with extreme values correct or accurate? Should these children be given priority for possible follow-up action?

CHAPTER SEVEN

CONCLUSON AND DISCUSSION

Overview

This research was inspired by two deficiencies inherent to traditional approaches to physical fitness assessment. The first, the high dependence on raw scores for component-related physical fitness indicators, limits the validity and accuracy of the interpretation of physical fitness assessment results because raw scores (unless used to derive further information, e.g., estimated VO_2max) indicate only the ordering of the performances, but might not provide "measures" with inferential value about the size of the differences between different raw scores (Bond & Fox, 2007; Wright & Mok, 2000). The second, the traditional approaches to physical fitness assessment is not an economical approach because it requires students to attempt all of the separate fitness indicators in order to get the whole picture about their abilities on the different components of physical fitness. Therefore, this research attempted to develop a new technique which could provide valid measures of students' overall physical fitness in an efficient way.

Towards that end, this thesis outlined the background and proposed the purpose of the study – to develop a Rasch Measurement Physical Fitness Scale (RMPFS) consisting of the physical fitness indicators routinely used in Hong Kong primary schools. The significance of the study, the advantages the RMPFS has compared to traditional approaches to physical fitness assessment, four research questions, and two basic assumptions for the study were outlined.

The literature review introduced a definition of physical fitness based on the structure of physical fitness as described by experts in the research field. Physical fitness test protocols and indicators used both in western countries and Hong Kong for children

fitness assessment were summarized as well. Furthermore, the Rasch model was discussed thoroughly with regard to its theoretical proposition, mathematical formulation, main features, and the existing applications of Rasch measurement in physical education and sports science. Although the Rasch model has been applied to develop or improve physical tests or motor ability scale as valid instruments in some studies (e.g., Bowles & Ram, 2006; Hands & Larkin, 2001; Heesch et al., 2006; Safrit et al., 1992; Zhu & Cole, 1996; Zhu & Kurz, 1994; Zhu & Safrit, 1993; Zhu et al., 2001), no attempt to combine a range of different physical fitness indicators into a single overall physical fitness scale was found in current literature.

Methodological issues remain at the heart of the research enterprise. Important aspects of the research methodology include consideration of the sample characteristics, as well as the fitness indicators administered in Hong Kong primary schools to obtain students' physical fitness data, along with the procedures for the collection of those data. Another important argument in this thesis has been concerning the justification of the Partial Credit Rasch Model as the more appropriate choice for creating fitness measures with the physical fitness data in this research. An iterative sequence of analytical steps was adopted and nine criteria were established to investigate the quality of the indicators and the ensuing scale.

Through thorough investigations derived from Rasch measurement along with some practical considerations, four physical fitness indicators (i.e., 6-mintue Run, 9-minute Run, 1-mintue Sit-ups and Dominant Handgrip) were successfully calibrated to form the RMPFS for Hong Kong primary school-aged students. The other five indicators (i.e., BMI, Sit-and-Reach, Right Handgrip, Left Handgrip, Standard Push-ups, and Modified Push-ups) were excluded from the scale for different and sufficient reasons. This RMPFS scale integrates three key components of physical fitness (i.e., cardiorespiratory fitness, muscular endurance, and muscular strength) into an overall measure of health-related physical fitness. The analytical results indicated that the RMPFS and its scale indicators showed sufficient fit to the Rasch model.

The developed RMPFS was successfully implemented to measure primary school-aged students' overall physical fitness levels and the Rasch-scaled overall physical fitness measures were examined against variables such as age, sex, and cohort. Students' overall physical fitness measures increase monotonically with age although the rate of development varied at different stages. Sex differences are statistically significant in favor of boys, but the differences for students aged 6 to 9 years are of no practical importance. Investigations on the overall fitness measures of different cohorts located two occasions of unexpected decrease in fitness for some cohorts and further exploration found that it might be influenced by subjectivity of the testing process. In addition to measurement of students overall fitness at group level, five exemplar cases (three boys and two girls) showed the apparent variety of individual students' overall fitness levels at any one time as well as their developmental patterns.

Moreover, the relationships between students' overall physical fitness, measured by the RMPFS, and anthropometric indicators including age, height, weight, and BMI were depicted for male and female students in the sample used in this research. The relationships are described in the form of percentile distributions (3%, 10%, 25%, 50%, 75%, 90%, 97%) which are empirically helpful for comparative interpretation of students' RMPFS measures since it provided a school-based reference. Any student's rank relative to the whole sample used in this research could be obtained by plotting the student into the percentile distributions according to any chose anthropometric trait.

Main Findings

The main findings of the study can be summarized succinctly as follows:

1. A RMPFS integrating three key core components of physical fitness (i.e., cardiorespiratory fitness, muscular endurance, and muscular strength) was developed through the Rasch calibration of primary school-aged students' physical fitness data

provided by a large partner school in Hong Kong.

Four physical fitness indicators - 6-mintue Run, 9-minute Run, 1-minute Sit-ups and Dominant Handgrip - were successfully calibrated to form the RMPFS. Another six routinely collected fitness indicators - BMI, Sit-and-Reach, Right Handgrip, Left Handgrip, Standard Push-ups, and Modified Push-ups - were excluded from the RMPFS because of violation of the Rasch model's requirements or practical considerations. The RMPFS can provide an overall measure of health-related physical fitness for students. This approach has a number of benefits over relying on the independent scores for separate fitness indicators or components. Even if the student had performed on any one of the four RMPFS physical fitness indicators, that student can be given an overall RMPFS fitness measure. This overall measure combines core fitness components - cardiorespiratory fitness, muscular endurance, and muscular strength - but is not the simple "average" of the performance on different components. The RMPFS overall fitness measure is equal-interval measure which has consistent and stable meaning with regard to the distances between persons or items so that it facilitates meaningful interpretation and comparison of students' performances on physical fitness indicators. The measure is sample-distribution free and item-distribution free. That means item/indicator measures should be independent of the particular sample used for item calibration and person measures should be independent of the particular items/indicators used for measuring the persons. Furthermore, the RMPFS can calibrate students' overall fitness levels and the indicator difficulties on a single unidimensional scale so that direct comparisons between person abilities and item difficulties can be easily conducted based on their locations on the latent trait continuum.

2. The RMPFS and its scale indicators showed fit to the Rasch model sufficient for the intended purposes of measuring overall fitness of children and tracking fitness levels over time.

The difficulty levels for the 4 calibrated indicators in the RMPFS range from -1.59 logits

to +1.25 logits; those locations are associated with very small S.Es (0.02 – 0.03 logits). The indicators' difficulties (M = 0.00, SD = 1.16) are appropriately matched to the fitness levels (M = -0.21, SD = 2.78) of students in this sample. The Infit and Outfit MNSQ statistics for all indicators range between 0.85 (Infit MNSQ for 9-minute Run) and 1.13 (Outfit MNSQ for Dominant Handgrip). All the 4 indicators are of the same polarity since the point-measure correlations for all of the RMPFS indicators approximate 0.8. The Rasch item reliability is 1.00 and the Rasch person reliability is 0.77. The item separation index is 43.16 and the person separation index is 1.83. These results suggest that the scale and indicators have sufficient fit to the Rasch model for practical measurement purposes – especially for such low-stakes decisions. The Item Characteristic Curves (ICC) and category probability curves provide further support for the valid functioning of the RMPFS scale. The empirical ICCs match the theoretical ICCs reasonably well, especially for students with median fitness levels, i.e., those located around the middle of the curves. The category probability curves for each of the four indicators show that the category structure for each indicator functions very well.

3. The RMPFS measures displayed Hong Kong primary school-aged students' overall physical fitness levels and developmental trends effectively.

Students' RMPFS measures increase monotonically from 6-years old to 11-years old, although the rate of development is not even across the six years, and increase with academic year and year level. There is statistically significant sex difference in overall RMPFS fitness levels favoring boys. Investigations of exemplar cases showed apparent variation in students' overall fitness levels at any one time and their developmental patterns over time. However, it is worth noting that the S.Es for the RMPFS measures at the individual level are quite large, while very small at the group (e.g., class, cohort or year) level. Therefore, the RMPFS measures and changes at the group level are more informative in depicting students' physical fitness development and it is not recommended to make high-stakes inferences about students' overall physical fitness estimations at the individual level because of the large measure error. Although some

other aggregation of the fitness data to produce an overall fitness score might be possible, the interval measurement characteristics of the RMPFS measures are demonstrably suitable for the tracking task.

4. The percentile distributions of overall physical fitness, measured by the RMPFS, for age, height, weight, and BMI were described graphically for the sample of this research.

Seven smoothed percentile curves (3%, 10%, 25%, 50%, 75%, 90%, 97%) were presented in graphs to depict the relationships between RMPFS measures and the traditionally used age, height, weight, and BMI indicators for male and female students in the sample used in this research. The percentile distributions facilitate provide better interpretation of students' RMPFS measures by providing a school-based reference and can be used to monitor an individual student's RMPFS measure relative to other students of the same age, height, weight, or BMI in a convenient and straightforward way. The percentile distributions also provide a highly useful empirical resource to assist physical education teaching. Teachers can make use of the information obtained from the percentile distributions to accommodate students' individualized requirements in delivering appropriate fitness programmes.

Implications for Practice

This research has important implications for practice in the field of physical education and physical fitness programme delivery for students in Hong Kong primary schools.

1. The successful development and application of the RMPFS provides strong evidence of the benefits derived from the techniques used in this research. It acts as a model practice that could be transplanted to other similar samples to build up school-based database so that more meaningful interpretation of physical fitness assessment results can be achieved.

2. As described in Chapter Five, two groups of students with substantially different overall physical fitness have highly similar performances on 9-minute Run, but different performances on 1-minute Sit-ups. It is reasonable to draw an inference that the difference might not come from students' fitness levels, but perhaps from other factors which might influence the assessment results; it is possible that rater severity could be one of these. This fact suggests that physical fitness indicators administered for primary school-aged students should be more objective in order to reduce unexpected influence as much as possible and obtain reliable measurement data really reflecting students' physical fitness. For example, it should be helpful to use standardized procedure for test administration in order to achieve consistency among raters' severity in physical fitness tests which involve raters' subjective judgments, e.g., 1-minute Sit-ups.

3. It is usual practice in Hong Kong to divide students into sex-based groups in PE classes. However, this is not the advice that would be given, based on the findings of this research - especially for junior primary school-aged students aged 6 to 9 years. Although, in terms of mean values, boys have statistically significantly higher levels of overall fitness than girls of the same age, there is a very large overlap of the overall fitness estimations for boys and girls. In other words, although boys are expected, on average, to be fitter than girls, but it would not be appropriate to make individual judgments, predictions or grouping just because of sex. Arbitrarily dividing students into sex-based groups and deliver different fitness programmes to these groups is not based on the empirical evidence. The levels of fitness programmes should reflect the developmental trends, rather than *a priori* sex–based assumptions which, *inter alia*, would neglect the needs of boys with relatively low fitness levels and girls with relatively high fitness levels as well as ignore the similarities of fitness levels among many boys and girls. In contrast, it seems more defensible to divide students into groups based on fitness levels in PE classes. For example, students within, or across year levels could be divided conveniently into three groups, namely, high fitness,

median fitness, and low fitness groups. Different programmes and physical activities then could be designed specifically for these groups so that students' more individualized requirements would not be overlooked. Furthermore, considering the high correlation between height and overall physical fitness, even height-based grouping would be better than sex-based grouping.

4. The findings of this research show that there are apparent individual differences in both overall physical fitness levels and developmental patterns for primary school-aged students. Therefore, physical education teachers need to cater for students' individual requirements and develop appropriate fitness programmes that could accommodate students' individualized requirements. This will be a considerable challenge to teachers used to traditional whole-class or sex-based group delivery of physical fitness programmes.

5. Height and weight are appropriate correlates of overall physical fitness. However, the use of BMI as an appropriate indicator of overall physical fitness is ill-conceived. BMI could be used as a good indicator of obesity and an alternative indicator of body composition. The correlation between BMI and overall physical fitness for Hong Kong primary school-aged students, measured by the RMPFS, is close to zero. Therefore, it indicates that interpretation of BMI results should be more cautious especially when it is presented together with other fitness assessment results.

6. This research has practical values for the partner school. The first, the partner school has dedicated a lot of resources to physical education, such as the sport climbing wall, the physical fitness room, the indoor swimming pool, the extra teaching time as well as teaching manpower for physical education classes. Although growth of students' fitness has always been accepted implicitly, now the evidence of fitness growth can be made explicit to all stakeholders including teachers, school sponsors and parents. Thus the partner school's investment in physical education can be justified, at least in part, by reference to the empirical evidence provided by this research. The second,

the RMPFS facilitates reporting students' fitness profiles by class or cohort at group level as well as at individual level as long as individual results are used for low-stakes decisions only. The school and parents now have a useful and convenient tool to investigate students' fitness growth over time. Furthermore, this research has suggestions with practical benefits for physical education teachers in the partner school, such as the recommendations on student grouping methods in PE classes made in the third point of this section.

Recommendations for Future Research

This research addressed problems inherent in traditional approaches to physical fitness assessment. However, this research has its own limitations and future research with emphasis on the following aspects will extend the contributions of this research to physical fitness assessment.

The first, since this study took the "data fit the model" position, the RMPFS integrates three components only, the indicators for other two components (BMI for body composition and Sit-and-Reach for flexibility) were excluded from the scale due to failure to fulfill the Rasch requirements or for other practical considerations. However, these two components can't be simply regarded as not related to the overall fitness at all. They were not integrated into the overall fitness measure because they have no appropriate indicators that can be calibrated into the RMPFS with sufficient fit to the Rasch model. Future research could explore this point further through two angles. One is to stick to the position of "data fit the model" and to make efforts to identify appropriate indicators for the components of body composition which can be successfully calibrated into the Rasch measurement scale. And those attempts could be made in a smaller, more closely controlled fitness testing context. The other is to explore the multi-dimensional and continuous Rasch models so as to identify a model to fit the data. However, this "the model fit data" approach probably loses the strong measurement benefits which could be

derived from Rasch model.

The second, the RMPFS developed in this research relies exclusively on the data from the partner school. That brings a limitation to the study which prevents the immediate generalization of the physical fitness scale developed in this research to other Hong Kong primary schools. Future research could utilize the technique used in this research and extend to a larger sample which might be representative for the whole Hong Kong primary school-aged student population so that a Rasch measurement physical fitness scale could be developed for use with the entire Hong Kong primary school-aged student body. On the other hand, future research could use the same technique to develop school-based databases for other similar samples and derive the same benefits for other schools. This research also has potential to be extended outside Hong Kong, such as nearby in mainland China. The scale developed and techniques used in this research will be very helpful to investigations on physical fitness measurement for mainland China primary schools. In addition to replicating the practical benefits, there are also theoretical benefits that could be derived from applying the same technique to other samples. The invariance of indicator measures (sample-distribution free) is one of the Rasch model's requirements. That means indicator measures should be independent of the particular sample used for indicator calibration. However, this research itself did not provide direct evidence of this feature since it did not apply the RMPFS to other samples. Future investigations of the invariance of indicator measures using already existing data from other Hong Kong schools or collected in mainland China schools could provide more evidence of validation to the RMPFS.

The third, the physical fitness data of the partner school did not function as well as might have been hoped in the Rasch analyses. Individual person estimates obtained by the RMPFS are associated with quite large measurement errors, although the estimates at the group level are quite precise. It limits the use of the overall fitness measure in tracking individuals' physical fitness development. Future research could attempt to find solutions to reduce the measurement errors of person estimates such as developing and calibrating

more appropriate physical fitness indicators into the Rasch scale. More indicators would provide more information to person estimation so that the overall fitness measure at the individual level could be more precise. There are two concerns need to be addressed with regard to calibrating more indicators into the RMPFS. On the one hand, what kind of indicators should be added into the scale? Body composition and flexibility have been shown to be inappropriate for inclusion into the overall physical fitness measure, but other indicators for the three components (i.e., cardiorespiratory fitness, muscular endurance, and muscular strength) could be considered in future studies. On the other hand, how many additional indicators are needed to be calibrated to the scale in order to obtain individual person estimates with sufficient measurement precision? According to Bond and Fox (2007), a difference greater than 0.5 logits might be regarded having both statistical and practical meaning. Thus a person estimate with a S.E. less than 0.5 logits should be acceptable. The following formula describes the mathematic relationship between the S.E. of person estimates and the number of indicators (M. Linacre, personal communication, March 27, 2009).

$$\text{S.E.} = k \,/\, \text{sqrt}\,(\text{L}) \qquad (6)$$

Where k is a constant depending on the indicator format, and L is the number of indicators in the scale. At present, the mean of model S.E. of person estimates obtained from the 3-indicator RMPFS – 6-minute Run and 9-minute Run act as a single indicator in fact because no student has scores on both of them – is 1.12 logits. According to the equation (5), around 15 indicators are needed in order to obtain a S.E. of 0.5 logits. That means calibrating 12 more indicators into the RMPFS could generate individual person estimates with sufficient precision. However, a dilemma future studies will face is that adding similar indicators for the same fitness component to the scale will probably add to the amount of local dependence at the same time. Although it is important and meaningful to build a scale which can generate individual person estimates with smaller measurement errors, there is a tension inherent in achieving this goal. More empirical studies are needed to explore this topic and find a balance between getting more precise person

estimates without adding to local dependence among indicators in the future.

This is not to deny that psychometric approaches to data analysis, other than the Rasch model, might be appropriate for producing a more comprehensive description of the variability in this large longitudinal data set of children's physical fitness indicators. At the conclusion of this research, it remains an open question as to whether other quantitative approaches might produce results that have better 'fit of the model to the data'. The completion of such a project could provide an interesting complement to the results of the 'data fit the model' Rasch measurement approach explicitly adopted at the outset of this investigation.

Summary

As an integral part of physical education curriculum, fitness assessment itself is not the goal of physical education, but a formative evaluation to further educational goals (Silverman, Keating, & Phillips, 2008). It is essential to provide precise and reliable fitness assessment and meaningful interpretation of assessment results to children, parents, and teachers so that appropriate follow-up actions could be undertaken to promote children's health.

This research explored a new approach to physical fitness measurement which has rarely been previously discussed in current literature and provided empirical evidence to the benefits of the new approach. The development of the RMPFS extended Rasch application in physical education field. The successful implementation of the RMPFS in depicting students' overall physical fitness levels and developmental trends built up a good model of practice for future studies. The major findings and implications for practice should make contributions to knowledge generation, teaching practice, and policy-related issues in the field of physical fitness measurement.

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APPENDIX A

DATA USE AGREEMENT

ADMINISTRATIVE DOCUMENTATION HAS BEEN REMOVED