THE RELATIONSHIP BETWEEN FUNDAMENTAL MOVEMENT SKILLS AND THE HEALTH AND FITNESS OF CANADIAN CHILDREN

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Human Kinetics)

THE UNIVERSITY OF BRITISH COLUMBIA
(Vancouver)

August 2008

ABSTRACT

The health and fitness status of Canadian children has been declining over the past several decades. Children's health and fitness impacts future health status as many health and fitness indicators track from youth into adulthood and are associated with serious illnesses such as cardiovascular disease (CVD). One potential determining factor of health and fitness may be the level of proficiency exhibited in performing fundamental movement skills (FMS). Failure to master FMS in childhood may decrease the physical activity options available in adulthood because FMS provide a foundation for all forms of physical activity pursuits necessary for health and fitness benefits. To-date, the relationship between health, fitness and proficiency of FMS has not been examined in Canadian children. Therefore, the purpose of the present investigation was to examine the current state of movement skill proficiency in relation to health and fitness in Canadian elementary-aged children. Boys (n = 71) and girls (n = 91 girls) ages 8 to 11 years were recruited from schools participating in the evaluation component of the Action Schools! BC program. Measures of fundamental movement skill proficiency (i.e., running, horizontal jumping, vertical jumping, jumping from a height, hopping, and skipping) and indicators of health and fitness (i.e., blood pressure, arterial compliance, weight status, musculoskeletal and cardiovascular fitness) were assessed. Results indicated low levels of FMS proficiency for both boys and girls. Analysis also revealed significant relationships between FMS and indicators of health and fitness. Correlation analyses found running and hopping to be significantly ($p < .01$) related to musculoskeletal and cardiorespiratory fitness tests. Significant ($p < .01$) relationships between vertical jumping and weight status, musculoskeletal and cardiorespiratory fitness were also found by the correlation analyses. Regression analyses were performed to determine the independent relationship between health and fitness indicators. Vertical jump was significantly ($p < .01$) related to blood pressure (BP) independent of confounding health and fitness variables. Finding significant relationships between FMS proficiencies and health and fitness indicators coupled with the low proficiencies demonstrated by our sample of children suggest the need for a greater emphasis on the development of FMS.

TABLE OF CONTENTS

3.2.2 Day 2: Blood Pressure and Arterial Compliance Assessments 43

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AS! BC	Action Schools! BC
BMI	body mass index
BP	blood pressure
CVD	cardiovascular disease
FMS	fundamental movement skills
HDL	high density lipoprotein
LDL	low density lipoprotein
PE	physical education
PLO	prescribed learning outcome
SD	standard deviation
SES	socioeconomic status
TGMD	Test of Gross Motor Development
VIF	variance inflation factor
VO_{2max}	maximal oxygen consumption
WC	waist circumference
WHO	World Health Organization

CHAPTER I: INTRODUCTION

The health and fitness status of Canadian children has been declining over the past several decades [1-4]. For example, the cardiorespiratory fitness levels of children are decreasing throughout developed nations [2, 4]. High cardiorespiratory fitness has the ability to attenuate numerous factors associated with health risk such as poor body composition, high blood pressure (BP) and surrogate measures of endothelial dysfunction [5-7]. As such, the ability to influence cardiorespiratory fitness and other health variables in a positive manner is of paramount importance. Further, children's health and fitness impacts future health status as many health and fitness indicators track from youth into adulthood and are associated with serious consequences such as cardiovascular disease (CVD), early morbidity and mortality [8-10]. This emphasizes the necessity for preventative action to be taken early in life. While several factors, such as heredity and lifestyle, are known to play a role in health status, proficiency in fundamental movement skills (FMS) may also play a significant role [11]. This is a potentially important factor because FMS are the foundational skills required for all forms of physical activities (i.e., the skills required for leisure time pursuits or more advanced sport and game activities). Therefore, it has been suggested that failure to master FMS in childhood decreases the number of activity options available to the individual in adolescence and in adulthood because children are unable to develop the specialized movement skills essential for lifelong activity [12, 13]. This is of concern given the evidence clearly indicating the positive effect of physical activity on health measures in adults and children [14, 15]. Therefore proficiency in FMS may have an influence on health and fitness in this manner. Thus far, the relationship between level of FMS proficiency and indicators of health and fitness has not been comprehensively examined in school-aged children. Previous investigations have primarily focused on adolescents [11, 16-18] and little is known about the level of FMS proficiency of children in general, and in Canada specifically. As such, the purpose of the present investigation was to examine the current state of FMS proficiency in Canadian elementary-aged children in relation to indicators of health and fitness. Previous investigations have found gender differences in FMS proficiency levels [11, 16, 19]. Therefore, a secondary purpose of this investigation was to determine the effect of gender on movement skill proficiency.

The present experiment was conducted in collaboration with the Action Schools! BC (AS! BC) program. This program is a best practices physical activity model designed to assist elementary schools in creating individualized school action plans to promote healthy living. The vision of AS! BC is to integrate physical activity into elementary schools to achieve long-term, measurable and sustainable health benefits. This program was originally piloted in 10 lower mainland elementary schools for 17 months between February 2003 and June 2004. Results from this initial pilot revealed that students enrolled in the AS! BC program exhibited improvements in cardiovascular health and enhanced bone health in comparison to students in non-participating schools. In the fall of 2005, AS! BC was expanded to schools throughout the province. Over the next three years, an extensive study was conducted to assess whether the AS! BC program was an effective means to positively change school environments and health-related behaviours in children when delivered across geographically diverse regions and cultures. The present investigation was conducted as part of the first stage of measurements in the evaluation component of the AS! BC program. Specifically, the purpose of the investigation was to examine the current state of FMS proficiency in elementary-aged children in relation to indicators of health and fitness. Measurements were collected from 162 students enrolled in three schools participating in the AS! BC program.

The present investigation examined six fundamental movement skills: running, skipping, hopping, vertical jumping, horizontal jumping and jumping from a height. To examine the state of proficiency in these skills we used an assessment tool specifically designed for this investigation. Fundamental locomotor skill items were chosen because locomotor skills require moving the body through space and more closely resemble movements employed during aerobic activities which are closely linked to health benefits [20]. Manipulative skills are also involved in many popular aerobic activities (e.g., tennis, basketball, soccer) as are non-locomotor skills (e.g., balance and stability) which are an integral part of locomotor activities. However, the amount of time available for data collection was limited and not all FMS were able to be examined. We also examined health and fitness indicators including: body mass index (BMI), waist circumference (WC), BP, arterial compliance, musculoskeletal fitness (grip strength, push-ups, curl-ups, and sit-and-reach) and cardiorespiratory fitness (maximal 20 m shuttle run). Proficiency in FMS items were assessed in relation to indicators of health, fitness and gender. We hypothesized that:

1. The degree of FMS proficiency would be significantly correlated to each of the health and fitness indicators (positively related to arterial compliance and physical fitness and negatively correlated to weight status and blood pressure)
2. There would be a significant gender effect with females demonstrating greater proficiency in skipping and hopping and males demonstrating greater skill in the remaining FMS items (running, vertical jump, horizontal jump, jump from a height)
3. The mean scores achieved by elementary-aged children would be in the lower two-thirds of our movement skill assessment tool.

CHAPTER II: LITERATURE REVIEW

This chapter reviews literature relevant to the present investigation. Movement skills will be discussed first followed by health and fitness indicators and the general limitations of previous literature. There are two sections pertaining to movement skills. The first provides an introduction to movement skills. The second section pays specific attention to FMS and their relation to health implications. In addition, the current status of FMS proficiency and the British Columbian physical education curriculum is examined. After a brief introduction to health and fitness indicators, three sections detail the specific health and fitness factors examined in this investigation (i.e., blood pressure and arterial compliance, weight status, and fitness). Within each health and fitness section, subsections discussing current status among youth, how each factor tracks from childhood to adulthood, common measurement techniques, as well as their relationship to FMS will be presented.

2.1 Movement Skills

Understanding the reasons for why proficiency in FMS should be examined in relation to children's health first requires an understanding of movement skills themselves. What are movement skills? What factors promote or limit their development? What role do movement skills play throughout the lifespan? The following section will address these questions and will also provide a framework for understanding how movement skills impact physical activity pursuits and the implications for the maintenance of health.

2.1.1 Movement Skills: What Are They?

Motor development is a continuous and progressive process from conception to death where changes in motor behaviour occur through the interactions of the individuals' biology, the task requirements and the surrounding environment [21, 22]. Therefore, changes in the performance of movements are a result of maturational processes and learning.

Movements performed in an organized manner are termed movement patterns. When combined in a meaningful way, movement patterns are able to accomplish specific tasks through which a person is then able to effectively interact with and in their environment. Such tasks are termed motor skills and involve voluntary physical body movements in order to achieve a specific goal [23].

Motor skills are often classified according to one-dimensional models, which discuss skills according to one aspect of the movement. There are three popular one-dimensional taxonomies which categorize skills according to 1) the size of musculature required to perform the skill, 2) temporal aspects of the movement, and 3) the environmental context in which the skill is being performed [23, 24]. Aside from providing a convenient way of identifying common characteristics, classifying skills permits us to establish a basis for studying how we learn and execute movement skills. In addition, they allow for the development of effective instructional strategies and guidelines for learning movement skills.

The categories of 'gross' and 'fine' divide motor skills according to the size of musculature used to perform the task. Gross motor skills use large muscles to perform movement tasks such as an infant lifting their head, crawling, walking and running while fine motor skills use small muscles. Examples of fine motor tasks include: picking up objects, writing, and cutting [24].

Temporal aspects of a movement refer to continuous, discrete and serial motor skills. Continuous and discrete skills are differentiated by the way in which a skill begins and ends. Continuous motor skills are repetitive and have an arbitrary beginning and ending (e.g., walking, running and skipping). Discrete movement skills have identifiable start and finish points (e.g., vertical jump, kicking and throwing). Serial motor skills are discrete skills which are repeated in succession (e.g., hopping and basketball dribbling) [24].

The environmental context in which the skill is performed categorizes skills as 'open' or 'closed'. A closed motor skill is one in which the environment is stable with other people and objects remaining fixed (e.g., horizontal long jump, running, and shooting a free throw in basketball). Comparatively, in an open motor skill the performer's environment is dynamic and adaptations are necessary to the performance of the skill. For example, during a game of basketball, the actions of players on both teams are continually changing forcing each player to make adjustments while in the midst of performing various movements (e.g., running and throwing) [23].

From a developmental perspective, motor skills may also be discussed with respect to the intended function of the movement skill according to three categories: stability (or nonlocomotion), locomotion, and manipulation. Stability skills are those which focus on maintaining balance such as standing. Manipulative skills involve the transfer or absorption of force to an object (e.g., throwing and catching); whereas locomotor skills are those that move the body through space (e.g., running and jumping).

2.1.2 Movement Skills: What Factors Promote or Limit Development?

A central premise of this investigation is that the development of movement skill proficiency plays a pivotal role for an active and healthy lifestyle. Thus, it is important to understand the factors which limit skill development and may subsequently hinder physical activity pursuits. This section will discuss the concept of developmental tasks, sensitive periods, constraints, and readiness as they relate to the development and limitation of movement skills.

According to the developmental task theory, there are developmental tasks which present themselves at a certain point in an individual's life. Particular tasks must be achieved by a certain point in time in order for the individual to accomplish subsequent tasks relevant to their successful functioning within the environment. Tasks which are not achieved at the proper time will be underdeveloped and failure to learn these tasks will result in the incomplete achievement of future tasks [12]. This relates to the notion of "sensitive" or "critical periods" of development, which are points in time when an individual is especially receptive to learning new tasks. These points in time are limited in duration and the learning of a particular task must take place during these sensitive periods if development and learning is to progress unhindered.

Developmental tasks arise from a combination of factors, biological maturation, cultural/societal expectations and personal values of the individual. When applied to movement tasks, the elementary-aged child encounters tasks required for participation in play and game activities. Biologically, this is a time of general growth for a child's muscles and bones. There is also a complementary neural maturation that occurs during this time to allow for more efficient muscular coordination. Culturally, there are different expectations placed on boys and girls when it comes to the learning and execution of movement skills with boys often expected to display a higher degree of competency then girls in most skills. Socially, the individual is rewarded by their peer group for successes and punished for failures in the performance of movement tasks. Movement tasks consequently become a product of an individual need and a societal demand which is resultant from a learner interacting with their environment. According to Havighurst [12], experiencing success in these movement tasks will lead to feelings of happiness and promote success in the attempt of more advanced movement tasks. In contrast, failure in movement tasks will elicit unhappy feelings and cause difficulties in performing successive movement tasks.

According to Newell's model of constraints [26] movement is influenced by the constraints of the individual performing the task, the environment in which the task is performed and the constraints of the task itself. Constraints of the individual would include the biological characteristics of the person. Structural constraints refer to constraints related to the structure of the body such as an individual's body weight, height, and shape. Functional constraints refer to constraints related to a behavioural function and are influenced by the neurological and musculoskeletal development of the individual. Each of these constraints plays a role in the execution of movement skills. As a child grows their body segments increase in size and their body proportions are altered. This in turn alters the biomechanics of the individual which changes the nature of their movements. For example, the emergence of adult-like gait patterns for walking in children occur in conjunction with the establishment of adult-like proportions in body segments. Endomorpic somatotypes[1] along with increases in height and body weight are often associated with poor performances in running and jumping activities. Running and jumping are activities which require an individual to propel his or her body through space and because excess adipose tissue (as in an individual with an endomorphic body type) contributes to increased body weight without parallel increases in strength, running and jumping performance is negatively affected. In contrast, height and body weight is often associated with greater muscular strength whereby the heavier child generally performs better in tasks which require an object (rather than his or her body) to be propelled through space. Gender differences in task performance may be related

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[1] Somatotyping refers to the characterization of body type based on the contribution of three components: endomorphy, ectomorphy and mesomorphy. Endomorphy is characterized by the predominance of the stomach and by a general roundness of body contours. Ectomorphy is characterized by a tall and thin body shape with minimal muscular development. Mesomorphy is characterized by the predominance of well developed muscle tissue.

to the differences between boys and girls in body size and relative muscle mass with boys tending to be bigger with greater contributions of muscle mass per unit body weight. Gender differences in motor tasks requiring balance may be in part the result of differences in center of gravity between males and females with females possessing a lower center of gravity than males. A lower center of gravity is beneficial for upright balance activities (e.g., standing on one foot). Subsequently females generally demonstrate superior performance on balance activities (e.g., hopping and balance-beam walking). All of these factors have the potential to act as individual constraints on the performance of a movement task [26, 27].

Environmental constraints are factors which are external to the individual and refer to the environment in which the task is to be performed. Environmental constraints are sometimes difficult to distinguish from task constraints because they depend on the nature of the task. While task constraints refer to the goal of the activity and the particular restrictions placed on the performance of the task, environmental constraints are generally those which are not adaptations of the task. This might include temperature, amount of light, or type of surface over which an action is being performed. For example, the movements performed by an individual attempting to walk across an ice surface are different from the movements performed by an individual walking across a carpeted surface [26].

Task constraints include the goal of the task, the rules surrounding the appropriate movement response and the implements used in the performance of the task. Tasks which have outcome goals, such as making a basket in basketball, often do not specify the specific movements that must be performed to achieve the goal (i.e., the basketball may be thrown towards the basketball hoop using a variety of different throwing techniques). Other tasks specify the type of movement that must be performed to accomplish the task. For example, movements in dance, diving, or gymnastics must often be performed in a very specific way. The task constraints imposed by the implements or objects involved in performing the task may include the size, weight and shape of the object being used. For example, if a person needs to move a box, the movements he or she performs will depend on how big the box is. Is the box small and light enough to carry or does it require pushing or pulling movements? Within individual and environmental constraints, the limitations of the task are ultimately responsible for the movements that are performed. Change the nature of the task and the movements required to perform the task inevitably change as well [26].

Newell's [26] model of constraints also pertains to the concept of readiness in motor development which has wide implications for the understanding of children's motor learning. Namely, in order for a child to learn a wide variety of movement skills (s)he must be exposed to an enriched environment with a variety of developmentally appropriate activities. Adults responsible for the child's immediate environment have the potential to provide a rich variety of appropriate movement experiences geared towards this end. The continual provision of new movement experiences facilitates the ongoing development of movement skills. Thus, each preceding movement experience helps ensure the child's state of readiness to encounter the next. Likewise, failure to provide the movement experiences necessary for skill development will inhibit the child's state of readiness for any subsequent learning experiences [28]. In reference to the acquisition of motor skills, the term readiness encompasses the knowledge, skills (cognitive, emotional and physical) and experience that an individual brings with them to the learning of a new movement pattern. Readiness is the convergence of these factors placing the individual in a situation where they are able, or 'ready', to learn new skills [28]. It was once thought that readiness was solely a function of maturational age[2]. It is now widely recognized throughout the motor behaviour literature, that children's readiness to learn is due in large to the environment in which a child is placed. This has substantial implications for a child's learning. Given the proper environment, a child's motor learning is able to advance towards increasingly greater degrees of movement competence. However, should a child lack access to an enriched and physically active environment, his or her ability to acquire a wide repertoire of motor skills may be hindered. Hence, the investigation of FMS is warranted as they may have consequences for children's physical activity pursuits and in turn, children's health and fitness. As such, the implications for the physical education setting are clear.

2.1.3 Movement Skills: What Role Do They Play Throughout the Lifespan?

[2] Maturation is defined as the progression towards a mature state. In this case, maturational age refers to the level of maturity attained by an individual's biological systems. In contrast an individual's chronological age refers simply to calendar time. Therefore, while two individuals may be the same chronological age, they could be very different in terms of maturational age.

Often overshadowed by the necessity of our society to participate in physical activities for the pursuit of health-related fitness (i.e., fitness that is related to some aspect of health), the development of movement skills is continually overlooked. Participation in physical activities is reliant upon one's ability to perform movement skills. The skills which comprise sport and game activities are termed specialized skills and these skills are based on the combination and variation of FMS. Thus, FMS proficiency is critical to the development of the specialized skills required for participation in physical activity endeavours throughout the lifespan. Moreover, the fundamental skills which comprise the specialized skills used in lifespan sport and game activities influence the development and maintenance of health-related fitness.

Skill acquisition may be examined as a sequential progression of motor capabilities across the lifespan. According to Gallahue's phases of motor development, individuals progress from reflexive movements, which are involuntary controlled movements that serve the foundation for all movement, through three voluntary phases: the rudimentary, fundamental, and specialized movement phases, respectively. When discussing each phase, it is important to keep in mind that the causal factor in the appearance (or disappearance) of a motor behaviour is not age but rather, an interaction between the individual, their environment and the task. While this interaction includes characteristics of the individual such as the physical and cognitive maturation that is associated with increasing age, age itself is not the cause of the motor behaviours exhibited [22].

Within the first two years of life, a child will develop the ability to exert control over his or her body by producing voluntary movements referred to as rudimentary movement skills. Children's development in this stage is often described according to developmental milestones. The rudimentary movement phase includes two stages, the reflex inhibition stage and the precontrol stage. Soon after birth, an infant begins transitioning away from dependence on reflexes and towards voluntary muscle control. This transition denotes the reflex inhibition stage. While movements become voluntary, they are primarily uncontrolled. Greater degrees of control can be observed at the precontrol stage of development. The child can now manipulate objects by reaching, grasping and releasing, stabilize his or her body to sit and stand and perform locomotor skills such as crawling. Rudimentary movement skills are essential precursors to the attainment of FMS [24].

The fundamental movement phase of a child's development typically occurs from two to six years of age. Examples of FMS include: standing on one foot, running, jumping, throwing, catching, skipping and striking. The changes that occur as FMS develop (referred to as a developmental sequence) are generally described as progressing through three stages: initial, elementary and mature. Each phase is characterized by particular movement characteristics, which fall along a continuum of increasing proficiency rather than belonging to discrete periods in development. The initial stage is characterized by a child's first attempts at the performance of a FMS and there are often perturbations in the execution of a controlled and coordinated movement pattern. Movement patterns demonstrated in the elementary stage are better coordinated and controlled than in the initial stage. However, many movements present as either exaggerated or constrained. Mature movement patterns are well coordinated, controlled and efficient in movement. Children are physically and mentally capable of performing most mature FMS patterns by five or six years of age [30].

Fundamental movement skills do not appear simply as a natural extension of the child's overall maturation. They require appropriate environmental supports such as effective instruction and opportunities for practice. Therefore, while the transition through these stages typically occurs during childhood, there is nothing to guarantee that an individual will ever reach the mature stage of any FMS during their lifespan. While physical growth (increase in body size) and maturation (development of biological systems) play a role in motor development, the emergence of a mature movement pattern is also inhibited if the individual is not provided opportunities to learn how to perform these skills with proficiency. This has important implications for the development of lifelong physical activity skills. Children who do not master FMS are inhibited in the development of more complex specialized movement skills such as those used in a variety of common sport and game activities [12].

The acquisition of specialized movement skills provides the individual with options to participate in recreational physical activities across the lifespan. Specialized movement skills are compilations of FMS. In this phase, FMS are assembled in an infinite number of combinations and are performed in contexts which are increasingly demanding. This stage includes three phases referred to as the transitional, application and lifelong utilization stages. During the transitional stage, FMS are further refined and combined to form specific movement patterns. These patterns are then applied to a variety of different contexts including various games and sporting activities. Participation in a large variety of general activities should be prevalent during this time to ensure the child develops an ample repertoire of movement patterns. From this point the child, who is now in late childhood (approximately 9 to 12 years of age) to adolescence (approximately 12 to 20 years of age) may begin to make decisions as to the types of activities he or she wishes to participate in and focus his or her attention on these specific activities. This is referred to as the application stage. In this stage, an individual's decision to participate in a given activity is reflective of the way in which the individual perceives the activity in relation to his or her ability to experience success and enjoyment through participation. Culminating the process of motor development is the lifelong utilization stage which persists from adolescence through adulthood. Physical activity participation at this stage takes into consideration a plethora of factors including those external to the individual (e.g., time and money) and also internal factors namely, an individual's acquired movement skill repertoire and experiences. The concept of 'lifelong utilization' is limited by the variety and extent of movement competencies acquired at the earliest phases of skill acquisition [31]. This demonstrates the importance of investigating the current state of fundamental movement proficiency in Canadian elementary-aged children.

2.2 Fundamental Movement Skills

Childhood typically denotes a time when children are learning the basic or fundamental skills of movement which will ultimately set the stage for the pursuit of lifelong physical activities. The following subsections are dedicated to describing: the developmental sequences of select FMS (with specific attention to fundamental locomotor skills), the health implications of movement skill proficiency, and the current status of movement skill proficiency in Canadian children.

2.2.1 Fundamental Movement Skills: Locomotor Skills

Due to their very nature, physical activities involve locomotor skills. While many physical activities also have manipulative and stability skills as central components for participation, it is most appropriate to focus the discussion on fundamental locomotor skills. Locomotor skills are defined as those skills used to move the body through space and are integral to participation in many popular sports, games and activities. As previously mentioned, the developmental sequences for fundamental skills are often categorized into progressive phase-like stages. The initial, elementary and mature stages within this phase of development contain specific movement characteristics that typify each progression. However, skill development occurs across a continuum where at any given time, an individual may exhibit movement characteristics from two or more stages. In addition, skill level is not always discussed according to initial, elementary and mature stages. Researchers also describe development according to a component approach where the movement characteristics are separated into arm, leg and sometimes trunk components with three or more stages describing each component. In addition, a total body approach also exists where body movements are described as a whole with multiple stages of increasing proficiency. Outlined here are some of the key movement characteristics seen throughout the developmental sequences for six FMS: running, jumping from a height, vertical jumping, horizontal jumping, hopping and skipping. The descriptions for each of these skills are not limited to any particular method of classification (i.e., they are not discussed solely according to either a whole body, body segment or initial, elementary and mature approach). However, as most FMS proficiency comparisons are made by comparing children who have and have not achieved mature movement patterns, reference to the mature form of each skill will be made along with some references to initial and elementary characteristics. In addition, the aforementioned stages and associated figures describe developmental changes that are qualitative in nature. Qualitative changes are observable changes in the quality of skill performance. They describe the movement characteristics of *how* a skill is performed. Quantitative changes (changes which are directly measurable such as running speed or jumping height) also take place as children grow and develop. The skills assessed in this investigation were analyzed from a qualitative perspective. Therefore, while general quantitative changes are presented, the following descriptions focus on qualitative aspects of skill development. The age at which children are capable[3] of performing these skills varies widely from skill to skill and from child to child. However, the majority of children are capable of performing mature patterns of most

[3] A distinction must be made between being capable of performing at a particular skill level and the actual performance at that skill level. Children are capable of performing mature movement patterns when they are physically developed enough to perform the demands of the movement task. However, this does not mean that they will naturally exhibit these movement characteristics because as previously mentioned motor skill development is not solely the function of maturation.

FMS by their preschool and early elementary school years [30, 32]. In addition, there is evidence to support gender differences in the performance of FMS. Across FMS, proficiencies are greater in boys than girls with the exception of hopping and skipping. Girls tend to exhibit mature patterns earlier than boys in these two skills while boys exhibit mature patterns of running and other jumping skills earlier than girls [19, 30, 33].

2.2.2 Fundamental Movement Skills: Running

Running is an exaggeration of walking (walking is also a FMS) yet is not dependent on the establishment of a mature walking pattern and is differentiated by the appearance of a flight phase. A flight phase exists when there is a brief period where both feet are unsupported by the ground. The first appearance of a flight phase usually occurs in the second year of life and by approximately five years of age children are capable of performing a mature running pattern [30, 32]. To begin with, children will run flat-footed and with little flexion at the knee. In addition, their flight phase is minimal. The child will gradually progress towards a heel-toe landing or, during sprinting the ball of the foot may contact the ground. Flexion at the knee, hip and ankle will increase gradually for greater force absorption and time spent in flight will lengthen. Concurrently, a child's arms will progress from contributing little (other than assistance with balance) to becoming active in the movement. Initially, arms will typically be held abducted to increase balance but are otherwise stiff and do not participate. Gradually, the arms will start to move according to body rotation. This will cause the arms to noticeably cross the body midline as they swing forwards and outwards from the body during the back swing. At this point, the elbows will start to bend slightly. Eventually, the arms will contribute to the running movement by driving along the sagittal plane with elbows bent to approximately 90°. In the mature running pattern, arm and leg movement will be coordinated in opposition [22]. As both boys and girls increase in chronological age from 3 to 17 years of age, their running times generally decrease indicating an improvement in their running performance [30]. Changes in joint angles with increasing age have also been found [34]. Fortney et al. [34] examined joint angles in children who were two-, four- and six-years of age. During contact[4] the angle of the

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[4] Contact refers to the point at which the leading foot initially contacts the ground after having been in flight.

swing leg's[5] knee was flexed more in the four- and six-year old children than in the group of two-year old children. During the point at which the front leg is making contact with the ground, the knee joint of the other leg (i.e., the leg which at this point can be referred to as the swing leg) is flexed to a greater degree in the two older age groups. At take-off[6], the knee joint of the support leg[7] displayed greater degrees of extension while the knee joint of the swing leg displayed greater degrees of flexion with increasing age. While Fortney et al. [34] did not find gender differences in running speeds they did find gender differences in various joint angles with boys demonstrating a greater range of motion in the hip of their swing leg during contact, take-off and mid-support[8].

2.2.3 Fundamental Movement Skills: Jumping

Jumping skills involve similar movement characteristics. The literature generally describes jumping by dividing the skill into preparatory, takeoff, flight, and landing phases individualized according to the particular type of jump being discussed. Jumping skills vary according to the direction of jump (e.g., downwards, upwards, or forwards) and by the number of feet used to perform the jump [35].

Jumping from a height (also referred to as a drop or depth jump) involves jumping downwards from an elevated surface. Initially, the child has difficulty taking off with two feet and there is no visible flight phase. The leading foot will land before the trailing foot leaves the supporting surface. The child attempts to use their arms for balance but does so in an exaggerated or ineffective way. These movements will progress to a two foot take-off and landing with the appearance of a flight phase in between. Hip, knee and ankle flexion will appropriately absorb impact upon landing. Arm movements at the mature stage will function to effectively assist with balance [22].

In the vertical jump, the child projects his or her body upwards reaching overhead with one hand. Mature forms of the vertical jump have been demonstrated in children as young as two years of age although most children have the capability to reach the mature stage of vertical jump at five years of age [36]. During the initial stage of performance, children exhibit limited preparatory flexion of the hips, knees, and ankles

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[5] Swing leg refers to the leg off of the ground during a running stride.
[6] Take-off refers to the point at which the support leg leaves the ground (at which time it will become the swing leg).
[7] Support leg refers to the leg which is in contact with the ground.
[8] Mid-support refers to the point at which the support leg is perpendicular with the ground.

(known as a preparatory crouch). As in jumping from a height, children have difficulty taking-off with both feet simultaneously. During flight, there is poor upward extension of the head and body. In the initial stage of development, the arms are not involved in the movement. During the elementary stage children will intentionally reach upwards with one arm however, their non-reaching arm will unintentionally reach upwards as well, therein limiting the amount of tilt by the shoulder girdle. By the mature stage, children will display a preparatory crouch before initiating a powerful upward extension at the hips, knees and ankles. Similar to a preparatory crouch, a countermovement is when there is a quick bend at the hips, knees and ankles before the upward thrust of the vertical jump. Countermovements and a preparatory crouch with knees bent to 115° have been shown to increase vertical jump height. In the mature stage, the shoulder girdle tilts as one arm reaches upwards while the non-reaching arm reaches downwards [37, 38]. The main contributor to vertical jump height is lower body strength and the ability to utilize this strength to produce a greater degree of muscular force. Increased muscular force production could be the result of intrinsic factors such as the proportion of fast-twitch muscle fibres or amount and type of training [39]. However, the performance of an arm swing has been shown to positively enhance vertical jump height by approximately 10% [37, 39]. The height of jump achieved increases with age up to 19 years in boys and 16 years in girls [30].

Mature movement patterns of the horizontal jump appear much later than in the vertical jump. The horizontal jump requires whole body involvement and not until approximately 9 to 10 years do the majority of children display a mature horizontal jump pattern [32]. During this skill, children propel their body forwards taking-off and landing on two feet. As in the initial stage of jumping from a height, children have difficulty taking-off and landing with both feet simultaneously. In addition, during the early stages of development children are inclined to jump upwards more than forwards. The child's arms initially serve to maintain balance throughout the performance of the skill rather than contribute to the forward driving motion as they will at more mature stages of skill development. Eventually, the child will swing his or her arms backwards in preparation and then forwards and up during flight before lowering them to a position in front of his or her body upon landing. The use of an arm swing has been shown to increase horizontal jump distance by approximately 21% [40]. As skill increases, the degree to which the trunk leans forward during the flight phase will also increase. Increases in forward lean on take-off demonstrate improved jumping distances [41]. The positions in which the thighs are held during the flight phase will also change as the child's movement pattern progresses towards a more mature pattern. Initially, the thighs are primarily vertical during the flight phase. However, by the mature stage the child carries his or her thighs parallel to the ground during flight. The degree of knee joint flexion at take-off and the range of movement in the knee joint throughout the flight phase is significantly greater in adults than children [42]. In addition, early on in the development of this skill, the center of gravity will largely remain over the child's feet during flight and on landing. By the mature stage of performance, the child's center of gravity will be well behind his or her feet upon landing requiring the forward momentum of the trunk to bring the center of gravity forward and over the base of support after initial foot contact has been made with the ground [22]. Boys increase their horizontal jump distance with age up to 18 years while girls increase their jump distance until 15 years of age [30].

A mature hopping pattern can be demonstrated in children by approximately seven years of age [30, 32]. This skill requires the performer to take-off and land repeatedly on one foot and therefore requires a greater degree of strength and balance than jumps performed on two feet. The early performer has difficulty projecting his or her supporting foot from the ground. Instead learners pull their foot up off of the ground by quickly flexing at their hip and knee, rather than using the extension of their hip, knee and ankle to propel their body off the ground. Gradually, this will convert to the smooth transition from preparatory leg flexion to extension upon take-off and absorption of force on landing. Initially, a child may not be able to perform more than a couple jumps in succession. The number of jumps the child is able to perform will increase with increasing skill proficiency. The non-supporting leg (referred to as the swing leg), is held high with the thigh approaching parallel with the ground. During the mature stage, the swing leg is held closer to vertical although it will react by lifting upwards with the force of each jump. The child's arms will at first be held abducted for balance and will move in reaction to a loss of balance. This will progress to the active involvement of the arms contributing to the jump [43]. With increasing age there are significant effects seen in the ratio of time spent in flight vs. time spent in contact with the ground. Flight times became proportionately longer than contact time with increasing age. This coincides with greater vertical force production in older children and adults when compared to younger children [44]. In addition, with increasing developmental level, stiffness of the hopping leg decreases [45].

2.2.4 Fundamental Movement Skills: Skipping

Skipping combines two other fundamental skills, the step and the hop, in a rhythmical and alternating pattern. Skipping is described as a repeated step-hop movement with the supporting leg alternating on each successive step and hop movement. The leg action component of the skip progresses from a one-footed skip to a two-footed skip. In the one-footed skip, one foot steps but does not hop whereas the other foot completes a step and hop. In the two-footed skip, both feet complete a step and hop. However, landing on the hop is with the whole foot. In the most mature pattern of the two-footed skip, the child's heel will not contact the ground on the hop. Meanwhile, the arm component of the skip progresses from the arms moving upwards together during the vertical component of the hop to the arms working in opposition with the legs and each other. The rhythm displayed by children at the initial stage is uneven and awkward with quick tempo while the rhythm at the mature stage is uniform and smooth with moderate tempo. Children at six or seven years of age are capable of performing a mature skipping pattern [30, 32].

2.2.5 Fundamental Movement Skills: Health Implications

Mature fundamental movement patterns required for the later development of specialized skills used in lifelong physical activity pursuits has been discussed extensively in the previous sections. This suggests a relationship between movement skill proficiency and health indicators. However, few investigations have adequately examined this relationship, especially in children. Briefly illustrated here are the potential health implications associated with demonstrated proficiency in FMS.

Given the integral role movement skills play in performing physical activities, it is not surprising that a relationship between FMS proficiency and organized physical activity participation has been found in Australian adolescents and American children [17, 47]. Okely et al. [17] showed that girls and boys who engaged in a greater number of hours per week in organized physical activity (defined as activities that included regular classes or training and that were organized with instructors) were more likely to demonstrate greater proficiency in FMS (i.e., running, vertical jumping, catching, overhead throwing, forehand striking, and kicking). Notably, after dividing children into quartiles according to motor proficiency, findings indicated a possible threshold effect where children who scored in the highest proficiency quartile had significantly longer average time spent in physical activity than the three lower proficiency quartiles (which showed significant differences in the average time spent in physical activity). Importantly, their investigation also found a significant relationship between motor skill proficiency and time spent in moderate and moderate-to-vigorous physical activity. After controlling for covariates (gender, socio-economical status, # of televisions in the home, # of children in the home, child and parent BMI z-scores and children's measure of self-perceptions of adequacy in and predilection for physical activity), motor skill proficiency still accounted for 8.7% of the variance in physical activity [47].

Physical activity participation, especially participation in moderate-to-vigorous activity is a necessary component for fitness. It then follows that a relationship between fitness and FMS proficiency may also exist. In fact, Okely et al. [11] have shown such a relationship among adolescents in grades 8 and 10. Running and throwing proficiency displayed significant correlations with fitness in girls, while running and kicking proficiency displayed significant correlations in males. Recently, a link has been demonstrated between movement skill capability in adolescents and their adiposity assessments (sum of skinfolds, BMI, waist circumferemce). Okely et al. [16] determined that twice as many overweight youth (classified by BMI values) scored in the lowest quintile of FMS proficiency than non-overweight youth. Waist circumstance measurements were also shown to increase with a decreasing capability in running, catching, throwing, striking, and kicking, irrespective of gender.

2.2.6 Fundamental Movement Skills: Physical Education Curriculum

Given the significant influence movement skills have on lifelong physical activity pursuits and the potential influence on health status, the implications for the physical education setting are clear. It is thereby relevant to consider the physical education (PE) curriculum. All Canadian children have access to PE through the education system whereas many children (particularly those from low socioeconomic backgrounds) may not have access to any form of physical instruction until they enter elementary school. It is therefore appropriate to consider the PE curriculum as the principal vehicle for the delivery of physical instruction. In addition, school-based settings offer easily accessible areas for the investigation of large numbers of children. Through the school system, investigations are able to assess the current state of movement skill proficiencies and implement intervention programs based on the subsequent findings. In fact, physical education curriculums designed to improve fundamental manipulative skills have been shown to positively impact skill performance in first- and second-grade Greek children [48]. When implemented as an eight-week program with two 45-minute classes per week, instruction geared towards improving fundamental manipulative skills significantly improved children's scores on the Test of Gross Motor Development. Pappa's et al.'s results support the notion that a physical education curriculum focusing on FMS development positively influences skill development in children. Knowing the role PE plays in the development of FMS, how much attention does the British Columbian PE curriculum pay to the instruction and evaluation of movement skills? And, what level of skills are required by the curriculum's prescribed learning outcomes (PLO's)?

The 1995 British Columbian physical education resource package organizes the curriculum into three areas: active living, movement, and personal and social responsibility. Movement is further divided into five areas, alternative environment activities, dance, games, gymnastics, and individual and dual activities. Within each movement area there are PLO's which describe the behaviours students are expected to demonstrate [49]. Instruction is then directed towards this end. Unfortunately, the present curricular PLO's are not specific in describing the level of skill students are expected to demonstrate. In addition, there is no reference to which particular movement skills are to be taught in each grade. Fortunately, the British Columbian Ministry of Education has recently developed a revised PE curriculum set for partial implementation in September 2008 and full implementation in September 2009. The specifics of the new curriculum will be discussed further in Chapter V.

2.2.7 Fundamental Movement Skills: Current Status

Literature examining the current state of FMS proficiency is limited worldwide and this knowledge is especially lacking among Canadian children. Okely and Booth [19] recently examined the prevalence of FMS mastery among Australian children. This investigation examined several fundamental skills in boys and girls in grades one, two and three. For children in grade one, the hop, skip, side gallop, overarm throw, kick, and leap skills were assessed. The leap, kick, two-hand strike, dodge, sprint run, and catch skills were examined in grade two children. Finally, static balance, sprint run, vertical jump, catch, kick, and overarm throw were examined in grade three children. Skills were assessed by the visual observation of process orientated behavioural characteristics. Mastery was determined by the achievement of all movement components. Near-mastery was also reported and defined as the achievement of all but one movement component. Results indicated that out of all movement skills tested only 35% of children achieved mastery or near-mastery levels of achievement. The proportion of children who did not exhibit near-mastery (let alone mastery) of fundamental skills is significant especially considering the participants of the aforementioned investigation were six years of age (grade one) or older. While the investigation performed by Okely and Booth [19] does not provide insight into the proficiency levels of Canadian children, combined with the dearth of information regarding this matter it certainly indicates the need for the current status of FMS to be examined among Canadian children.

2.3 Indicators of Health and Fitness

Cardiovascular disease is a disorder in which the normal physiological functions of the heart or blood vessels are impaired. The ultimate consequence of CVD is death or disability from a vascular event such as a heart attack or stroke. Preliminary vascular disorders such as hypertension and arterial stiffening may be present long before a vascular event may actually occur [10, 50, 51].

In the following section, specific attention will be given to various health and fitness indicators. In particular, blood pressure, arterial compliance, weight status, musculoskeletal fitness and cardiorespiratory fitness will be addressed.

2.4 Indicators of Health and Fitness: Blood Pressure and Arterial Compliance

This section is dedicated to the discussion of BP and arterial compliance as they relate to health, tracking from childhood to adulthood, the measurement of BP and arterial compliance, as well as their potential relationship to FMS.

High BP and decreased arterial compliance are related to health consequences such as atherosclerosis [52]. Atherosclerosis is a hardening of the arteries that develops over several decades and is preceded by decreased arterial compliance (also known as decreased elasticity of the arteries or vascular stiffness) and is initiated by the dysfunction of the endothelial cells lining the artery wall. The endothelium normally functions as a semi-permeable and protective barrier between the blood and tissues playing an important role in the passage of metabolic substances and gases into and out of the circulating blood. By detecting and responding to hemodynamic changes in the blood through vasodilation and vasoconstriction the endothelium also maintains vascular homeostasis. Endothelial dysfunction may be the result of several different factors including injury from mechanical forces which impair the proper function of the endothelium [50, 53]. Mechanical forces may consist of the tensile stresses caused by hypertension along with shear stresses caused by the viscous drag and nonlaminar flow of blood against the endothelial surface therein disturbing the endothelial cells [52]. Blood platelets and monocytes adhere to the site of injury and interactions between these substances may trigger the movement of smooth muscle cells into the area and initiate a proliferative response. Such disruption to the endothelium on a chronic basis leads to the calcification of lesions and the eventual establishment of an atherosclerotic plaque which compromises blood flow due to the narrowing of the lumen and limits the blood vessel's ability to vasodilate [53]. Plaque rupture may follow leading to a thrombosis or embolism which in turn may lead to a heart attack or stroke and finally result in death or disability [52, 53].

Arterial compliance is a surrogate marker of endothelial dysfunction as changes in the compliant properties of the small and large vasculature are suggestive of functional and structural changes to the endothelium taking place during the early stages of the atherosclerotic process [10]. For this reason, decreased compliance measurements are often indicative of current or future vascular health problems [10, 54-56]. For example, along with the development of atherosclerosis, arterial compliance is also associated with hypertension. It is not certain however, if hypertension precedes or follows decreased compliance [55-57]. Cohn et al. [54] investigated the effectiveness of using arterial compliance testing for the detection of vascular disease. They found subjects diagnosed with hypertension and coronary disease to have arterial compliance measurements that were reduced by 31% and 24% respectively when compared to age-matched normotensive and coronary disease-free control subjects.

Liao et al. [55], Perticone et al. [56] and Arnett et al. [57] investigated the relationship between BP and vascular compliance. In a six-year follow-up investigation, Liao et al. [55] examined the relationship between the development of hypertension and carotid artery stiffness in a group of normotensive men and women. This investigation was conducted as part of the Atherosclerosis Risk in Communities study investigating cardiovascular and pulmonary diseases. The results revealed a graded association between greater baseline carotid artery stiffness and the subsequent development of hypertension. This relationship was independent of baseline BP measurements and showed that even the normotensive group subjects with higher baseline artery stiffness had higher baseline BP measurements [55].

Within a hypertensive population, forearm endothelial function measured by the vessel's vasodilatory response to acetylcholine has demonstrated the ability to predict future cardiovascular events [56]. Patients with a longstanding history of hypertension were measured for their peak percent increase in forearm blood flow during infusion of acetylcholine as an indication of their vasodilatative response. Participants were then grouped into tertiles based on their degree of forearm blood flow (vasodilatory) response with those participants who had the lowest blood flow response (i.e., greatest endothelial dysfunction) being placed in the first tertile and those who had the greatest blood flow response (i.e., lowest endothelial dysfunction) placed in the third tertile. Upon a seven-year follow-up, approximately 57% of participants classified in the first tertile compared to approximately 14% of those in the third tertile had experienced some form of cardiovascular event such as: myocardial infarction, stroke, transient cerebral ischemic attack, unstable angina, or bypass surgery/angioplasty [56]. In addition, Grey et al. [10] demonstrated reduced small artery compliance as being an independent risk factor for cardiovascular events such as myocardial infarction and stroke with those persons who had not experienced a cardiac event having significantly higher compliance measurements.

2.4.1 Blood Pressure and Arterial Compliance: Tracking from Childhood to Adulthood

Importantly, the association between arterial compliance and BP is not limited to the later adult years but can also be identified between the years of adolescence and early adulthood. A subset of participants from the Minnesota Children's Blood Pressure Study took part in a long-term investigation designed to examine the relationship of arterial compliance with BP [57]. Participants had their BP assessed twice in their final two years of High School and one final time two years after they completed High

School. Five years following completion of High School, participants were categorized into high-risk and low-risk groups based on BP measurements taken during High School. At this time (five years post High School), both groups had BP and arterial compliance measurements taken. After statistically controlling for possible confounding variables such as sex, height, weight, insulin, HDL and LDL cholesterol levels, Arnett et al. [57] found a significant relationship between the five year post High School measurements of systolic BP and large and small artery compliance.

In addition, Arnett et al. [57] explored a further association between BP measurements taken throughout adolescence and arterial compliance measurements taken during young adulthood. They found that the slope of BP measurements taken throughout adolescence were predictive of future arterial compliance measurements in young adulthood. Similarly, BP measurements in adolescents aged 12 to 18 years predicted the development of a preclinical marker for atherosclerosis later in life [58]. As a part of the Cardiovascular Risk in Young Finns Study, Raitakari et al. (2003) reported that the cardiovascular risk profiles of adolescents 12 to 18 years of age were directly related to adult common carotid artery intima-media thickness measurements (a preclinical marker for atherosclerosis) which were taken twenty-one years later. In both males and females, youth systolic BP was related to adult intima-media thickness independent of age, sex and current (adult) BP status.

As a reflective measure of endothelial dysfunction, the appearance of reduced arterial compliance precedes the appearance of unhealthy BP measurements. Therefore, the assessment of arterial compliance is an important technique for the early detection health risks and allows for a preventative rather than treatment approach towards health [10, 54, 57].

2.4.2 Blood Pressure and Arterial Compliance: Measurement

Particularly relevant to the discussion of arterial compliance is the cushioning function of the arteries. Cushioning function assists the steady conduction of blood by mitigating the pulsations resultant from the hearts intermittent contractions. An artery's cushioning ability can be expressed in terms of its compliance or elasticity [52]. Waveforms and reflections generated by the arterial system reveal information concerning the functional state of the arteries. Upon ejection of blood from the left ventricle, an initial pressure wave is formed with a secondary reflective wave being formed in discontinuous areas of the periphery such as points of branching and bifurcation. In healthy young individuals, the reflective wave travels back towards the heart during diastole [51]. The decay of BP from one ventricular contraction to the next (termed diastolic decay) and the oscillatory component of the reflective wave affords the analysis of vascular compliance by expressing the change in vessel volume by the change in vessel pressure [52]. Non-invasive analysis can be performed though implementation of the HDI/*PulseWave* CR – 2000 CVProfilor (Hypertension Diagnostics Inc Cardiovascular Profilor system). The CVProfilor system employs an electrical analog model known as a modified Windkessel model to provide an assessment of the small and large vasculature. A tonometer is placed over a superficial artery (in this case, the radial artery) to detect changes in beat-by-beat pressure and elucidate a computer generated tracing of a pressure waveform. Calculations derived from applying an algorithm to the waveform are taken to represent small and large artery compliance. While this non-invasive technique diminishes some of the high-frequency oscillatory components of the pressure waveform, it none-the-less yields large and small artery compliance findings which are statistically similar to those obtained through invasive measurements making it a valid means of assessing arterial compliance [54]. Data obtained using this non-invasive method has demonstrated reliability over both short and intermediate measurement collections [59, 60].

2.4.3 Blood Pressure and Arterial Compliance: Relationship to FMS

A relationship between BP, arterial compliance and FMS proficiency has not been examined. In fact, few experiments have investigated BP and arterial compliance profiles of children. As BP and arterial compliance play a vital role in the determination of disease later in life, factors that may be associated with these measurements (such as proficiency in FMS) should receive closer examination.

2.5 Indicators of Health and Fitness: Weight Status

High levels of adipose tissue are associated with several health risks including CVD, premature mortality and morbidity [9, 61, 62]. Additionally, weight status shares strong associations with other indicators of health and the clustering of several obesity related health problems (large waist circumference, insulin-resistant glucose metabolism, impaired glucose tolerance, type 2 diabetes mellitus, dyslipidemia and increased BP) is termed metabolic syndrome. People with metabolic syndrome have a one and a half to three times greater risk of suffering from coronary heart disease and stroke [61]. In a 13-year follow-up on the Canada Fitness Survey, Katzmarzyk et al. [9] found a positive relationship between BMI and risk of mortality in adult males and females. Furthermore, research has shown that men and women's risk of all-cause mortality is one and a half times higher and mortality from coronary heart disease is two times greater if they were overweight during childhood [62]. This is a long-term affect of childhood overweight and obesity in addition to the onslaught of immediate and intermediate consequences.

Complications of childhood overweight and obesity typically manifest themselves several decades after childhood. However, the immediate and intermediate consequences of child obesity are becoming apparent. Investigations consistently find overweight and obese children to be at greater risk for becoming hypertensive than normal-weight children [63-65]. Paradis et al. [65] examined the relationship between BP and BMI in Canadian children aged 9, 13 and 16 years. Findings indicated associations between BMI, systolic and diastolic BP across each age and gender group that were independent from fasting insulin level, resting heart rate and family history of hypertension [65]. As continuous variables, BP and BMI share a linear relationship with incremental increases in BMI associated with incremental increases in BP across age, gender and racial group [63]. When temporal trends in BMI and BP are investigated a relationship is also apparent [66]. Parallel to increases in weight status between the years 1988 and 2000, is an increase in the systolic and diastolic BP of children and adolescents. Once the increase in BMI was controlled for, the increase in systolic and diastolic BP was reduced by 29% and 12% respectively. Thus, Muntner et al. [66] attributed the rise in BP in part to the rise in obesity. The mechanism by which obesity is related to BP is not clear however, the relationship may be partially mediated by altered vascular structure and function as decreased vascular health has also been demonstrated among obese children [64, 67].

Severely obese children (defined by a BMI *z*- score three or more standard deviations above the age- and sex- specific means) while normotensive, present with greater indices of wall stress, intima-media thickness and lower indices of compliance and endothelial function. Further to this, results from the Cardiovascular Risk in Young Finns Study show an association between childhood BMI and adult risk for atherosclerosis through both increased artery intima-media thickness and decreased carotid artery elasticity [58, 68]. For males and females, adult compliance was inversely related to both childhood BMI and skinfold thickness. The association between childhood BMI and adult compliance became non-significant when adult BMI was entered into the multivariable analysis however, children's risk score (calculated as the child's total number of risk factors e.g., high LDL and low HDL cholesterol, high systolic BP and high skinfold thickness) remained highly significant even after controlling for these variables in adulthood. While the association between individual childhood risk variables was largely attenuated after adjustment for the effects of adult risk factors (such as adult BMI status), Juonala et al. [68] reported approximately 14% of the variance in adult compliance could still be explained by a child's calculated risk score. A large portion of the variance in adult compliance can be explained by adult risk factors therefore, the authors surmised that a partial link between childhood risk factors and adult compliance is likely due to the significant tracking of risk factors from childhood to adulthood. Yet, a substantial relationship independent of adult risk factors still exists, thus providing evidence that there is a direct link between childhood risk factors and adult compliance status [58, 68].

2.5.1 Weight Status: Current Status among Youth and Tracking to Adulthood

Regardless of measurement technique, sample population, or definition of overweight and obesity, investigations continue to demonstrate a rise in the prevalence and degree of excess adiposity levels among Canadian youth [1, 3, 69-71]. He and Beynon [71] determined the BMI values for children in grades one to six who attended 11 different elementary schools in the south Ontario area. They classified the BMI results into overweight and obese categories based on two different classification methods: the United States Centers for Disease Control and Prevention body mass index-for-age references and Cole's international BMI references [72]. Both methods of classification resulted in similarly high prevalence rates for overweight and obesity among male and female elementary school children with approximately 25% of children falling in the unhealthy weight categories. Canning et al. [69] compared the prevalence of overweight and obesity among Newfoundland and Labrador preschool children born in 1984 and 1997 and found those children born in 1997 were significantly more likely to be overweight or obese than those born in 1984 suggesting that monitoring weight status should begin before the age of three. Tremblay and Willms [3] showed increases in overweight and obesity in Canadian boys and girls ages 7 to 13 years. From 1981 to 1996 the percentage of boys and girls classified as overweight increased from 11% to 33% and 13% to 27% respectively. The prevalence of obesity during the same time period rose from 2% to 10% in boys and from 2% to 9% in girls. Not only is there an increasing prevalence of Canadian children with BMI values in overweight and obese categories, there is also an increased proportion of children in the higher BMI categories. In addition, there is also a more drastic rise in the rate of increased obesity prevalence among children than adults [3]. These trends are of particular concern because excess adiposity has been demonstrated to track from youth to adulthood, thus the prevalence of obesity in the adult population of Canada is set to become progressively more obese in the future [73-75].

Reasons for Canada's rise in overweight and obesity are unclear. Yet, they appear to be multifaceted and are thought to be in part, a result of decreases in physical activity level. In fact, in Canadian children aged 7 to 11 years, participation in unorganized sport was negatively associated with overweight and obesity and the benefit of participation in unorganized sport increased with age [76]. Conversely, while participation in organized sport was also negatively associated with overweight and obesity, this benefit decreased with age. The contribution of physical inactivity to unhealthy weight status was examined by determining time spend viewing television, and playing video games. These activities were significant risk factors for overweight and obesity. Two hours of television viewing per day appeared to be a threshold for overweight status while three hours per day was a threshold for obesity. In their investigation, Tremblay and Willms [76] also considered family background characteristics (i.e., socioeconomic status (SES) and one or two parent family). They considered these characteristics to be partially overlapping risk factors in as much as SES and family structure were both significantly related to overweight and obesity. Yet, the relationships between high weight status, unstructured physical activity participation and television viewing totaling less than two hours per day were maintained across all levels of SES. Furthermore, participation in unstructured physical activity resulted in the same decrease in the likelihood of having an unhealthy weight as from the association between high SES and decreased risk for overweight and obesity [76].

Paradoxically, when Eisenmann [77] conducted an investigation compiling data from several large-scale US and Canadian studies he found that self-reported Canadian physical activity levels had increased between the years 1981 and 1988 and remained steady between the years 1988 and 1998. Explanations for the seemingly contradictory data (i.e., increases in weight status without parallel decreases in physical activity) may be the result of using self-reported physical activity questionnaires. Measurement errors could be the result of respondent bias towards an over-estimation of actual physical activity levels or due to inaccuracies in memory recall [77]. Another possible explanation for the increase in weight status without an apparent decrease in physical activity is an increase in energy consumption. Yet according to US data, this is not the case. However, as with the physical activity data, Eisenmann [77] reported that the investigations on dietary intake and composition also used self-reported measures which were prone to the same limitations as the physical activity questionnaires. Namely, questionnaires lack a gold standard against which their validity may be compared [78].

2.5.2 Weight Status: Measurement

Anthropometric measurements such as BMI and WC are often used as indicators of overall and central adipose tissue respectively. These measurement techniques are simple and are easily employed in large sample sizes making them practical and thus frequently utilized for population-based investigations of overweight and obesity.

Due to the nature of anthropometric measurements, BMI and WC measurements cannot discern between fat mass and fat free mass and they are not direct measures of body adiposity rather, they are indicators of adiposity. There is potential for a child who is heavy due to increased amounts of fat free mass to be mistakenly classified as having a BMI in the overweight or obese category. Likewise, a 'normal' weight child with unhealthy amounts of fat but perhaps low fat free mass may be mistakenly classified as of 'normal' or healthy weight. In addition, different racial groups have been found to have different amounts of fat mass than Caucasian individuals for the same BMI values. For example, certain groups of Asians, tend to have higher fat mass for a given BMI compared to their Caucasian peers [79]. Despite this, the World Health Organization maintains their recommendation of BMI cut-off points corresponding to ≥ 25 kg/m^2 for overweight and ≥ 30 kg/m^2 for obese stating that:

> The purpose of a BMI cut-off point is to identify, within each population, the proportion of people with a high risk of an undesirable health state that warrants a public health or clinical intervention. When applied to a population, the purpose of anthropometric cut-off points is to identify independent and interactive risks of adverse health outcomes associated with different body compositions…" [80].

Therefore, the precise determination of percent body fat is not necessary for these purposes [81].

There is substantial evidence to indicate that children and adolescents classified as overweight or obese are in fact at higher risk for a variety of health problems ultimately leading to increased risk of morbidity. Research also suggests that if anything, the use of BMI as a diagnostic tool underestimates the presence of obesity because while the chances of obtaining a false positive (i.e., the chance of incorrectly classifying a child as having an obesity-related health risk when they really do not) are low, the chances of obtaining a false negative are moderate to high, meaning that there may be children who have an obesity-related health risk yet are not classified as such [81]. Therefore, despite possible limitations, BMI has demonstrated extensive validity in the detection of health risk associated with overweight and obesity in both adults and youths [81-88]. Similarly, WC is a valid indicator of abdominal adipose tissue and has also demonstrated utility in the detection of risk factors [83, 85, 88-90]. Lemieux et al. [85] investigated the validity of using WC as a measure of visceral adipose tissue by comparing WC measurements against abdominal computerized tomography scans. They found WC measurements to be significantly correlated to and predictive of visceral adipose tissue independently of BMI and age in both men and women. Han et al. [89] found WC measurements to have high sensitivity (i.e. low false positive) and specificity (i.e. low false negative) in detecting men and women with high BP as well as total and high density lipoprotein cholesterol. Waist circumference has also been established as a predictor of health risk in children and for a given BMI category (normal weight, overweight or obese) children with higher WC measurements are more likely to have an increased number of health risk factors [90, 91].

2.5.3 Relationship to FMS

Recently, adiposity assessments (sum of skinfolds, BMI, WC) have demonstrated relationships to movement skill capability in both children and adolescents. McKenzie et al. [92] showed an inverse correlation wherein male and female children's ability to balance and jump decreased as their sum of skinfold measurements increased. Additionally, Okely et al. [16] determined overweight youth (classified by BMI values) to be several times less likely to exhibit an advanced level of FMS proficiency when compared to their non-overweight peers. Waist circumstance measurements were also shown to increase with a decreasing capability in running, catching, throwing, striking, and kicking, irrespective of gender. Further, children who are overweight perceive themselves as less skilled then their leaner peers [18] and self-perception in physical skills is a possible determinant of participation in physical activity [93].

2.6 Indicators of Health and Fitness: Fitness

Musculoskeletal and cardiorespiratory fitness are commonly used health indicators and both of these forms of fitness are associated with health status in adults [94, 95]. Low musculoskeletal fitness (grip strength, sit-ups, and vertical jump), is predictive of disease, disability and all-cause mortality while overall fitness (cardiorespiratory and musculoskeletal) has been found to account for 11 to 30% of adult metabolic risk factors for coronary heart disease [95].

Among Canadian males and females, musculoskeletal fitness has been linked with an increased risk of early mortality. In particular, after controlling for covariates (age, smoking, weight, WC and aerobic fitness) progressively lower levels of abdominal endurance (i.e., number of sit-ups performed in 60 s) were associated with a increasingly higher risk of mortality in both men and women [94]. The authors proposed that the reason for such an association could be due to the relationship between strength and skeletal muscle mass or simply a result of sufficient strength for the maintenance of independent living. Much more information is needed regarding the role of musculoskeletal fitness in either reducing or preventing the development of arterial stiffness and high weight status especially when one considers the moderately stable tracking of musculoskeletal fitness items (including sit-ups, push-ups, and grip strength) from youth to adulthood [96, 97]. For these reasons, children's musculoskeletal fitness levels should be given appropriate consideration for their possible role in the maintenance of health.

The relationship between higher levels of cardiorespiratory fitness and greater health is consistently indicated throughout the literature in both children and adults [7, 95, 98-101]. An investigation conducted by McGavock et al. [101] shows greater arterial compliance among individuals with greater levels of aerobic fitness. Adult male and female participants were distributed among three groups (sedentary, physically active and endurance trained) according to their self-reported physical activity levels. Aerobic fitness, as indicated by a maximal oxygen consumption test (known as VO_{2max} or maximal aerobic power) performed on a cycle ergometer, was significantly higher within the physically active group compared to the sedentary group and higher still within the endurance trained compared to the physically active group. Controlling for related variables such as age, BMI and serum triglycerides, pulse wave analysis confirmed the association between cardiorespiratory fitness level and arterial compliance. While participants in the physically active group had compliance measurements that were higher than the sedentary group, the endurance trained group had significantly higher compliance measurements than both of the lower fitness groups suggesting that in particular, frequent vigorous physical activity is associated with considerably improved vascular health measures. As in adults, there is a significant correlation between a child's vascular health profile and a child's fitness level [7, 95]. A Canadian investigation looked at children aged 9 to 18 years old and found cardiorespiratory fitness (measured as physical working capacity on a progressive cycle ergometer test) to account for 11 to 30% of the variance in risk factors for developing coronary heart disease [95]. In a recent investigation conducted as part of the Action Schools! BC program, a positive correlation was identified between children's large and small artery compliance and aerobic fitness [7]. Reed et al. [7] showed increased compliance measurements to be associated with higher fitness levels in both male and female children aged 9 to 11 years old. Moreover, it has been shown that the unhealthy vascular profiles of children and adults can be partially reversed with an increase in cardiovascular fitness [99, 102].

The cardiorespiratory fitness of children and adults is associated with reduced abdominal adipose tissue and abdominal fat, independent of risk predicted by BMI and may counteract excess adiposity-related risk factors [5, 6]. As part of the 1981 Canada Fitness Survey the cardiorespiratory fitness, WC, skinfolds and BMI of men and women were assessed. Participants were separated into quintiles according to their maximal aerobic power score as measured indirectly from a submaximal exercise step test (Canadian Aerobic Fitness Test). The two upper (high fitness) and the two lower (low fitness) quintiles were used in the analysis. Independent of age, both men and women in the high fitness groups had lower measures of adiposity than those in the low fitness groups. More specifically, for a given BMI those in the high fitness groups had lower sum of skinfold and WC measurements than those in the low fitness groups. These findings demonstrate a means by which cardiorespiratory fitness decreases the health risk associated with obesity as both total and abdominal adiposity are reduced in persons with moderate to high cardiorespiratory fitness levels [6]. Similar results have also been found among overweight and obese children in Greece [5]. Children aged 6 to 13 years had skinfold, height and weight measurements taken to determine percent body fat and BMI scores, respectively. The 20 m shuttle-run was used as an indirect measurement of Maximal aerobic power for the evaluation of cardiorespiratory fitness. Children were classified by gender before being further divided into two groups (nonoverweight and overweight/obese) according to age- and sex-specific BMI scores. Children were also grouped into quintiles according to age- and sex-specific cardiorespiratory fitness scores. Individual characteristics such as height and age were not significantly different between the nonoverweight and overweight obese groups or among the fitness quintiles. The results were consistent in all cases for males and females alike and for those categorized as either nonoverweight or overweight/obese, children in the higher fitness quintiles had statistically lower body fat (as indicated by skinfolds measurements and calculated percent body fat) than children in the lower fitness quintiles. As in the adult population investigated by Ross and Katzmarzyk [6], the authors of the aforementioned investigation concluded that cardiorespiratory fitness also partially attenuates the health risk associated with overweight and obesity within a pediatric population [5].

While greater cardiorespiratory fitness is associated with lower measures of adiposity regardless of weight status, improvements in fitness have resulted in positive effects on the vascular profiles of children [99, 100]. Woo et al. [99] found that the vascular dysfunction (as indicated by the response to reactive hyperemia and arterial intima-media thickness) of overweight and obese children can be somewhat reversed within six weeks with a combination of diet and exercise. Woo et al. [99] employed a combination of aerobic (lasting 10 minutes) and resistance (circuit style lasting 30 minutes) exercise training which the participants performed twice a week for six weeks. Vascular health was further improved with the continuance of a follow-up exercise program performed once a week for one year [99]. Watts et al. [100] found similar results among obese children after an eight week aerobic exercise program comprised of various physical activities including games requiring continuous play. Male and female obese (defined by age- and sex- specific cutoffs) participants who averaged between eight and nine years of age were investigated along with a group of lean male and female control participants. Body composition was assessed through the use of skinfold measurements along with BMI. Changes in fitness levels were determined by comparing pre and post heart rate responses to a submaximal exercise cycle test. Vascular function was evaluated by flow-mediated dilation in response to reactive hyperemia. At baseline, obese participants displayed significantly lower vascular health measures compared to the group of lean control participants. Upon completion of the eight week exercise program the obese children had significantly improved their vascular function. Notably, improvements in vascular health were found without corresponding improvements in skinfold or BMI measurements. Built into the study design was the assessment of variables after an eight week period of detraining. Importantly, the vascular improvements attained after eight weeks of training were not maintained upon cessation of exercise. Thus, it would appear that physical activity behaviour needs to be continued in order to maintain the associated health benefits [100].

Despite the fact that risk factors for adult health status have their antecedents in childhood, only a minimum number of investigations have examined health indicators using child participants. Given the level of influence held by cardiorespiratory fitness over various health indicators (e.g., BP, arterial compliance and weight status) [5-7, 99-102] and its relation to mortality [94, 95] cardiorespiratory fitness is clearly established as an essential component to the investigation of health and fitness.

2.6.1 Fitness: Current Status among Youth and Tracking to Adulthood

Research conducted on the temporal trends of children's musculoskeletal fitness and on the tracking of musculoskeletal fitness from childhood to adulthood is sparse. Certain musculoskeletal fitness items in childhood have shown significant tracking to adulthood. Grip strength and sit-ups were shown to track in male and female children

10, 11 and 12 years to 35 years old [97]. Between all age ranges (10 to 35, 11 to 35, and 12 to 35 years of age) female grip strength (absolute and relative to body mass) tracked significantly displaying moderate correlations which increased as the baseline age of the child increased. That is to say, the correlations between childhood and adult grip strength became progressively higher across the 10 to 35, 11 to 35, and 12 to 35 age ranges. In males, absolute grip strength in all childhood ages was also significantly correlated to adult absolute grip strength and demonstrated the same trend of increasingly higher correlations across the age ranges as the female data. However, male grip strength relative to body mass had the reverse trend of progressively lower correlations across the 10 to 35, 11 to 35 and 12 to 35 age ranges. In addition, the correlations between child and adult grip strength relative to body mass were insignificant in males. Results from the data tracking childhood sit-up performance to adulthood sit-up performance showed significant correlations across all age ranges in females. The age ranges of 11 to 35 and 12 to 35 years demonstrated significant correlations in males [97].

More information exists on the status and tracking of children's cardiorespiratory fitness. Alarmingly, the cardiorespiratory fitness levels of children and adults are declining throughout developed nations [2, 4]. A comprehensive investigation compiled data collected from fifty-five investigations conducted in eleven different countries worldwide on the 20 m shuttle run performance in youth between the years 1980 and 2000 [2]. Results from Tomkinson et al.'s [2] review indicated that the vast majority of children had cardiorespiratory fitness levels which were increasingly lower than their predecessors. While there was a fair degree of variability according to country, children's mean performance (all age groups 6 to 17 years old combined) on the 20 m shuttle run decreased over a twenty year period (with the exception of girls in North Ireland and Greece and boys in Belgium whose performance increased over the same time period). The rate at which shuttle run performance decreased per year in Canadian children was roughly -0.7% in boys and -0.5% in girls. When data was analyzed by rate of performance change according to age groups results were less variable, children's performances decreased -0.5 to -0.3% per year while adolescents' performance decreased approximately -1.0% per year [2]. A more recent investigation conducted by Reed et al. [4] as part of the Action Schools! BC program compared the change in cardiorespiratory fitness of Canadian children between the years 1981 and

2004. As in Tomkinson et al's [2] meta-analysis, Reed et al. [4] also used children's shuttle run performance as an indicator of cardiorespiratory fitness. Maximal aerobic power scores achieved by children in a separate investigation conducted in 1981 using identical protocols were compared to the scores achieved by the same age (9 to 11 years) and sex of children in Reed et al.'s [4] 2004 investigation. Using an equation which incorporated the child's age and maximal running speed attained during the shuttle run test, maximal aerobic power was indirectly determined. For all ages (9, 10 and 11 years) the estimated maximal aerobic power of both boys and girls in 2004 were found to be significantly lower than the estimated maximal aerobic power of boys and girls in 1981. Data from the two investigations were also compared according to the percentile norms respective to children in 1981 and 2004. Results indicated that a boy who scored in the 50th percentile for aerobic fitness in 2004 would have only scored in the 14th percentile in 1981. Similarly, a girl who scored in the 50th percentile in 2004 would have scored in the 23rd percentile in 1981. This is an indication of a decrease in health-related fitness. Combined data from boys and girls indicate that overall, children measured in 2004 had aerobic fitness performances which decreased by approximately 30 centiles over a twenty-three year time period [4].

The trend of declining cardiorespiratory fitness among children is of concern because children's aerobic fitness has been shown to track from childhood to adolescence and from adolescence to adulthood [103, 104]. At baseline boys aged 8 to 12 years and girls aged 7 to 11 years had their aerobic fitness assessed through direct maximal aerobic power measurement on a cycle ergometer [104]. Maximal aerobic power scores were re-measured once a year for five years. While correlations between baseline fitness levels and follow-up measurements decreased as the period of time between measurements increased, there remained low to moderate tracking of fitness for boys and girls throughout the five year investigation period [104]. Malina [103] considered the information available on the tracking of cardiovascular fitness and found moderate correlations between childhood and adolescent fitness and also between adolescent and adulthood fitness to be prevalent throughout the literature.

2.6.2 Fitness: Measurement

Children's cardiorespiratory fitness is often measured indirectly via the Leger [105] 20 m shuttle run test. Two lines are marked-off 20 m apart. Participants run back and forth between the two lines to the pace set by a compact disc which initially starts at a running speed of 8.5km/hr and increases in speed every minute by 0.5km/hr. Participants continue running back and forth between the 20 m lines for as long as possible until they are unable to keep pace with the compact disc recording or until volitional fatigue. A researcher records the final number of laps completed by each participant. The speed corresponding to the final lap number is then entered into an equation to indirectly assess the participants' maximal aerobic power. This has shown to be a valid and reliable method in the estimation of maximal oxygen consumption in both adults and children [105-108]. The original protocol for Leger's 20 m shuttle run was conducted using time increments of 2 minutes where the elapsed time between each beep noise decreased every two minutes. However, in subsequent investigations, Leger & Lambert determined that using time increments of only 1 minute demonstrated savings in administrative time and increased motivation with school children. While direct assessment is always preferred it is not always practical. Such is the case when investigating larger groups and in particular, larger groups of children. Performing maximal aerobic power tests in a laboratory on a treadmill or cycle ergometer is time-consuming and expensive. Also, when considering the practicality of investigating school-aged children it often becomes necessary to evaluate the children during the school day and on the school grounds making a valid and reliable field test such as the 20 m shuttle run the measurement of choice. The 20 m shuttle is advantageous in the investigation of children's cardiorespiratory fitness because it can be implemented indoors (in a school gymnasium) or outdoors, is a progressive maximal test and thus resembles standard direct measurements of maximal aerobic power testing, is easy to administer and is able to maintain child motivation [108]. Validation studies have found the 20 m shuttle run to have consistently high correlations with directly measured maximal aerobic power scores.

2.6.3 Fitness: Relation to FMS

Our knowledge is minimal regarding the relationship between FMS proficiency and fitness. Musculoskeletal fitness has not been examined in relation to FMS proficiency. It is possible that musculoskeletal fitness is associated with the proficient performance of movement skills because greater muscular fitness is achieved through the engagement of proficient movement skills. However, the current literature has not given attention to the nature or direction of this potential relationship. Okely et al. [11] have shown that FMS may play a potentially important role in promoting cardiorespiratory endurance among adolescents in grades 8 and 10. Skill in running and throwing demonstrated the greatest correlation between FMS proficiency and fitness in girls, while kicking (followed by running) produced the greatest correlation in males. Overall, male students exhibited superior proficiency in FMS in comparison to female students. However, Okely et al. [11] suggest there may be a gender bias in favour of male students due to the particular skills investigated. Further examination into the role that FMS plays in cardiorespiratory fitness levels of children is clearly warranted.

2.7 General Limitations of Previous Literature

A select number of investigations suggest that certain types of movement skill capabilities may account for the variance in weight status and fitness among youth [11, 16, 109]. However, this concept has been examined in a limited number of populations and there has been little consistency in the selection of fundamental motor skills analyzed. In addition, an emphasis on the use of product-orientated assessment tools and measurement protocols (versus process-orientated measurement) has been evident. Product-orientated analysis does not allow for a description of movement skill performance rather, it is limited to providing only the end result of a performance with no reference to the manner in which the performance result was attained. Take, for example, an assessment of a child's running skill. A product-orientated analysis would use running speed or running distance as the outcome variable. As a result, no information regarding the behavioural characteristics of the skill is gained. In contrast, a process-orientated measurement would be an evaluation of the movement characteristics the child performs while he or she is running (e.g., does the child's arms move in opposition to his or her legs and along the sagittal plane? Is there a definite flight phase?). The inability to compare investigations employing product-orientated assessments to those using process-orientated measurements is apparent and results in difficulties when attempting to establish a clear picture of FMS proficiency among children.

Motor behaviour researchers commonly employ process-orientated assessment tools because they provide information regarding a child's behavioural characteristics.

The Test of Gross Motor Development (TGMD) is an accepted evaluation tool which analyzes movement skills from such a perspective. The TGMD is a convenient method of assessing children's motor development because it can be easily employed in a field setting. The behavioural components assessed by the TGMD generally indicate a mature movement pattern [110]. However, the TGMD has its limitations. First, each skill is only evaluated according to three or four criteria. While evaluating only a few behavioural components simplifies testing protocols, other movement characteristics are not assessed. Second, there is no scale for which behavioural components are graded, they are evaluated as either being present or absent from the child's performance. This method does not place skills along a continuum of development. This severely diminishes the amount of information that can be learned from the assessment because children are simply classified as either having obtained or having not obtained a mature movement pattern. This method of evaluation does not describe the skill level of the children who have not yet obtained a mature movement pattern. As a result, no distinction is made between those children who are close to a mature pattern and those who may be developmentally delayed [111]. Third, evaluation is performed via visual observation. The visual observation of a child's performance can lead to two methodological problems. If the observation occurs in real time while the child performs the skill (i.e., the performance is not video-taped for repeated viewing), extraneous aspects of a child's performance may distract the observer from other important characteristics of the behaviour. Or, the observer may simply miss key components of the performance. Video taping skills as they are demonstrated can alleviate this problem by allowing the observer to spend more time assessing the skill. However, the skills are still assessed through visual observation and thus have limited objectivity. Despite good intentions, an observers' assessment may be clouded by personal bias. In addition, it is difficult to determine the accuracy of joint angles which are measured via visual observation.

Okely et al. [11, 16, 17] have examined the relationship between FMS and body composition, cardiorespiratory fitness, and physical activity. In comparison to other research [92, 109, 112], Okely et al. [11, 16, 17] employed more FMS items in their assessment. Utilizing six FMS measures, including locomotor (sprint run and vertical jump) and manipulative (catch, kick, over arm throw and forehand strike) movement skills, they were able to provide a more informative picture of this relationship in comparison to other investigations. However, Okely et al. [11, 16, 17] based their assessments on observational checklists which contained only a handful of behavioral components (usually four to six items). While this allowed for greater ease of use during observations, important process characteristics of a skill were not assessed.

The cardiovascular measurements employed by Okely et al. [11, 16, 17] consisted of standard measurements: BMI, WC, physical activity questionnaires and maximal shuttle run. While our investigation will include similar measurements we will also assess BP and arterial compliance. The assessment of arterial compliance is a novel aspect of the proposed investigation. Arterial compliance has been established as an important tool for the detection of health risk before the appearance of high BP measurements [57]. Despite its significance as a preventative tool, few studies have used arterial compliance to assess a childhood population. Our investigation of BP, arterial compliance, weight status and fitness measurements combined with our movement skill assessment items will provide a better understanding of the relationship between movement skill proficiency and indicators of health and fitness.

CHAPTER III: METHODOLOGY

3.1 Participants

A sample of 162 boys and girls (ages 8 to 11 years) were recruited from three schools in the Burnaby and Vancouver School Districts. All participants were part of the full evaluation component of the Action Schools! B.C. Program (AS! BC). Informed consent (refer to Appendix A) was received from 91 female (mean age = 10.0 yrs, SD = 0.6) and 71 male (mean age = 9.9 yrs, SD = 0.6) students enrolled in schools implementing the AS! BC program. The investigation was carried out according to ethical guidelines set by the University Clinical Science Screening Committee for research involving human participants.

3.2 Procedure

All data was collected on three separate days at the participating elementary schools (see Figure 3.00). On Days 1 and 3, children were temporarily excused from their classrooms and brought into the school's gymnasium in groups of approximately 8 to 10 children. On Day 2, children were temporarily excused from their classrooms two at a time. Day 1 consisted of weight status measurements, Day 2 entailed BP and arterial compliance measurements and Day 3 consisted of musculoskeletal fitness, cardiorespiratory fitness and FMS assessments.

3.2.1 Day 1: Weight Status Measurements

The first day of assessments were comprised of weight status measurements. Measurements of weight and WC are potentially sensitive issues with some children. To help alleviate any emotional anxiety which children may experience during these measurements, each child had his or her weight status taken individually to ensure that the child's privacy was respected. These measurements took approximately 30 minutes per group.

Day 1: Weight Status	Day 2: Blood Pressure and Arterial Compliance	Day 3: Fitness and Fundamental Movement Skill			
		Pre-test Screening	Musculoskeletal Fitness	FMS	Cardiorespiratory Fitness
1. Height 2. Weight 3. Waist Circumference	1. Blood Pressure 2. Arterial Compliance	1. Blood Pressure	1. Sit and Reach 2. Grip Strength 3. Push-ups 4. Curl-ups	1. Run 2. Skip 3. Hop 4. Vertical Jump 5. Horizontal Jump 6. Jump from a Height	1. Shuttle Run

Figure 3.00 Day 1 - 3 Health, Fitness and Fundamental Movement Skill Procedure

3.2.2 Day 2: Blood Pressure and Arterial Compliance Assessments

The second day of measurement was comprised of BP and arterial compliance assessments. Arterial compliance and BP measurements were taken on a separate day from the fitness and FMS testing to ensure that arterial compliance and BP readings were not influenced by prior physical activity. Each child was required to rest quietly in a supine position for five minutes before arterial compliance and BP readings were taken. Blood pressure readings were obtained in conjunction with the arterial compliance measurements. As such, the recorded BP readings were taken from a supine position. These measurements took approximately 10 minutes per group of two children.

3.2.3 Day 3: Fitness and Fundamental Motor Skill Assessments

Musculoskeletal fitness, cardiorespiratory fitness and FMS were assessed on the third day of testing. Seated BP measurements were taken prior to the fitness and FMS assessment to screen for children who had resting BP above the 95th percentile (120/80). As a precaution against an unsafe rise in BP during the fitness assessments these children were excluded from the fitness and FMS testing. Musculoskeletal testing (i.e., push-ups, curl-ups, sit and reach, and grip strength) were conducted next, followed by the FMS assessment (i.e., run, skip, hop, horizontal jump, vertical jump, and jump from a height). It was necessary to conduct the FMS assessment prior to the shuttle run to minimize the effects of fatigue on movement skill proficiency. The shuttle run was conducted last, allowing for the greatest amount of time to rest between the musculoskeletal items which require maximal physical exertion, and the maximal effort shuttle run. Together, these assessments took approximately one hour per group of 8 to 10 children.

3.3 Cardiovascular Disease Risk Assessments

3.3.1 Blood Pressure and Arterial Compliance

From a supine position, BP was taken using an automatic sphygmomanometer (left arm). Arterial compliance was measured using radial applanation tonometery (right wrist) (Hypertension Diagnostics/PulseWave CR – 2000 CVProfilor). The radial arterial waveform was obtained simultaneously with BP readings from the left arm. This non-invasive technique allowed for the indirect assessment of endothelial function. Small artery (ml/mmHg x 10) and large artery (ml/mmHg x 100) indices were used for entry into the multiple regression analysis. Systolic and diastolic BP measurements were used in the analyses.

3.3.2 Weight Status

Height (cm) was measured (to the nearest 0.01 cm) by applying gentle upward pressure on the base of the mastoid process. Weight (kg) was measured (to the nearest 0.01 kg) using an electronic scale (SECA, Germany). Two measurements of height and weight were averaged for analysis. Body mass index (kg/m^2) scores were derived from those measurements. Waist circumference was determined by measurements taken at the level of noticeable waist narrowing using an anthropometric girth tape [113]. Two measures were averaged for analysis.

3.3.3 Musculoskeletal Fitness

Grip strength, push-ups, curl-ups and sit-and-reach comprised the musculoskeletal fitness components of this investigation. These items are typically used to assess muscular fitness and were chosen based on their previously established relation to health indicators [94]. The assessment protocols were modified versions of those described by the Canadian Society for Exercise Physiology [113]. Children were asked to complete as many push-ups and curl-ups as possible and the total number of push-ups and curl-ups was entered for data analysis. Maximum grip strength was determined by summing the maximum score from the greater of two trials of the right and left hand. Sit-and-reach scores (cm) were determined by the maximum distance over two trials. Maximum grip strength and sit-and-reach scores were used in the analyses. General descriptions for each musculoskeletal test are provided below. For a detailed description of the testing instructions refer to Appendix B.

Curl-ups were measured by having the children lie on their backs with their knees bent to 90° and their feet flat on the floor. They were then asked to stretch their hands down towards their feet until the tips of their middle fingers were touching the marker. The children were asked to curl their head, neck and shoulders up off of the mat while reaching their hands along the mat towards their feet until their middle fingers touched the marker. They were then instructed to curl back down until their head once again touched the mat. Each curl-up was performed to the sound of a metronome set to 40 bpm.

Push-ups were measured by having the children lie on their stomachs with their legs straight and feet together. Their hands were placed just outside of their shoulders with their fingers pointing forward. Children started from an 'up' position with their elbows straight and body up off the mat. Using their feet as a pivot point, they were then instructed to bend their elbows to lower their body down until their elbows were bent to 90° before pushing their body back up until their elbows were once again straight.

To measure grip strength, children were asked to stand holding a dynamometer 45° out from the side of their body. They were then asked to squeeze the dynamometer as hard as they could. This was performed twice for each hand, alternating between hands.

Finally, sit-and- reach was measured by asking the children to remove their shoes and sit facing the sit- and- reach box with their legs straight in front of them and soles of their feet placed flat on the sit- and- reach box. They were then instructed to place one hand on top of the other and push the sliding block as far forwards as possible with their finger-tips.

3.3.4 Cardiorespiratory Fitness

Cardiorespiratory fitness was assessed using Leger's 20 m shuttle run, which is a maximal progressive exercise test [105]. Participants are asked to run back and forth between 20 m markers keeping pace with a 'beep' noise recorded on a compact disc. The time between beeps decreased every minute (referred to as 'stages') such that it became progressively more difficult to maintain running pace. This test has shown to be a valid and reliable test of cardiorespiratory fitness [105] and has been used extensively with children [2, 105]. The total number of laps corresponds to a particular stage which in turn corresponds to the child's maximal running speed. Final running speed can be entered into a regression equation $VO_{2max} = 31.025 + (3.238*speed) - (3.243*age) + (0.1536*speed*age)$ to produce an indirect measure of maximal oxygen uptake (VO_{2max} ml/kg/min) [105].

3.4 Fundamental Movement Skill Assessment

Participants were required to perform six FMS: running, skipping, hopping on the spot, vertical jumping, horizontal jumping, and jumping from a height. Although participants were assessed in groups of approximately ten or less, each child performed the required locomotor skills individually. All children in the group executed one skill before moving onto the next. Each child was assigned a number and the children performed the first FMS in numerical order. However, for each successive skill, the children's order of performance was rotated such that whichever child was first to perform the previous skill was the last to perform the following skill. This was done to minimize the influence of learning effects.

Unlike previous investigations [11, 16-19, 92, 109, 114, 115], the performance of FMS was captured by two video cameras and videotaped for later analysis. Refer to Figure 3.01 for a schematic of the experimental set-up. A camera was placed at the end of a 10 m lane (which was marked on the floor) to capture a front view, and a second camera was placed perpendicular to the lane to capture a side view. The side camera was set-up in such a manner as to ensure that the middle 8 m of the 10 m lane was captured on videotape. A 1 m x 1 m square was outlined in the centre of the 10 m lane to mark the performance area for the jumping and hopping skills. The 1 m x 1 m square also provided a visual marker for the calibration of siliconCOACH Pro software for further data analysis. The following are specific instructions for the performance of each skill.

For the running skill, each participant was instructed to run in a straight line down the 10 m lane. The experimenter instructed the children that it was not a race and they did not need to run as fast as possible. Instead, the children were instructed to run as they normally would on the playground during recess. Each child began at the start line and ran towards the end camera until reaching the end line.

For the skipping skill, each participant was asked to skip in a straight line down the 10 m lane to the best of his or her ability. Each child began at the start line and skipped towards the end camera until reaching the end line.

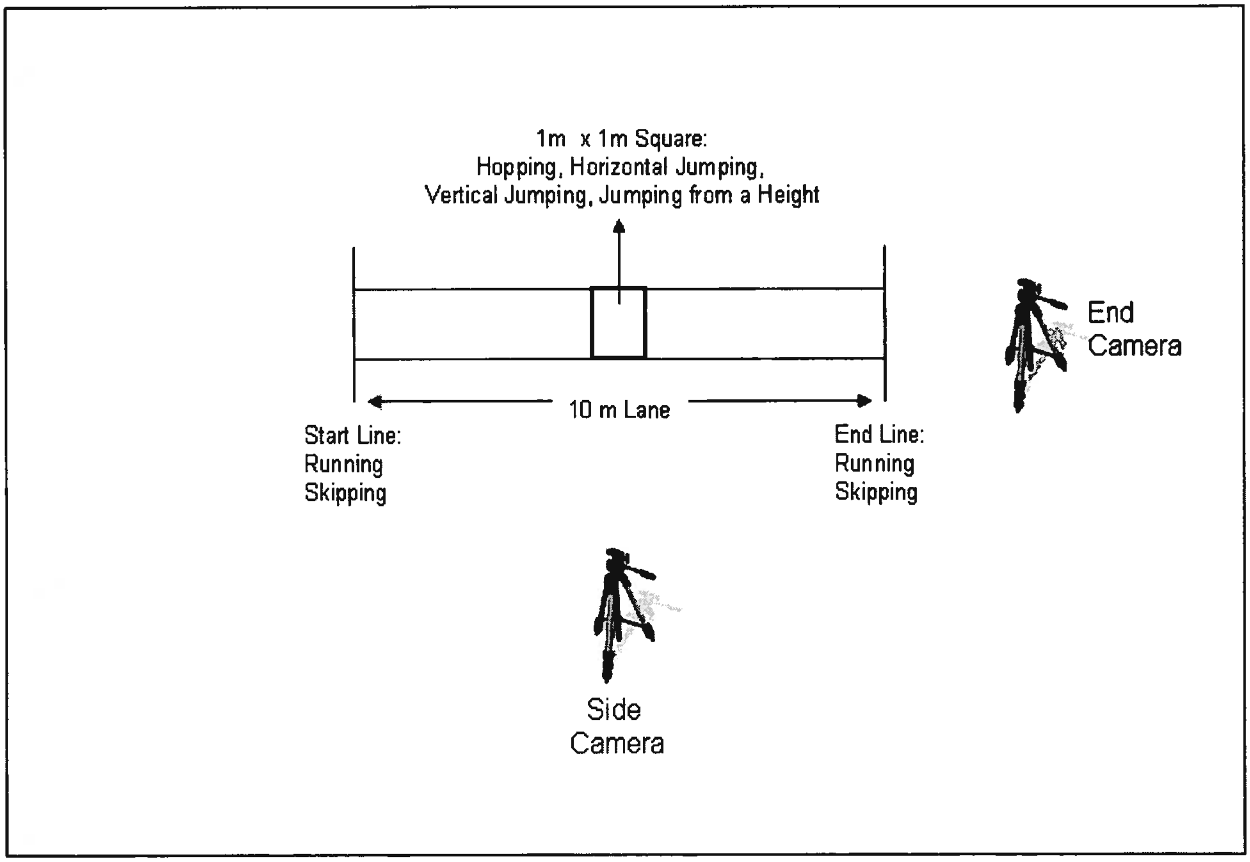


Figure 3.01 Schematic Diagram of Experimental Set-Up

Hopping was assessed by asking the participant to stand in the middle of the 1 m x 1 m square facing the side camera. He or she was then asked to hop five consecutive times on one foot followed by five consecutive times on the other foot while remaining in the square.

For horizontal jump, children started with their toes on a line marking one edge of the square. Each child was asked to perform a big jump towards the front view camera by taking-off and landing on two feet.

For vertical jump, children stood in the middle of the marked square facing the front view camera. The participant was then instructed to jump and 'try to touch the sky' with one hand by taking-off and landing in the middle of the square with two feet.

Jumping from a height was assessed by having the participant stand on a 30 cm high block facing the front view camera. From this position, the child was asked to jump down from the bench so that they landed with both feet in the area of the square.

3.5 Analysis of Fundamental Locomotor Skills

To determine level of skill proficiency, the videotaped performances were analysed via video analysis software (siliconCOACH Pro) and a coding system specifically designed for this investigation.

SiliconCOACH Pro software was used to determine ankle, knee, hip and elbow joint angles from the side view video images while the degree of lateral movement of the arms, legs, and trunk was determined from front view images. A coding system was then employed to determine level of movement skill proficiency (see Tables 3.00 to 3.05). The coding system includes a checklist of 30 behavioural characteristics per locomotor skill. The checklist items are based on the process characteristics displayed during varying stages of motor skill acquisition as previously described in developmental sequences provided in the literature [24, 34, 35, 45, 93, 116-121]. Each locomotor skill checklist has ten behavioural components, referred to as 'critical elements'. Each critical element has items regarding performance technique. A child's level of proficiency for each item was given a score ranging from 1 to 3 based on the corresponding description. Skills were assessed for each critical element and graded from 1 to 3 with 1 representing characteristics of immature or elementary movement patterns and 3 representing characteristics of mature or advanced movement patterns. Scores of 0 refer to the demonstration of alternative behavioural characteristics that

Table 3.00 Proficiency Assessment: Running

Ideal: Participant exhibits a definite flight phase with legs driving forward along the sagittal plane, fully extending in the air. The thigh approaches the horizontal on the forward drive while the rear foot approaches the level of the buttocks upon recovery. Landing is on metatarsal arch. Arm movements are in opposition of legs and drive along the sagittal plane with wrists reaching up to shoulder level on the forward swing and hip level on the back swing. Arms are held in an adducted position with elbows flexed at approximately 90°.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Arm Drive	0=Unclassifiable movement. 1=Minimal and stiff movement of arms. 2=Arms move along the oblique plane and may or not cross the body midline. 3=Arm movement drives along the sagittal plane. Wrist reaches up to shoulder level and back to hip.	**Front View.** Measured via visual observation. Score of 3 measured from vertical line down from shoulders and compared to the upper and lower arm.	
Arm Placement	0=Unclassifiable movement. 1=Arms are held in an abducted position throughout arm swing. 2=Arms move from abducted to adducted positions throughout arm swing. 3=Arms are held in an adducted position throughout arm swing (≤10° out from shoulders).	**Front View.** Measured via visual observation. Score of 3 measured from angle between vertical line down from shoulders and upper arm at two points during arm swing: forward and back.	
Elbow Flexion	0=Unclassifiable movement. 1=Elbow flexion is a combination of too extended (>105°) and/or too flexed (<75°) during the entire arm swing. 2=Elbow flexion is inconsistent (elbow may flex on forward swing and extend on back swing). However, at least half of the arm swing (either the forward swing or the back swing) must have an elbow flexion between 75° - 105° (otherwise score 1). 3=Elbow flexion is held at between 75° - 105° during both the forward and back swing.	**Side View.** Measure angle between shoulder and wrist at two points during arms swing: forward and back.	
Arm/Leg Opposition	0=No arm opposition. 1=Opposition is inconsistent and sporadic. 2=Arms move in opposition to legs but in the horizontal plane. 3=Arms move in opposition independent of spinal rotation.	**Side View.** Viewed at full speed. Measured via visual observation.	
Leg Drive	0=Unclassifiable movement. 1=Noticeable ‘toeing out’ of the foot (lower leg swings outwards) or a large crossing of the body’s midline during recovery. 2=Slight ‘toeing out’ of the foot (no lower leg swing, external rotation of foot only) or slight crossing of the body’s midline during recovery. 3=The thigh drives forward along the sagittal plane. Foot also stays along the sagittal plane.	**Front View.** Forward drive measured from vertical lines down from hips and compared to the placement of the thigh from the point of recovery throughout the forward drive. Crossing of body midline determined by viewing foot placement upon recovery.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Landing	0=Unclassifiable movement. 1=Feet land flat. 2=Feet land heel-toe. 3=Feet land on metatarsal arch.	**Side View.** Measured via visual observation.	
Flight Phase	0=Flight phase is inconsistent. 1=Flight phase is consistent but stunted; legs do not extend fully in air or time off ground is minimal. 2=Definite flight phase however, stride lacks power and/or extension. 3=Definite flight phase. Stride length is at maximum extension and power.	**Side View.** Viewed at full speed. Measured via visual observation.	
Recovery: Hip Flexion	0=Unclassifiable movement. 1=Hip flexion of forward driving leg is >120°. 2=Hip flexion of forward driving leg is between 106° – 120° 3=Hip flexion between <90° – 105° on the forward drive.	**Side View.** Hip flexion of the swing leg measured between the thigh and body in the first frame that shows the support leg taking off.	
Recovery: Knee Flexion	0=Unclassifiable movement. 1=Flexion at the knee is >105°. 2=Flexion at the knee is between 90° – 105°. 3=Flexion at the knee is <90°.	**Side View.** Knee flexion of the swing leg measured between hip and ankle in the first frame that shows the support leg contacting the ground.	
Take-off	0=Unclassifiable movement. 1=Angle at knee joint is <150°. 2=Angle at knee joint is between 150° - 165°. 3=Angle at knee joint is >165°.	**Side View.** Knee flexion of the support leg measured between the hip and ankle in the first frame that shows the support leg taking-off.	
TOTAL			**/30**

(Carr, 1997; Fortney, 1983; Gallahue, 2002; Payne, 2002; Roberton & Halverson, 1984)
*General measurement area: angles are always measured on the leg or arm that is facing the side view camera during a point in which the participant is either just before, or in, the square that is marked by the four centre cones.
Scores of 0 which are described as being 'Unclassifiable' include the following movements: **a. Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Gross inconsistencies such that if a measurement were taken only from the defined 'General measurement area' (described above) the resulting score would not be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (eg. a child who overtly changes the movement characteristics of their running stride multiple times). **c.** Not applicable to this skill. **d.** Not applicable to this skill.

Table 3.01 Proficiency Assessment: Skipping

Ideal: Participant exhibits a consistent, proportional and rhythmical 'step-'hop' on one leg followed by a 'step-hop' on the other leg. Landing is toe first (heel does not contact the ground) with weight transferred to the supporting foot on the 'hop'. Arms move in a relaxed manner and in synchronous opposition to the legs. Movement follows a straight pathway.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Rhythm	0=Unclassifiable movement. 1=Sporadic rhythm. 2=Exaggerated movements but rhythm consistent. 3=Consistent rhythm with no exaggerated movements.	**Side View.** Viewed at full speed. Observe from the full width of peripheral view. Measured via visual observation.	
Leg Coordination	0=Unclassifiable movement. 1=Exhibits a galloping movement. 2=Exhibits a skipping movement however is uncoordinated or inconsistent (double hops or steps may occur). 3=Exhibits a step and hop on one leg followed by a step and hop on the other leg. Repeats this pattern consistently.	**Side View.** Viewed at full speed. Observe from the full width of peripheral view. Measured via visual observation.	
Vertical Component	0=Unclassifiable movement. 1=Exaggerated 'step' or 'leap' (could include exaggerated vertical component). 2=Exaggerated vertical component upon hop (does not included exaggerated step or leap). 3=Step and hop movements are in proportion to each other. Vertical hop is low.	**Side View.** Viewed at full speed. Observed from the full width of peripheral view. Measured via visual observation.	
Movement Path	0=Unclassifiable movement. 1=Movement does not follow a straight pathway. 2=Movement mostly follows a straight pathway. 3=Movement follows a straight pathway.	**Front View.** Measured via visual observation.	
Head Position	0=Unclassifiable movement. 1=Head downwards, eyes watching feet. 2=Head placement inconsistent. Head looks downwards at times. 3=Head held straight, looking forwards for the entire duration of the skill.	**Combined View.** Measure via visual observation.	
Arm Action	0=Unclassifiable movement. 1=Arms contribute very little to the movement. 2=Exaggerated use of arms in order to aid in lift-off during the 'hop' or are inconsistent in action (sometimes contribute little sometimes are relaxed and rhythmical). 3=Arms are rhythmical and relaxed in their movements (movement reduced during weight transfer).	**Side View.** Observe from one 'step' to another 'step'. Measured via visual observation.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Arm Opposition	0=Unclassifiable movement. 1=Both hands held consistently in front of body (ie. No opposition). 2=Limited or inconsistent opposition with both hands in front of the body at some point in time. 3=Full opposition with arms and legs moving in synchrony.	**Side View.** Wrist moves behind body on the backswing. Observe from the full width of peripheral view. Measured via visual observation.	
Foot Landing	0=Unclassifiable movement. 1=Heel toe landing (as would be seen during a stepping action). 2=Flat footed landing (heel touches the ground before weight transfer). 3=Toe first landing (heel does not touch the ground).	**Side View**. Observe from the frame showing foot contact with ground during the step. Measured via visual observation.	
Weight Transfer	0=Unclassifiable movement. 1=Weight transfer completed upon the 'step' movement before the 'hop'. 2=Weight transfers to supporting foot on the 'hop' but is inconsistent and/or awkward. 3=Weight transfers to supporting foot on the 'hop' and is consistent and rhythmical.	**Side View.** Observe from the landing of the step to the landing of the hop. Observe consistency and rhythm at full speed from the full width of peripheral view. Measured via visual observation.	
Swing Leg Position	0=Unclassifiable movement. 1=Swing leg's ankle held high (at or above support leg's knee) swing leg's thigh may also be held high. 2=Swing leg's ankle held between support leg's mid shin and knee. 3=Swing leg's ankle held low to the ground (between support leg's ankle and mid shin).	**Side View.** Observe from the point between lift-off of the hop and the landing of the hop. Measured via visual observation.	
TOTAL			**/30**

(Gallahue, 2002; Payne, 2002; Roberton & Halverson, 1984)
*General measurement area: Full width of side view.
Scores of 0 which are described as 'No observable skipping movement is made/Unclassifiable' includes the following movements: **a. Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Gross inconsistencies in the demonstrated movement skill such that if a measurement were taken only from one portion of the skill performance, the resulting score would not be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (eg. a child who initially exhibits a skipping movement but is unable to maintain this movement pattern throughout the measurement area (described above) and subsequently reverts to a different movement skill such as galloping or running). **c.** The performance of an unrelated skill such as running. **d.** The performance of movements which are precursors to skipping such as galloping (with the exception of the critical element, 'leg coordination' which accounts for the demonstration of a galloping movement).

Table 3.02 Proficiency Assessment: Vertical Jump

Ideal: Participant flexes knees to approximately 90° and draws arms straight back behind body in preparation for jump. Reaching arms swings upwards the through the sagittal plane with maximal tilt of the shoulder girdle while the non-reaching arm reaches downwards. Simultaneously, there is forceful and full extension from the legs and body. Landing is controlled (balance is maintained without the use of the arms) and there is very little displacement on landing from the point of take-off.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Preparatory Leg Position	0=No identifiable preparatory position/unclassifiable movement. 1=Knee flexion >120° or <60°. 2=Knee flexion 60° - 89°. 3=Knee flexion between 90° - 120°.	**Side View.** Measure angle between hip and ankle from the point at greatest flexion in crouch position.	
Arm Swing	0=Arm starts from a raised position/unclassifiable movement. 1=Arm bends upward rather than swings upward. 2=Arm is straight and swings forward and up starting from a position behind the body but must also swing to the side or backwards for balance. 3=Arm is straight and swings forward and up starting from a position behind the body.	**Side View.** Measured via visual observation. Observe from start of lift-off to the landing.	
Arm Coordination	0=Reaching arms starts from a raised position therefore, not coordinated with non-reaching arm/unclassifiable movement. 1=Other arm follows reaching arm. 2=Non-reaching arm does not follow reaching arm. 3=Non-reaching arm reaches downwards.	**Front View.** Measured via visual observation. Observe from the frame showing the highest point of jump.	
Arm Coordination with Legs	0=Arm starts from a raised position and is therefore not coordinated with leg actions/unclassifiable movement. 1=Arm actions are not coordinated with leg actions (arm does not lift simultaneously with legs). 2=Arm actions are partially coordinated with leg actions but do not contribute to jump height. 3=Arm actions are coordinated simultaneously with leg actions and contribute jump height.	**Side View.** Measured via visual observation. Observe from point of lowest crouch to point of highest jump.	
Shoulder Girdle and Arm Extension	0=Unclassifiable movement. 1=Arm is not fully extended at the elbow or shoulder. Minimal or no tilt of shoulder girdle. 2=Arm is either: not fully extended at the elbow or shoulder or, there is minimal tilt of shoulder girdle. 3=Arm is fully extended at the elbow and shoulder. Maximal tilt of shoulder girdle.	**Front View.** Measured via visual observation. Observe from the frame showing the highest point of jump.	
Head Action	0=Unclassifiable movement. 1=No head lift. 2=Small head lift up towards target. 3=Definite head lift up towards target.	**Front View.** Measured via visual observation. Observe from the frame showing the highest point of jump.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Leg Action on Take-off	0=Unclassifiable movement. 1=Knees flex to bring heals up towards buttocks. 2=Hips and knees extend fully, ankles do not extend fully. Extension of joints lacks power. 3=Full extension of hips, knees and ankles. Extension of joints is powerful.	**Side View.** Measured via visual observation. Observe from point at which toes leave the ground. Power viewed at full speed.	
Trunk Action on Take-off	0=Unclassifiable movement. 1=Body starts in an extended position. 2=Body does not entirely extend. 3=Full body extension.	**Side View.** Measured via visual observation. Observe from greatest point of extension.	
Leg Action on Landing	0=Unclassifiable movement. 1=Hips, knees and ankles do not flex to absorb landing force. Or, exaggerated absorption of force. 2=Hips and knees flex to absorb landing force but landing is flat footed or on toes. Landing may appear awkward or have a jarring appearance. 3=Controlled landing is from toes to heels with appropriate absorption of impact from hip knee and ankle.	**Side View.** Measured via visual observation. Observe foot landing from first frame showing foot contact with ground to last frame before child completes the skill.	
Displacement on Landing	0=Unclassifiable movement. 1=Landing is >0.3m square. 2=Landing is between 0.2m and 0.3m square. 3=Landing is <0.2m square.	**Combined View**. Set horizontal reference distance of 1m between the cones at the bottom of the screen in the side view. Measure from toes at point of take-off (frame just before toes leave ground) to point of landing (first frame to show toes touch ground). Repeat for front view.	
TOTAL			**/30**

(Gallahue, 2002; T. Martin & A. Stull, 1969)
*Assess the one arm vertical jump.
**Scores of 0 which are described as 'No observable skipping movement is made/Unclassifiable' includes the following movements: a. Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. b. Not applicable to this skill. c. Not applicable to this skill. d. The performance of movements which are precursor skills (in the case of vertical jump, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g. Arm Swing: arm starts from raised position/unclassifiable movement).

Table 3.03 Proficiency Assessment: Hopping

Ideal: Flight phase appears relaxed with no delay between successive take-offs and landings. The support leg's hip, knee then ankle flex, followed by a pretake-off extension in the hip, knee and ankle resulting in full leg joint extension during the flight phase. Landing occurs with a smooth transfer and absorption of force. Meanwhile, the non-support leg is held with the knee flexed to approximately 90°. The arms are carried close to the body with the elbow flexed to approximately 90° and lift upwards vigorously in conjunction with the support leg extension.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Arm Action	0=Unclassifiable movement. 1=Arms swing upward briefly and medially rotate at the shoulder prior to take-off. Or, arms move in response to a large loss of balance. 2=Arms move minimally as a result of hopping rhythm or due to a slight loss of balance. 3=Arms move up and down consistently.	**Side View.** Viewed at full speed. Measured via visual observation.	
Arm Coordination	0=Unclassifiable movement. 1=No coordination. Arm movements are sporadic or inconsistent due to loss of balance. 2=Arm action is minimal (and therefore cannot be truly 'coordinated'). 3=Arms are coordinated, moving together consistently.	**Side View.** Viewed at full speed. Measured via visual observation.	
Arm Position	0=Unclassifiable movement. 1=Arms are both held in abducted positions to aid in balance (may be asymmetrical or symmetrical). 2=Arms are asymmetrical (one arm adducted one arm abducted). Or, both arms are adducted but with elbows approximately straight. 3=Arms are held in symmetrical, adducted positions with both elbows flexed to approximately 90°.	**Combined View.** Adduction/abduction and elbow flexion measured via visual observation.	
Arm Coordination with Legs	0=Unclassifiable movement. 1=Arm movement is not coordinated with leg action. Arms move in response to loss of balance rather than contributing to jump. 2=Arms action is either minimal (and therefore cannot be truly coordinated with legs) or inconsistently coordinated with leg action. 3=Arms move purposefully and in opposition to hopping leg in order to contribute to jump height.	**Side View.** Viewed at full speed. Measured via visual observation.	
Flight Phase	0=Unclassifiable movement. 1=Vertical displacement is a result of pulling the foot up off the floor. Or, foot barely clears floor. 2=Flight phases appear stiff and somewhat awkward. There may be a slight delay between successive jumps. 3=Flight phases appear relaxed and occur in rapid succession as a result of successive joint flexion and extension. Perceptible pretake-off extension occurs in the support leg, hip, knee, and ankle.	**Side View.** Viewed at full speed. Measured via visual observation.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Swing Leg Position	0=Unclassifiable movement. 1=Thigh held between 45°and 90°. 2=Either thigh approximately vertical (<45°) or knee flexed to ≤90°. 3=Thigh approximately vertical (<45°) and knee flexed to ≤90°.	**Side View.** Position of thigh measured from between vertical line down from hips to thigh. Knee angle measured between ankle and thigh. Measure angles on third jump on landing.	
Support Leg: Take-off and Flight Phase	0=Unclassifiable movement. 1=Foot is lifted off the floor by bending at the knee or by lifting the knee upwards (may resemble a stomping action). Or, foot barely clears floor. 2=Take-off and flight phase appear stunted (hip, knee and ankle do not extend fully in air or time off ground is minimal). 3=Take-off and flight phase occur smoothly and legs (hip, knee and ankle) extend fully in the air.	**Side View.** Viewed at full speed. Measured via visual observation.	
Support Leg: Landing	0=Unclassifiable movement. 1=Landing resembles the 'catching' of the body's weight (resembling a stomping action) or, hip, knee and ankle joint do not flex to absorb landing force. 2=Landing appears stiff and awkward however, hip, knee and ankle absorb landing force with a small delay between successive take-off and landings. 3=Smooth transfer and absorption of force from the hip, knee and ankle from take-off and landing. No delay between successive take-off and landings.	**Side View.** Measured via visual observation.	
Head Position	0=Unclassifiable movement. 1=Head looks down at feet. 2=Head sometimes stays straight, sometimes looks down at feet. 3=Head stays straight, looking forward.	**Side View.** Measured via visual observation.	
Body Position	0=Body turns while performing the skill/unclassifiable movement. 1=Trunk is not held consistently in a stable position (moves in response to loss of balance). 2=Trunk is held in a stable position but is not upright. 3=Trunk is held consistently in a stable position, upright and vertical (within 10°).	**Side View.** Measure via visual observation. For a score of 3, measured angle btw vertical line drawn up from hips and line from hips to shoulders.	
TOTAL			**/30**

(Gallahue, 2002; Lolas Halverson & Kathleen Williams, 1985; Payne, 2002)

*Assess the first leg chosen by the child.

Scores of 0 which are described as being 'Unclassifiable' include the following movements: **a. Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b**. Gross inconsistencies such no one measurement could be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (e.g., a child who overtly changes the movement characteristics of their hopping multiple times) **c.** Not applicable to this skill. **d.** The performance of movements which are precursor skills (in the case of hopping, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g., Body Position: body turns while performing the skill/unclassifiable movement).

Table 3.04 Proficiency Assessment: Horizontal Jump

Ideal: Take-off is two-footed and simultaneous with the participant's arms and legs extending fully (hips hyper-extending). The body has a forward lean of >30° during take-off and flight. During flight, the arms lower to reach forward in preparation for landing while the knees flex followed by hips flexing to bring the legs into a 'tucked' position where the thighs are approximately horizontal. The knees then extend forward of the body in preparation for landing. Landing is two-footed and on heels.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Body Position on Take-off	0=Unclassifiable movement. 1=Trunk leans forward slightly (< 30°). 2=Trunk leans forward (30° - 60°). 3=Trunk leans forward (>60°).	**Side View**. Measure angle between vertical line drawn up from hips and from line drawn between hips and shoulders in the first frame before the feet have left the ground.	
Knee Angle on Take-off	0=Movement is from a one foot take-off/Unclassifiable movement. 1=Knees primarily maintain flexion, extending little into take-off (<140°). 2=Knees extend almost fully into take-off (140° - 160°). 3=Knees extend fully into take-off (>160°).	**Side View.** Measure via visual observation. For a score of 2 or 3, measure angle between hip and ankle in the first frame before the feet have left the ground.	
Hip Angle on Take-off	0=Movement is from a one foot take-off/Unclassifiable movement. 1=Hips partially extend upon take-off (<170°). 2=Hips extend during take-off (170° - 180°). 3=Hips hyperextend into take-off (>180°).	**Side View.** Measure angle between shoulder, hip and knee in the first frame before the feet have left the ground.	
Arm Action During Flight	0=Unclassifiable movement. 1=Arms abduct. Or, elbows are bent and arms extend minimally (<145°). 2=Minimal to no abduction. Either, elbows straight, or arms reach near full extension (≥145°). 3=No abduction. Elbows straight and arms reach full extension (>165°).	**Combined View.** Abduction and elbow angle measured via visual observation. Extension measured from side view by measuring angle between elbow, shoulder and hip at the point of greatest arm extension.	
Leg Position During Flight	0=Legs do not 'tuck' or are asymmetrical/Unclassifiable movement. 1=Legs 'tuck' minimally (>45° below horizontal). 2=Legs 'tuck' partially (15° - 45° below horizontal). 3=Legs 'tuck' fully (within 15° of horizontal).	**Side View.** Measure angle between horizontal line drawn out from hips and thighs at the point of greatest flexion during flight.	
Leg Action During Flight	0=Legs do not 'tuck'/Unclassifiable movement. 1=Legs are asymmetrical throughout flight. 2=Legs are symmetrical throughout the entire flight. Knees and hips flex simultaneously. 3=Legs are symmetrical throughout flight. Knees flex before hips.	**Combined View.** Measured via visual observation. View leg symmetry from the front and side views and leg action from the side view.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Arm Action on Landing	0=Arms are not used during the movement/Unclassifiable movement. 1=Arms move to maintain balance. Arms may abduct and medially rotate (parachute landing). 2=Arms lower from flight position but end out to the side of the body or continue through to end behind body. 3=Arms lower from flight position to reach forward at landing.	**Side View.** Measured via visual observation. Observed between the first frame that shows foot contact with ground and the last frame before the child stands up or walks away after completing the skill.	
Leg Action on Landing	0=Movement is from a one foot take-off/Unclassifiable movement. 1=Knees are not extended for landing. Landing resembles more of a catch. 2=Knees extend for landing. 3=Knees extend forward for landing (feet are forward of centre of gravity).	**Side View.** Measured via visual observation. Observe leg action during flight to landing.	
Foot Coordination	0=Feet do not take-off or land simultaneously (as might be seen as the result of a one foot take-off) /Unclassifiable movement. 1=Feet either take-off simultaneously or land simultaneously. 2=Feet take off and land simultaneously. Landing is either flat footed or on toes. 3=Feet take-off and land simultaneously. Landing is on heels.	**Side View.** Measured via visual observation. Observe foot coordination from take-off to landing (first frame that shows feet leaving the ground to the first frame that shows the feet contacting the ground).	
Balance	0=One foot landing/Unclassifiable movement. 1=Balance is lost (child falls or must step/hop forward to maintain balance). 2=Balance is unstable. Child is able to maintain landing by lifting onto toes or swinging arms. 3=Balance is maintained. Child 'sticks' landing.	**Side View.** Measured via visual observation. Observe from landing (first frame that shows foot contact with ground) to the last frame before the child stands up or walks away after completing the skill.	
TOTAL			**/30**

(Gallahue, 2002; T Horita et al., 1991; Roberton & Halverson, 1984; M. Wakai & N. Linthorne, 2005)
*Scores of 0 which are described as being 'Unclassifiable' includes the following movements: **a.** An unusual movement which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Not applicable to this skill. **c.** Not applicable to this skill. . **d.** The performance of movements which are precursor skills (in the case of horizontal jump, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g. Knee Angle on Take-off: Movement is from a one foot take-off/Unclassifiable movement).

Table 3.05 Proficiency Assessment: Jump from a Height

Ideal: Participant flexes their knees and hips in preparation and then extends hips and knees on take-off. Take-off is two-footed with feet together. Body stays vertical throughout jump with arms held out to the sides for balance. Landing is from toes to heels with ankles, knees and hips flexing to absorb impact. Participant is able to maintain balance on landing.

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Arm Action	0=Unclassifiable movement. 1=One arm pinned to side while other is used to maintain balance or exaggerated/ineffective use of arms for balance. 2=Minimal use of arms. 3=Arms held out to the sides for balance and contribute to height of jump.	**Front View.** Measured via visual observation.	
Knee Joint on Take-off	0=Step down movement/Unclassifiable movement. 1=Knees do not flex in preparation or extend upon take-off. 2=Minimal preparatory flexion and/or extension of knee joint upon take-off (movement may appear stiff or awkward. Or, movement may resemble a 'hop' down movement). 3=Knee joint flexes in preparation and also extends upon take-off.	**Side View.** Measured via visual observation.	
Hip Joint on Take-off	0=Step down movement/Unclassifiable movement. 1=Hip joint does not flex in preparation or extend upon take-off. 2=Minimal preparatory flexion and/or extension of hip joint upon take-of (movement may appear stiff or awkward. Or, movement may resemble a 'hop' down movement). 3=Hip joint flexes in preparation and then extends upon take-off.	**Side View.** Measured via visual observation.	
Take-off	0=Step down movement/Unclassifiable movement. 1=One foot leads on take-off (feet are unsynchronized on take-off but not due to a 'step' down movement). 2=Two foot take-off but feet are asymmetrical shortly after take-off. 3=Two foot take-off and feet are symmetrical on take-off.	**Combined View.** Measured via visual observation.	
Flight Phase	0=Step down movement/Unclassifiable movement. 1=Flight phase due to either knees lifting upwards or heals lifting to buttocks. 2=Minimal flight phase (as would be exhibited in a hop down motion) or, definite flight phase however, either knees are brought upwards or heels lifted to buttocks. 3=Definite flight phase (as would be exhibited in a jump down motion).	**Side View.** Measured via visual observation.	
Lateral Body Alignment During Flight	0=Unclassifiable movement. 1=Body twists or bends laterally during jump. 2=Body appears 'loose' or unstable during jump (flight phase lacks control). 3=Body stays straight throughout jump (controlled flight phase).	**Combined View.** Measured via visual observation.	

Critical Element	Description of Movement Pattern	Measurement Notes	Score /3
Ankle Flexion on Landing	0=Step down movement/Unclassifiable movement. 1=Little to no flexion of ankle therefore, does not absorb force appropriately (ie. landing is on toes and heels do not lower to ground). 2=Flexion at ankle increases for force absorption however, landing may be flat footed or heel first. 3=Flexion at ankle is appropriate to absorb landing force.	**Side View.** Measured via visual observation.	
Knee and Hip Flexion on Landing	0=Step down movement/Unclassifiable movement. 1=Little to no flexion at the knee and hip. 2=Exaggerated flexion at knee and hip. 3=Flexion at knee and hip relative to height of jump.	**Side View.** Measured via visual observation.	
Foot Landing	0=Step down movement/Unclassifiable movement. 1=Feet do not land simultaneously (feet are unsynchronized on landing but not due to a 'step' down movement). 2=Feet land simultaneously, however landing is flat footed, heel first or toe-first but heels do not lower fully to the ground. 3=Feet land simultaneously and toes contact ground first with heels lowering fully to the ground.	**Combined View.** Measured via visual observation.	
Balance	0=Step down movement/Unclassifiable movement. 1=Balance is lost. Child must step or hop forward to keep from falling. 2=Balance is maintained by lifting onto toes or swinging arms. 3=Balance is maintained. Child 'sticks' landing.	**Combined View.** Measured via visual observation.	
TOTAL			**/30**

(Gallahue, 2002)

*Scores of 0 which are described as being 'Unclassifiable' includes the following movements: **a.** An unusual movement which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason **b.** Not applicable to this skill **c.** Not applicable to this skill **d.** The performance of movements which are precursors to a 'jump down' movement, such as a 'step down' movement.

**A 'Step down movement' refers to a child who seems to *require* a one foot take-off in order to maintain their balance as they leave the box. This will present as a definite stepping down movement with the leading foot stepping down below the box height level before the remaining foot leaves the surface of the box. This does not refer to a child whose feet fail to simultaneously leave the box or whose feet simply come apart as they hop of jump off of the box.

could not be appropriately classified as a score of 1, 2, or 3 (refer to the footnotes located at the bottom of the individual assessment tools for each skill in Tables 3.00 to 3.05). Scores for each critical element were tallied for a total score out of 30. Each item score was summed to achieve a total score for that locomotor skill. A score of 30 out of 30 represents the greatest degree of proficiency in a movement skill.

3.6 Statistical Analysis

Variables were tested for the assumptions of each specific analysis. Due to the large number of analyses performed, significance was set at $p < .01$. Missing data was removed from the analysis pairwise such that a participant's data was only excluded if their missing score was for a variable involved in the analysis. If their missing score was for a variable not involved in the analysis their data was retained.

Descriptive statistics were used to determine the FMS proficiency in boys and girls. Means and standard deviations for each FMS critical element were calculated. Overall means and standard deviations for each FMS were also calculated. Also calculated were the means, standard deviations, high and low scores for individual critical elements to determine those movement characteristics which were particularly challenging for our participant group. Further, a separate analysis was performed looking at the frequency of zero scores in each critical element and the primary reason for their assignment (see foot notes on individual assessment tools in Tables 3.00 to 3.05).

To determine gender differences between fundamental locomotor skills a Gender (2) x Fundamental Locomotor Skill (6) Analysis of Variance (ANOVA) was conducted. Variables were assessed for normal distribution via the Kolmogorov-Smirnov test and for homogeneity of variance using Levene's test. Non-normally distributed data was log transformed and the analysis was performed a second time. The non-parametric Kruskal-Wallis test was performed to corroborate the ANOVA results and because the skipping distribution could not be corrected by the log transformation.

Bivariate correlations were performed using the Spearman correlation coefficient in the case of non-normally distributed data. Hierarchical multiple regression analyses were performed to determine which FMS skills best predicted our health and fitness indicators. For each regression model, a health or fitness indicator was entered as the dependent variable. Health and fitness variables were entered into the first block of predictor variables to determine the relationship between FMS proficiency and health and fitness indicators independent of other health and fitness indicators. To determine the unique contribution of FMS to the dependent variable, the second block of the regression model consisted of FMS skills. Only variables showing significant relationships in the bivariate correlation matrix were entered into the regression analyses. Since previous investigations [11, 16, 17, 19, 92, 109] have found significant differences between males and females, correlation and regression analyses were performed separately for males and females. We also performed analyses on combined male and female data sets and controlled for gender to determine whether gender moderated the findings. Possible multicollinearity among predictor variables was assessed by searching for zero order correlation coefficients R >.30. For regression models containing predictor variables with correlation coefficients R >.30, multicollinearity was then assessed by examining collinearity statistics; specifically the variance inflation factor (VIF) and tolerance statistics. Regression analyses were further assessed for homoscedasticity and linearity by plotting *ZRESID against *ZPRED. Normally distributed and independent errors were determined with the use of normal probability plots and the Durbin-Watson test.

Data were analyzed using SPSS statistical software for Windows version 12.0.

CHAPTER IV: RESULTS

4.1 Participant Characteristics

General descriptive, anthropometric and health and fitness characteristics are provided in Figures 4.00 to 4.05. Table 4.00 displays the mean BMI values for boys and girls by age and the percent prevalence of overweight and obesity. The percentage of children classified as overweight or obese was determined using internationally established age- and sex-specific criteria [72]. Mean BP measurements were normal for both sexes however, 4.3% of boys and 6.6% of girls were classified as having high systolic BP (>120mmHg). Unfortunately, cut-off values associated with increased health risk are not available for children in the arterial compliance, waist circumference or the fitness measurements employed. Mean diastolic BP (males 55.5 ± 5.7 vs. females 57.8 ± 5.8), small artery compliance (males 6.1 ± 2.2 vs. females 5.2 ± 1.8) and sit-and-reach (males 25.9 ± 5.5 vs. females 31.0 ± 7.4) scores were significantly different between boys and girls ($p < .01$) with boys demonstrating lower diastolic BP and higher small artery compliance measurements and girls demonstrating a greater degree of flexibility in sit- and- reach.

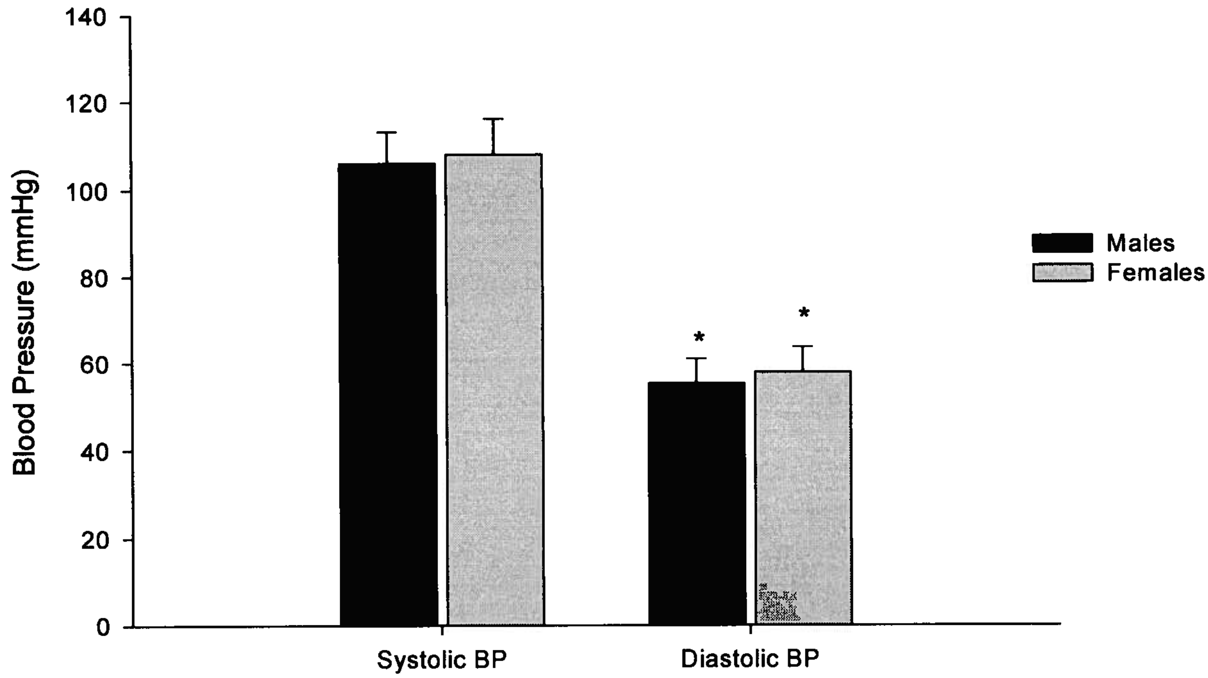
4.2 Movement Skill Proficiency

4.2.1 Critical Elements

Figures 4.06 through 4.11 display the means and standard deviations for the critical elements assessed for each FMS (see Tables 3.00 through 3.05 for descriptions of each critical element).

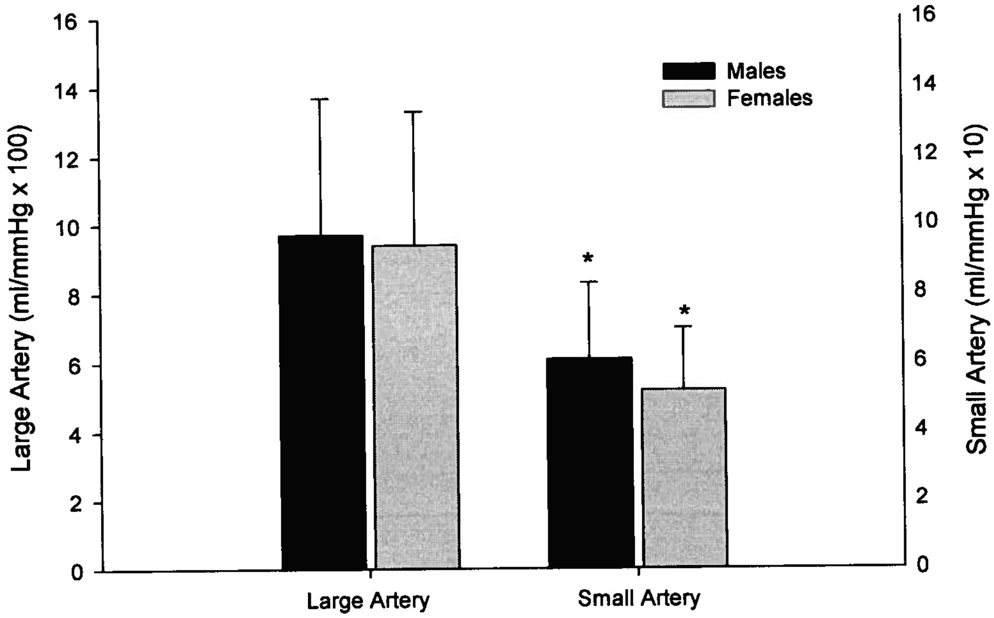
For the skill of running, males and females scored lowest in the critical element Elbow Flexion (mean 1.2 ± .5). Scores for the critical element Take-off were the highest in males (mean 2.2 ± .6) and Take-off (mean 2.2 ± .5) and Leg Drive (mean 2.2 ± .7) were the highest in females.

Results for skipping showed the critical elements Foot Landing (mean 1.0 ± .2) and Weight Transfer (mean 0.8 ± .4) to be the lowest and the critical elements Movement Path (mean 2.3 ± 1.1) and Leg Coordination (mean 2.3 ± 1.1) to be the highest in males. The results for skipping in females indicated that scores for the critical elements Weight Transfer (mean 0.9 ± .3) and Foot Landing (mean 1.0 ± .4) were the



*significantly different between males and females $p < .01$

Figure 4.00 Mean Blood Pressure as a Function of Gender



*significantly different between males and females $p < .01$

Figure 4.01 Mean Arterial Compliance as a Function of Gender

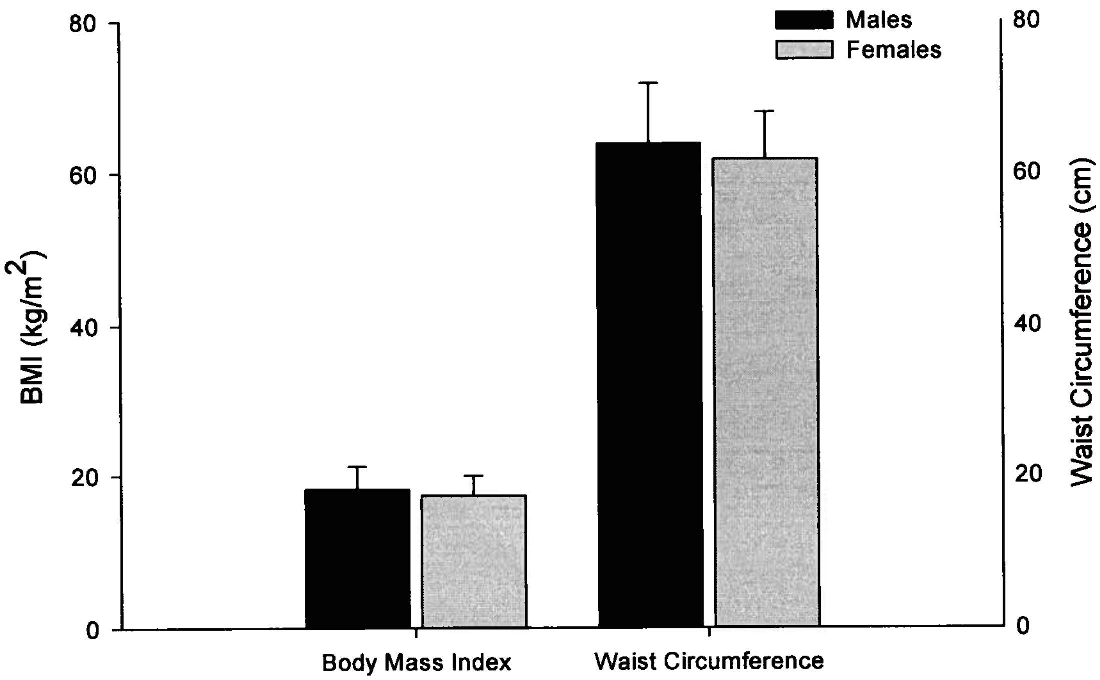


Figure 4.02 Weight Status as a Function of Gender

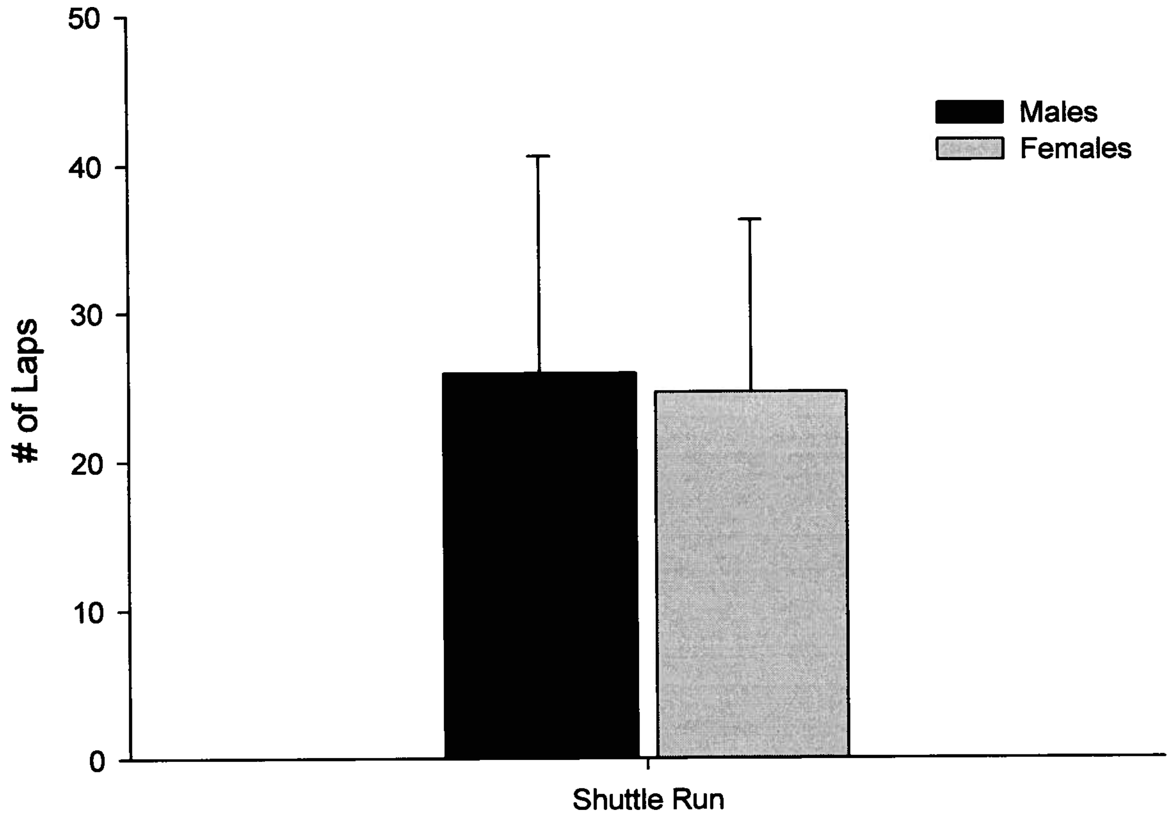


Figure 4.03 Cardiorespiratory Fitness as a Function of Gender

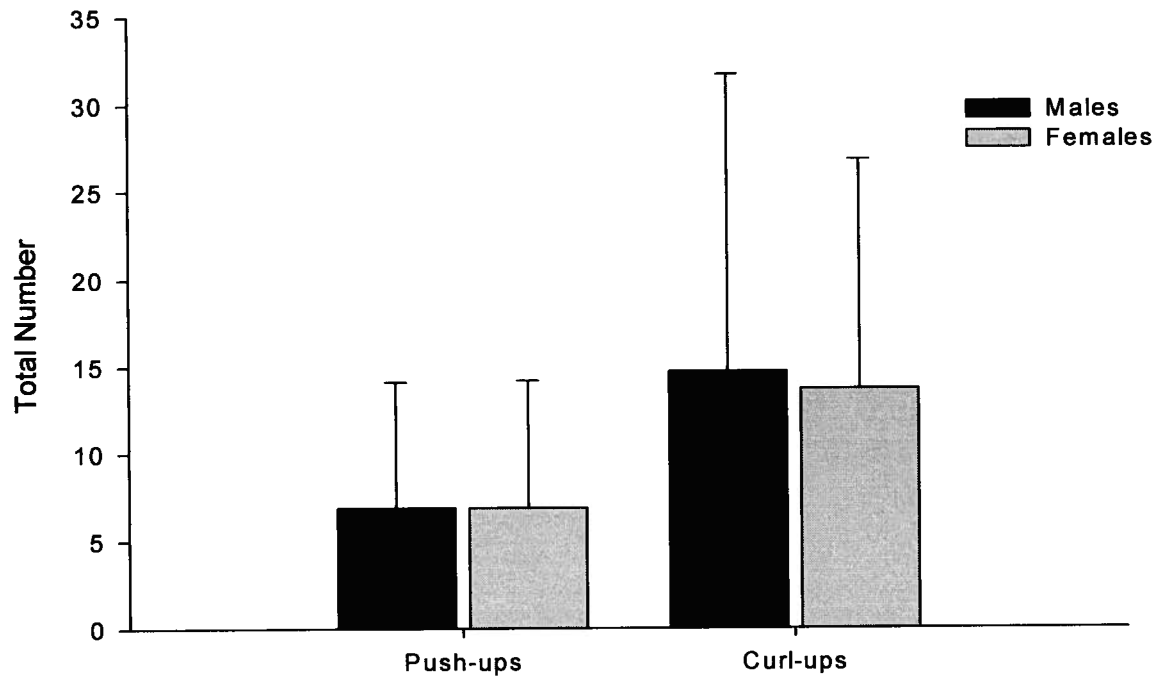
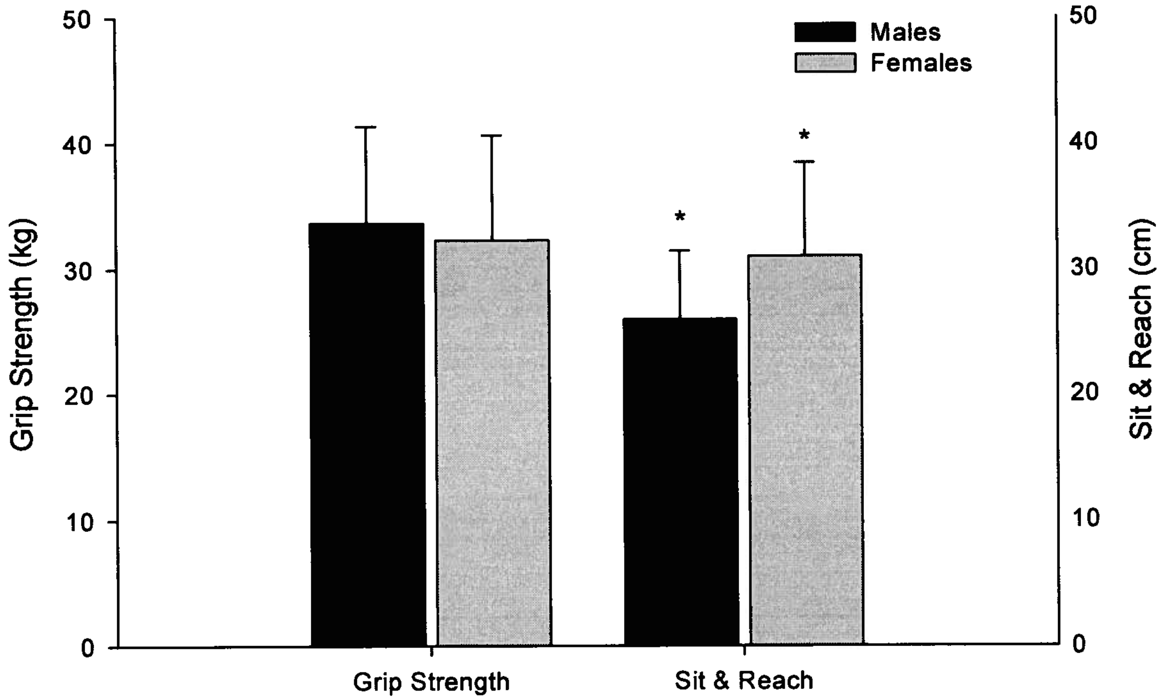


Figure 4.04 Mean Push-ups and Curl-ups as a Function of Gender



*significantly different between males and females $p < .01$

Figure 4.05 Grip Strength and Sit & Reach as a Function of Gender

Table 4.00 Means and SDs of BMI Values for Boys and Girls by Age and Percent Prevalence of Overweight and Obese

Age (years)	N	Males	% Overweight	% Obese	N	Females	% Overweight	% Obese
8yrs	1	18.6	0	0	n/a	n/a	n/a	n/a
9yrs	15	18.1 ± 3.2	33.3	6.7	18	17.3 ± 2.9	16.6	5.5
10yrs	38	17.5 ± 2.3	18.4	0	48	17.2 ± 2.4	12.5	2.1
11yrs	16	19.7 ± 3.8	6.3	18.8	25	18.1 ± 2.7	16.0	0

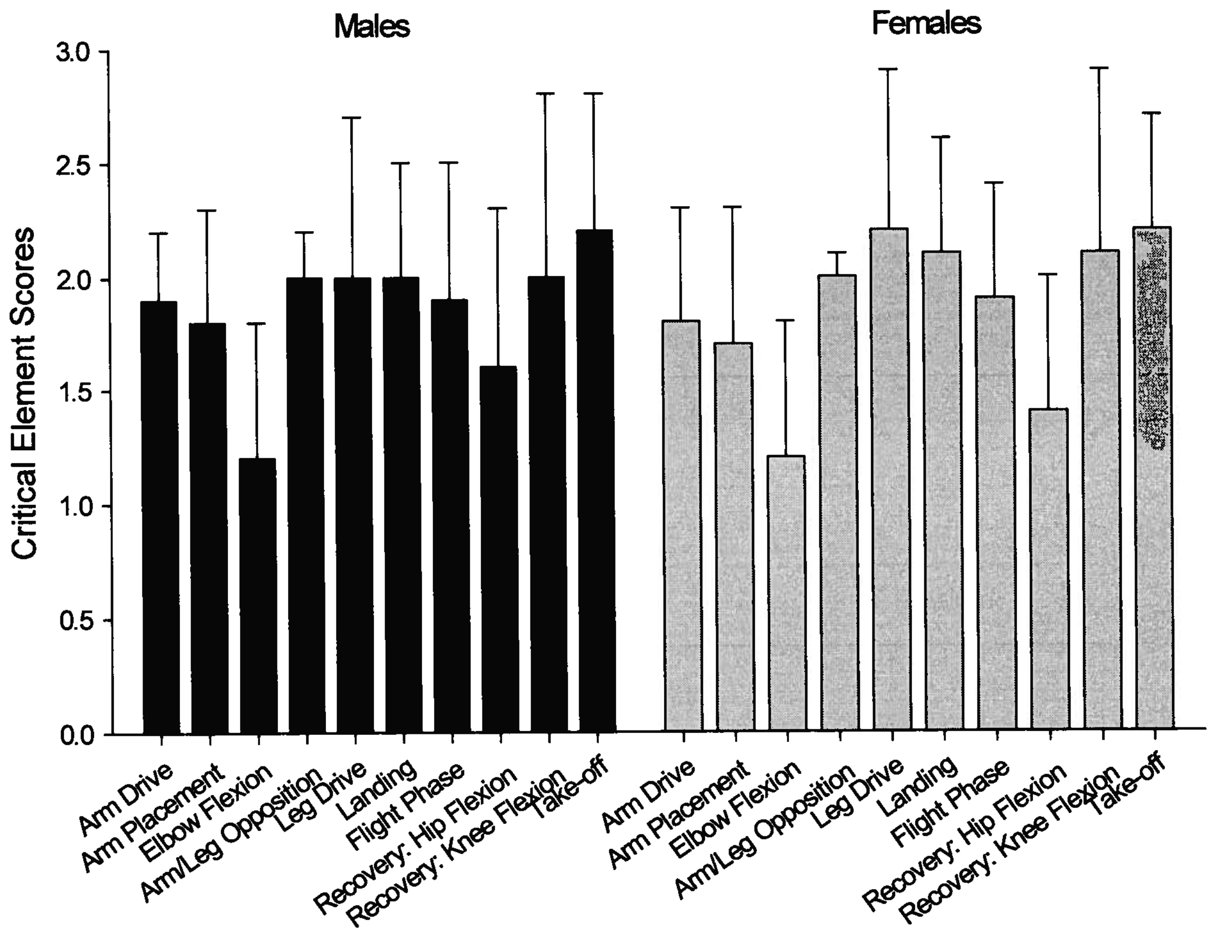


Figure 4.06 Critical Element Scores for Running in Males and Females

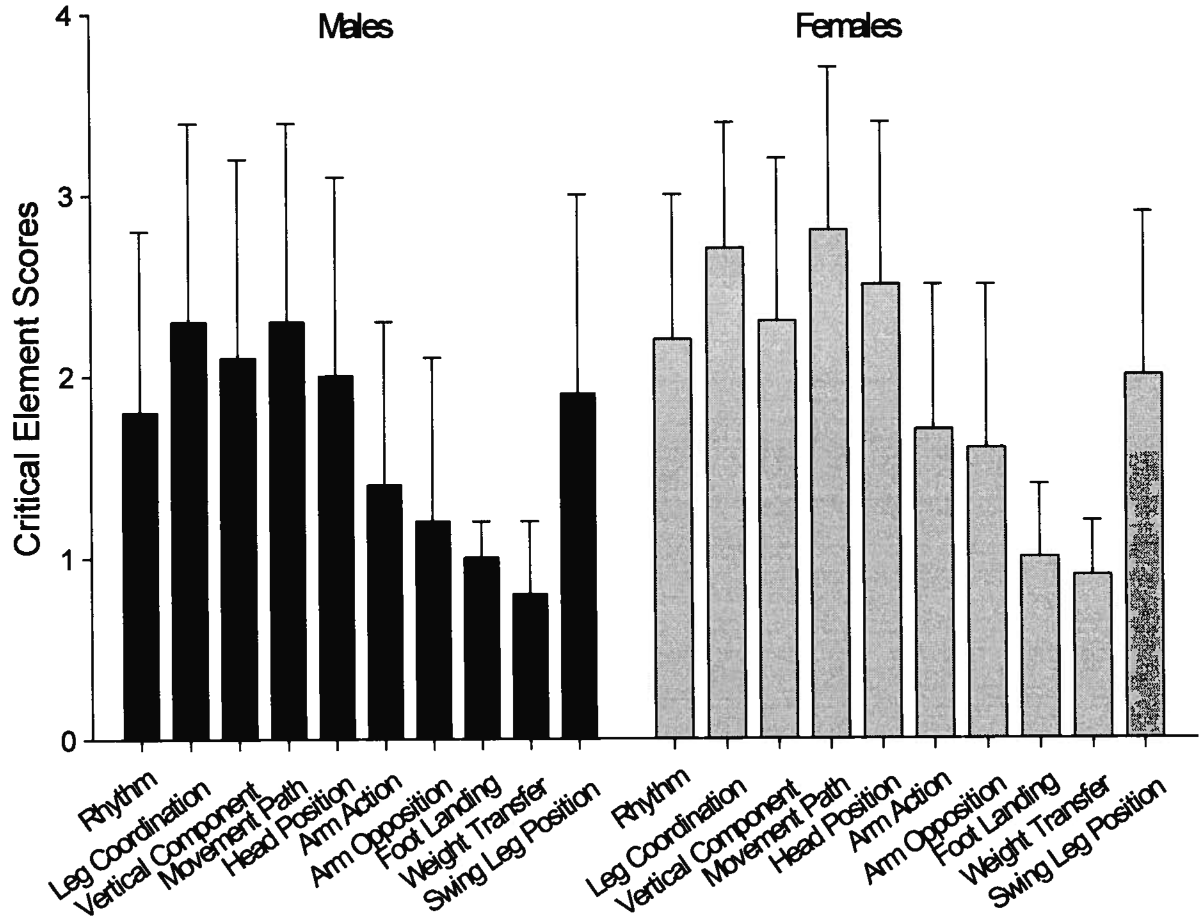


Figure 4.07 Critical Element Scores for Skipping in Males and Females

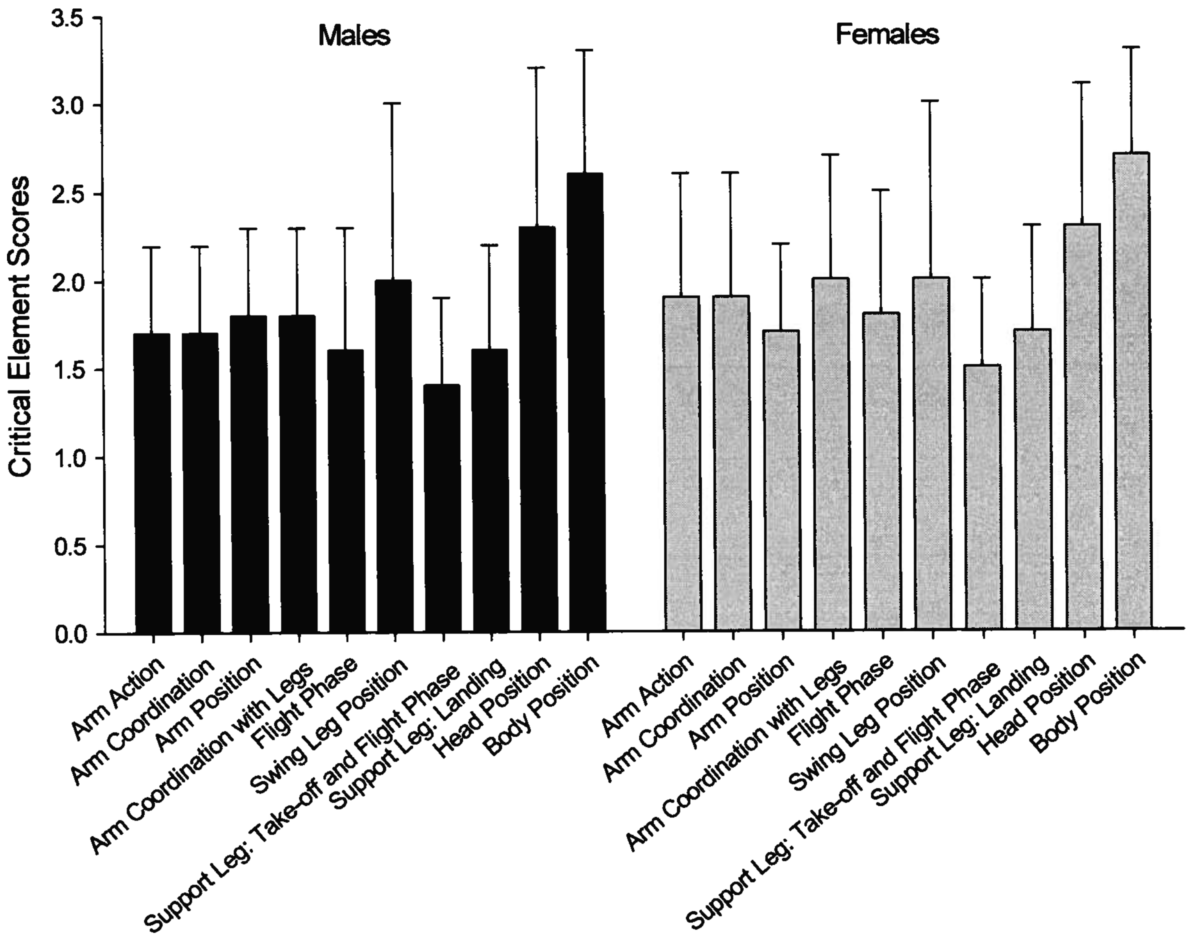


Figure 4.08 Critical Element Scores for Hopping in Males and Females

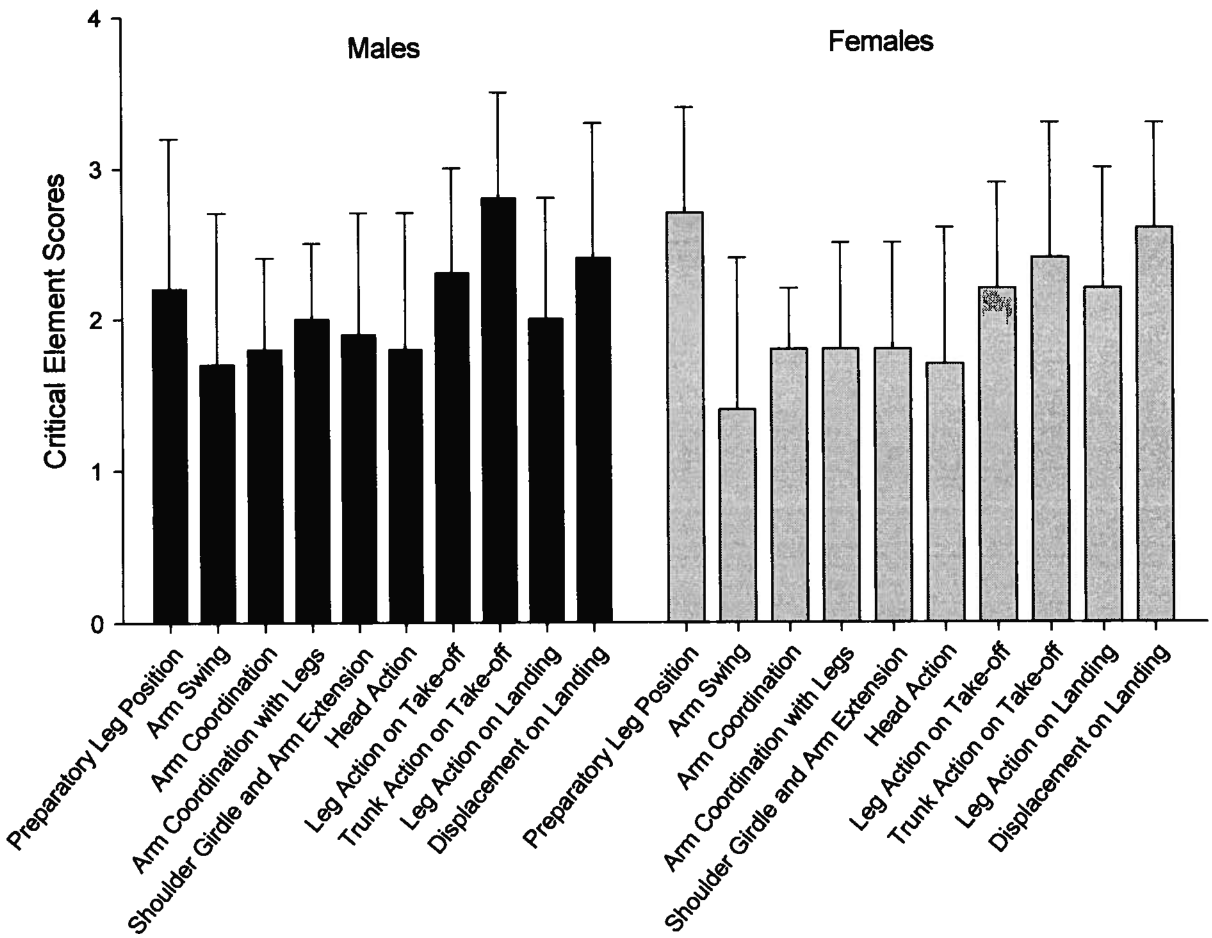


Figure 4.09 Critical Element Scores for Vertical Jumping in Males and Females

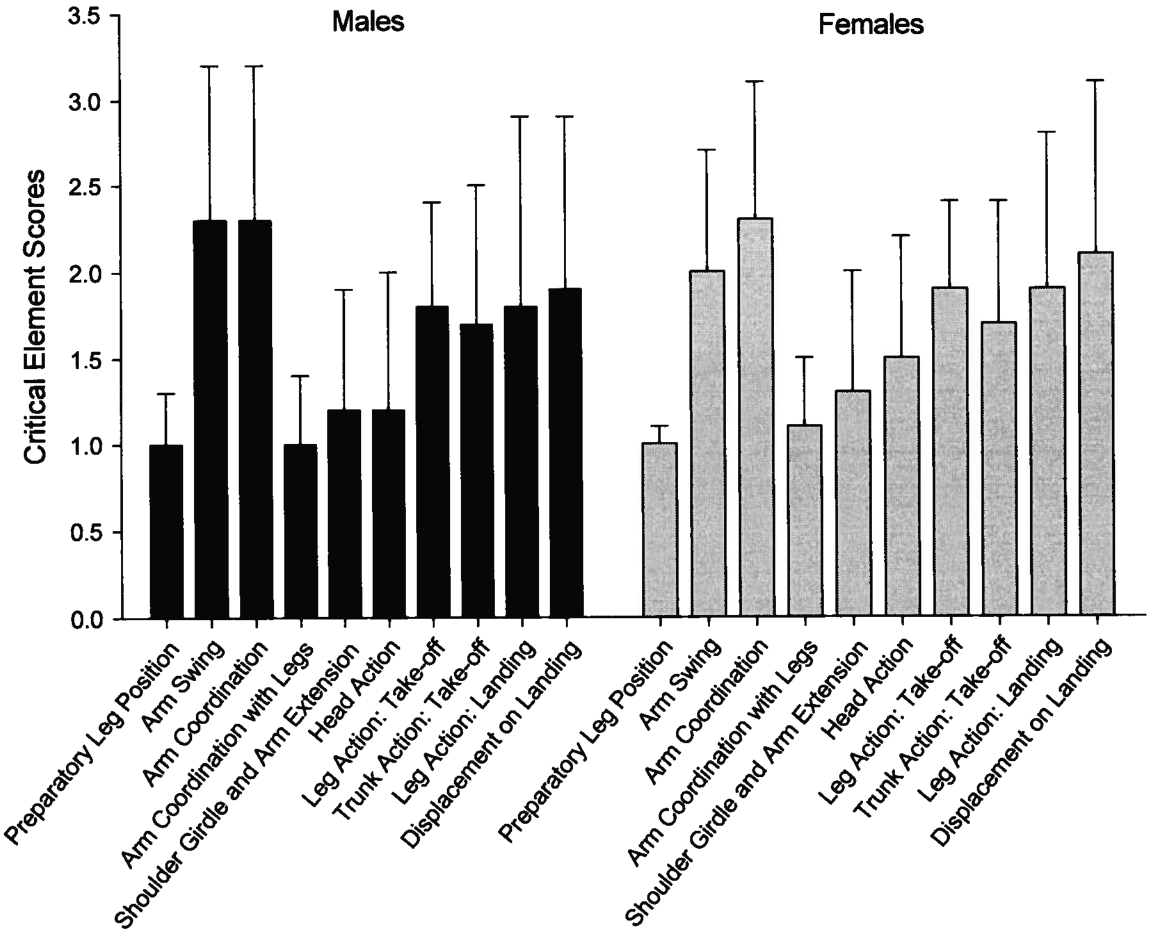


Figure 4.10 Critical Element Scores for Horizontal Jumping in Males and Females

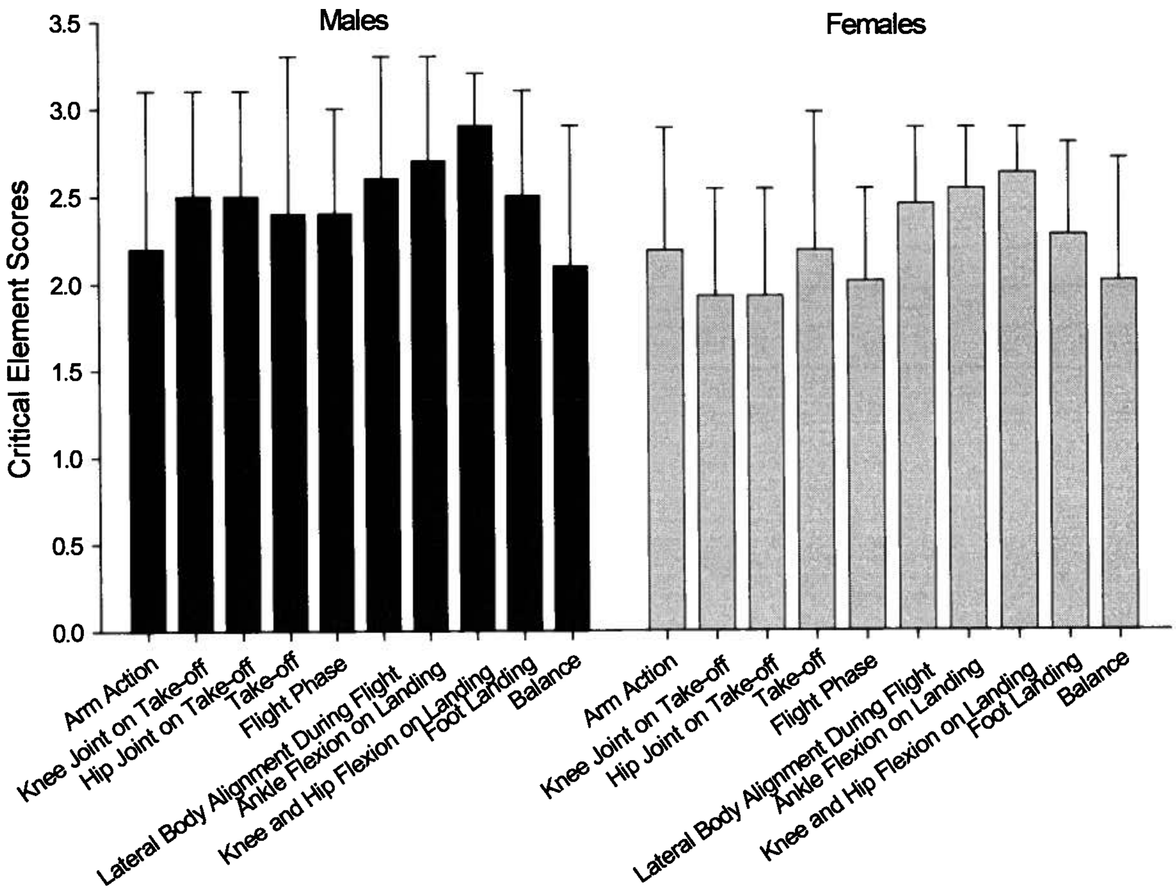


Figure 4.11 Critical Element Scores for Jumping from a Height

lowest while Movement Path scores were the highest (mean 3.0 ± .2). Support Leg: Take-off and Flight Phase (males mean 1.4 ± .5, and females 1.5 ± .5), represents the lowest critical element scores and Body Position (males mean 2.6 ± .6, females 2.7 ± .5) represented the highest critical element scores for hopping in both genders.

The lowest critical element scores for vertical jump are Head Action in males (mean 1.8 ± .9) and Arm Swing (males mean 1.7 ± 1.0, females mean 1.4 ± 1.0). The highest critical element score is for Trunk Action on Take-off (mean 2.8 ± .7) in males and Preparatory Leg Position (mean 2.7 ± .7) in females.

The lowest critical element scores for horizontal jump are Preparatory Leg Position (mean 1.0 ± .3) and Arm Coordination with Legs (mean 1.0 ± .4) in males and Preparatory Leg Position (1.0 ± .1) in females. The highest critical elements are Arm Swing (mean 2.3 ± .9) and Arm Coordination (mean 2.3 ± .9) in males and Arm Coordination (mean 2.4 ± .6) in females.

In jump from a height, male scores were the lowest in the critical element of Balance (mean 2.1 ± .8) and highest in the critical element of Knee and Hip Flexion on Landing (mean 2.9 ± .3). Females scored lowest in the critical elements Knee Joint on Take-off (mean 2.2 ± .7) and Hip Joint on Take-off (mean 2.2 ± .7). Females scored highest in the critical element of Knee and Hip Flexion on Landing (mean 3.0 ± .3).

4.2.2 Zero Scores

The percentages of children who scored a zero in at least one critical element are listed for each FMS in Table 4.01. Tables 4.02 through 4.07 display the specific number of children who scored zero in each critical element. The lowest percentage of zero scores was seen in jump from a height where 1.1% of females and 2.9% of males scored zero in at least one critical element. In males, horizontal jump had the greatest percentage of children (25.7%) who scored zero in at least one critical element; whereas hopping exhibited the greatest percentage zero scores in at least one critical element (15.4%) for girls. Only in skipping did scores of zero on individual critical elements translate into an overall score of zero. This resulted in 11.4% and 4.4% of boys and girls, respectively displaying overall scores of zero.

Table 4.01 Percentage of children who scored zero in at least one critical element

	Males (N = 70)	Females (N = 91)
Run	8.6%	9.9%
Skip	22.9%	7.7%
Hop	18.6%	15.4%
Vertical Jump	14.3%	14.3%
Horizontal Jump	25.7%	14.3%
Jump from a Height	2.9%	1.1%

Table 4.02 Number of children with zero scores in each critical element for Run and most commonly attributed reason

	Males (n=6)		Females (n=9)	
Critical Element	**# of Zero Scores**	**Most Common Reason***	**# of Zero Scores**	**Most Common Reason***
Arm Drive	1	b	4	a and b
Arm Placement	2	a and b	4	a and b
Elbow Flexion	4	a and b	9	b
Arm/Leg Opposition	1	a	0	n/a
Leg Drive	1	a	0	n/a
Landing	1	a	0	n/a
Flight Phase	1	a	0	n/a
Recovery: Hip Flexion	1	a	0	n/a
Recovery: Knee Flexion	1	a	0	n/a
Take-off	1	a	0	n/a

***a.** Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Gross inconsistencies such that if a measurement were taken only from the defined 'General measurement area' (described above) the resulting score would not be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (e.g., a child who overtly changes the movement characteristics of their running stride multiple times). **c.** Not applicable to this skill. **d.** Not applicable to this skill.

Table 4.03 Number of children with zero scores in each critical element for Skip and most commonly attributed reason

Critical Element	Males (n=16)		Females (n=7)	
	# of Zero Scores	Most Common Reason*	# of Zero Scores	Most Common Reason*
Rhythm	11	c	5	c
Leg Coordination	9	c	6	c
Vertical Component	12	c	7	c
Movement Path	11	c	6	c
Head Position	11	c	6	c
Arm Action	16	c	6	c
Arm Opposition	16	c	6	c
Foot Landing	12	c	7	c
Weight Transfer	12	c	7	c
Swing Leg	12	c	6	c

***a.** Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Gross inconsistencies in the demonstrated movement skill such that if a measurement were taken only from one portion of the skill performance, the resulting score would not be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (e.g., a child who initially exhibits a skipping movement but is unable to maintain this movement pattern throughout the measurement area (described above) and subsequently reverts to a different movement skill such as galloping or running). **c.** The performance of an unrelated skill such as running. **d.** The performance of movements which are precursors to skipping such as galloping (with the exception of the critical element, 'leg coordination' which accounts for the demonstration of a galloping movement).

Table 4.04 Number of children with zero scores in each critical element for Hop and most commonly attributed reason

Critical Element	Males (n=13)		Females (n=14)	
	# of Zero Scores	Most Common Reason*	# of Zero Scores	Most Common Reason*
Arm Action	3	a	0	n/a
Arm Coordination	2	a	0	n/a
Arm Position	3	a	0	n/a
Arm Coordination with Legs	2	a	0	n/a
Flight Phase	0	n/a	0	n/a
Swing Leg Position	11	b	13	b
Support Leg: Take-off & Flight	0	n/a	1	b
Support Leg: Landing	0	n/a	0	n/a
Head Position	0	n/a	0	n/a
Body Position	1	b	0	n/a

***a.** Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b**. Gross inconsistencies such no one measurement could be representative of the entire skill performance or would otherwise give an invalid impression of the child's level of skill performance (e.g., a child who overtly changes the movement characteristics of their hopping multiple times) **c.** Not applicable to this skill. **d.** The performance of movements which are precursor skills (in the case of hopping, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g., Body Position: body turns while performing the skill/unclassifiable movement).

Table 4.05 Number of children with zero scores in each critical element for Vertical Jump and most commonly attributed reason

Critical Element	Males (n=10)		Females (n=13)	
	# of Zero Scores	Most Common Reason*	# of Zero Scores	Most Common Reason*
Preparatory Leg Position	1	a	0	n/a
Arm Swing	4	d	10	d
Arm Coordination	3	d	9	d
Arm coordination with Legs	3	d	10	d
Shoulder Girdle and Arm Extension	0	n/a	0	n/a
Head Action	0	n/a	0	n/a
Leg Action: Take-off	3	a	0	n/a
Trunk Action: Take-off	1	a	0	n/a
Leg Action: Landing	5	a	1	a
Displacement on Landing	4	a	1	a

***a.** Unusual movements which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Not applicable to this skill. **c.** Not applicable to this skill. **d.** The performance of movements which are precursor skills (in the case of vertical jump, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g., Arm Swing: arm starts from raised position/unclassifiable movement).

Table 4.06 Number of children with zero scores in each critical element for Horizontal Jump and most commonly attributed reason

Critical Element	Males (n=18)		Females (n=13)	
	# of Zero Scores	Most Common Reason*	# of Zero Scores	Most Common Reason*
Body Position: Take-off	0	n/a	1	a
Knee Angle: Take-off	4	d	3	d
Hip Angle: Take-off	4	d	3	d
Arm Action: Flight	3	a	1	a
Leg Position: Flight	10	d	11	d
Leg Action: Flight	6	d	5	d
Arm Action: Landing	2	a	1	d
Leg Action: Landing	2	a and d	6	d
Foot Coordination	10	d	5	d
Balance	3	d	4	d

***a.** An unusual movement which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason. **b.** Not applicable to this skill. **c.** Not applicable to this skill. **d.** The performance of movements which are precursor skills (in the case of horizontal jump, this would refer to alternative movements that may be listed along side 'unclassifiable movement' e.g., Knee Angle on Take-off: Movement is from a one foot take-off/Unclassifiable movement).

Table 4.07 Number of children with zero scores in each critical element for Jump from a Height and most commonly attributed reason

Critical Element	Males (n=2)		Females (n=1)	
	# of Zero Scores	Most Common Reason*	# of Zero Scores	Most Common Reason*
Arm Action	1	a	0	d
Knee Joint: Take-off	1	a	1	d
Hip Joint: Take-off	1	a	1	d
Take-off	1	a	1	d
Flight Phase	1	a	1	d
Lateral Body Alignment: Flight	0	n/a	0	d
Ankle Flexion: Landing	1	a	1	d
Knee and Hip Flexion: Landing	0	n/a	1	d
Foot Landing	1	a	1	d
Balance	0	n/a	1	d

***a.** An unusual movement which cannot be classified as scoring either a 1, 2 or 3 in which the child is drawing attention to themselves either to hide an inability to perform the skill, as a result of simple misbehaviour, or, for some unknown reason **b.** Not applicable to this skill **c.** Not applicable to this skill **d.** The performance of movements which are precursors to a 'jump down' movement, such as a 'step down' movement[9].

[9] A 'Step down movement' refers to a child who seems to *require* a one foot take-off in order to maintain their balance as they leave the box. This will present as a definite stepping down movement with the leading foot stepping down below the box height level before the remaining foot leaves the surface of the box. This does not refer to a child whose feet fail to simultaneously leave the box or whose feet simply come apart as they hop of jump off of the box.

4.2.3 Gender Effects

Means and standard deviations for each locomotor skill are presented in Figure 4.12. The results of the ANOVA did not indicate significant ($p < .01$) differences between males and females in any of the movement skills. A second ANOVA was performed after log transformations were completed to reduce the degree of negative skewness on the FMS variables running, hopping, vertical jump, horizontal jump and jumping from a height. Results were the same as the ANOVA performed on untransformed data. Further, because the assumption of homogeneity of variance was violated in horizontal jump, and because skipping displayed a bimodal distribution which could not be corrected through log transformation, the non-parametric Kruskal-Wallis test was also performed. Results of the non-parametric tests yielded similar results to the previously reported parametric tests. FMS proficiency was not significantly different between males and females ($p < .01$).

4.3 Relationships between FMS and Indicators of Health and Fitness

4.2.1 Correlation Analysis

The assumption of normality was violated by four out of six FMS variables and 5 out of 11 health and fitness variables in the male data set. In the female data set, all FMS variables and 8 out of 11 health and fitness variables violated the assumption of normality. Therefore, a Spearman correlation coefficient was employed in the bivariate correlation analysis to determine significant relationships between FMS and indicators of health and fitness. Several significant relationships were revealed (see Tables 4.08 through 4.10). Running, hopping and vertical jumping were significantly ($p < .01$) related to musculoskeletal and cardiorespiratory fitness tests. Vertical jumping was also significantly ($p < .01$) related to weight status.

4.2.2 Regression Analysis

Hierarchical regression analyses (see Tables 4.11 and 4.12) were performed to determine independent predictors of health and fitness variables. These analyses controlled for possible confounding health and fitness variables and determined the unique contribution of each FMS to the prediction of health and fitness indicators. None of the FMS variables independently predicted our health and fitness variables in males.

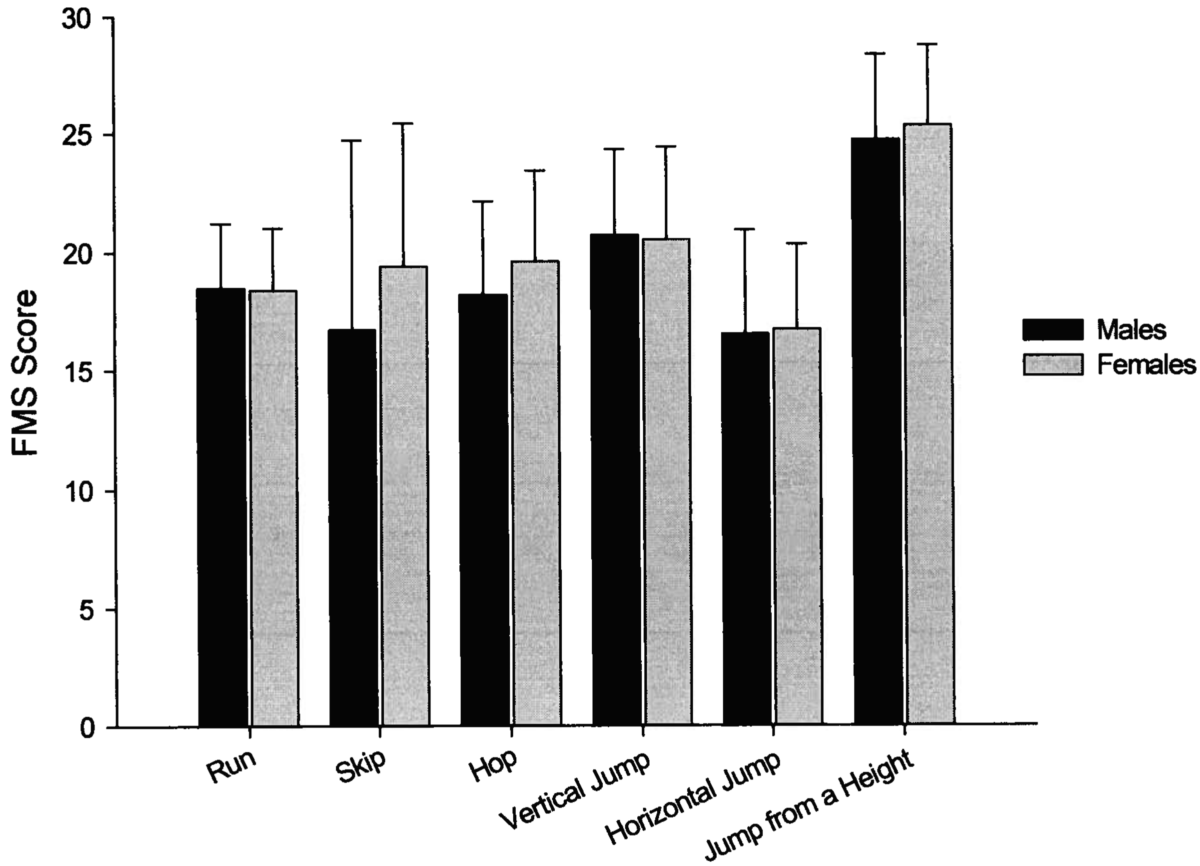


Figure 4.12 FMS Proficiency as a Function of Gender

Table 4.08 Results of spearman correlation analysis between male FMS and health and fitness variables. Vert. Jump=vertical jump, Horiz. Jump=horizontal jump, Height Jump=jump from a height, SBP=systolic blood pressure, DBP=diastolic blood pressure, BMI=body mass index, WC=waist circumference, S&R=sit and reach, Curl=curl-ups, Push=push-ups, Grip=grip strength.

	Run	**Skip**	**Hop**	**Vert. Jump**	**Horiz. Jump**	**Height Jump**
SBP	NS	NS	NS	NS	NS	NS
DBP	NS	.231*	.207*	NS	NS	NS
LAC	NS	NS	NS	NS	NS	NS
SAC	NS	NS	NS	NS	NS	NS
BMI	NS	-.241*	NS	-.276*	NS	NS
WC	-.214*	NS	NS	-.317**	NS	NS
S&R	.420**	NS	NS	.320**	NS	.288**
Curl	NS	NS	NS	.252*	NS	NS
Push	NS	NS	NS	NS	NS	NS
Grip	NS	NS	NS	NS	NS	NS
Shuttle Run	.208*	.257*	.382**	.348**	NS	NS

* *p* (one-tailed) < 0.05, ***p* (one-tailed) < 0.001

Table 4.09 Results of spearman correlation analysis between female FMS and health and fitness variables.
Vert. Jump=vertical jump, Horiz. Jump=horizontal jump, Height Jump=jump from a height, SBP=systolic blood pressure, DBP=diastolic blood pressure, BMI=body mass index, WC=waist circumference, S&R=sit and reach, Curl=curl-ups, Push=push-ups, Grip=grip strength.

	Run	**Skip**	**Hop**	**Vert. Jump**	**Horz. Jump**	**Height Jump**
SBP	NS	NS	NS	NS	NS	NS
DBP	NS	NS	NS	.269**	NS	NS
LAC	NS	NS	NS	NS	NS	NS
SAC	NS	NS	NS	NS	.192*	NS
BMI	NS	NS	NS	-.190*	NS	NS
WC	NS	NS	NS	-.186*	NS	NS
S&R	.222*	NS	NS	NS	NS	NS
Curl	.301**	NS	NS	.291**	.175*	NS
Push	NS	NS	.219*	NS	NS	NS
Grip	.300**	NS	.372**	NS	.185*	NS
Shuttle Run	.284**	NS	.391**	.241*	.186*	NS

* *p* (one-tailed) < 0.05, ***p* (one-tailed) < 0.001

Table 4.10 Results of spearman correlation analysis between combined male and female FMS data and health and fitness variables.
Vert. Jump=vertical jump, Horiz. Jump=horizontal jump, Height Jump=jump from a height, SBP=systolic blood pressure, DBP=diastolic blood pressure, BMI=body mass index, WC=waist circumference, S&R=sit and reach, Curl=curl-ups, Push=push-ups, Grip=grip strength.

	Run	**Skip**	**Hop**	**Vert. Jump**	**Horz. Jump**	**Height Jump**
SBP	NS	NS	NS	NS	NS	NS
DBP	NS	NS	NS	.184*	NS	NS
LAC	NS	NS	NS	NS	NS	NS
SAC	NS	NS	NS	NS	NS	NS
BMI	NS	NS	NS	-.222**	NS	NS
WC	NS	NS	NS	-.238**	NS	NS
S&R	.258**	NS	NS	NS	NS	NS
Curl	.211**	NS	NS	.269**	NS	NS
Push	NS	NS	.178*	NS	NS	NS
Grip	NS	NS	.210**	NS	NS	NS
Shuttle Run	.244**	NS	.370**	.286**	NS	NS

* *p* (one-tailed) < 0.05, ***p* (one-tailed) < 0.001

Table 4.11 Results of multiple regression model for diastolic blood pressure in females.

Model	**Predictor Variables**	**Unstandardized Beta**	**Standardized Beta**
1	Systolic blood pressure	.47	.64
	Small artery compliance	-.14	-.04
	Shuttle run	-.01	-.03
2	Systolic blood pressure	.48	.66
	Small artery compliance	-.09	-.03
	Shuttle run	-.04	-.07
	Vertical jump	.33	.22*

Note R^2 = .423 for block 1; ΔR^2 = .045 for block 2; *p < .01

Table 4.12 Results of multiple regression model for diastolic blood pressure combined male and female data.

Model	**Predictor Variables**	**Unstandardized Beta**	**Standardized Beta**
1	Gender	1.53	.13
	Systolic blood pressure	.43	.56
	Small artery compliance	-.08	-.03
	Shuttle run	.02	.04
2	Gender	1.58	.77
	Systolic blood pressure	.44	.06
	Small artery compliance	-.05	-.02
	Shuttle run	-.01	-.02
	Vertical jump	.33	.21*

Note R^2 = .366 for block 1; ΔR^2 = .040 for block 2; *p < .01

For females, diastolic BP was significantly predicted by vertical jump (p = .008). Additional FMS variables were not found to be independent predictors of the remaining health and fitness variables in females. In the regression analyses performed on the combined male and female data set (which controlled for gender as a covariate), the data also showed a significant (p = .002) relationship between diastolic BP and vertical jump. No other significant (p < .01) relationships were found between the remaining FMS and indicators of health and fitness in the combined male and female data. The regression analyses met all assumptions tested.

CHAPTER V: DISCUSSION

5.1 FMS Proficiency

The hypothesis that children would score in the lower two-thirds of the proficiency assessment tool was supported by the results for males and females in all skills with the exception of vertical jumping and jumping from a height which scored in the upper third of our assessment tools. In general, the proficiencies displayed by the children were moderate for horizontal jumping and low for the remaining skills. Although previous literature has shown that the majority of children are capable of exhibiting mature movement patterns in skills such as running, skipping, hopping, vertical jumping and jumping from a height by six years of age, this was not demonstrated in the present investigation. In contrast, characteristics of a mature movement pattern for horizontal jumping are more commonly achieved later in childhood at approximately 9 or 10 years of age [24, 35]. While horizontal jumping scores were in the lower two-thirds of our assessment tools this is not unexpected given the fact that the average age of the children examined in this investigation was 10 years. Therefore, children of this age would not necessarily be expected to exhibit a mature movement pattern in horizontal jumping.

These findings are similar to the findings of Okely & Booth [19] who investigated FMS proficiency in Australian children aged six to eight years old. They found that less than 10% of boys and girls six years of age achieved mastery in the skills of skipping and hopping, less than 15% of eight year old boys and 10% of eight year old girls displayed mastery in running, and less than 10% of eight year old girls and boys displayed mastery in the vertical jump skill. Okely & Booth [19] also included the additional category of near mastery (a category defined by displaying all but one mature movement characteristic) to determine the percentage of children who may be close to achieving mastery. With the inclusion of a near mastery category the percentage of children who achieved an advanced fundamental skill level (near mastery or mastery) increased substantially. Nonetheless, proficiency for children six to eight years old remained below 40% in the skills of running, skipping, hopping and vertical jump for boys and girls [19]. Okely & Booth [19] interpreted their results as indicating low degrees of proficiency.

Reasons for the low level of proficiency displayed by the children in the present investigation may be due in part to the wide variety of assessment tools used to measure proficiency in addition to differences in the individual FMS assessed. The nature of our assessment tools may have resulted in a more rigorous evaluation of children's skill level producing proficiency scores lower than in other investigations [19, 30]. The present investigation utilized videotaped recordings of participants performing FMS which allowed their performances to be viewed multiple times. Videotaped recordings also allowed the performances to be viewed frame-by-frame and in slow motion. Our investigation utilized videotaped recordings of participants performing FMS skills which allowed us to view performances several times. We were also able to view performances frame by frame and in slow motion. For several movement characteristics, a quantitative measurement of joint angles was obtained rather than relying on a visual estimate of the joint angles observed. The combination of using videotaped performances and the measurement of joint angles provided a more objective and precise assessment of FMS proficiency than in previous investigations. Using video recordings and measuring joint angles rather than using visual observation alone is preferable as it offers a more objective determination of a child's level of motor proficiency. This low level of FMS proficiency may also be indicative of a larger trend wherein the level of children's proficiency could have declined since the original investigations were performed over 20 years ago [30, 32, 36].

Overall, mean scores for both males and females were greatest in jumping from a height and lowest in horizontal jumping. Horizontal jump was the only skill investigated in which mastery is not commonly achieved by at least seven years of age. As previously mentioned, a mature movement pattern in horizontal jump is not displayed by the majority of children until 9 or 10 years of age [32]. Therefore, mean scores for the horizontal jump should be the lowest of the skills investigations given that the average age of the children in this investigation was 10 years.

Findings revealed specific behavioural characteristics which were especially difficult for participants to perform with a high level of proficiency. For example, several trends emerged when critical elements were examined according to body segments (see Table 5.00). For example, in running, children appeared to have the greatest difficulty in critical elements pertaining to upper body movements and the least difficulty in lower body movements. In hopping, children had the least difficulty in mid-body

	Run	Skip	Hop	Vertical Jump	Horizontal Jump	Height Jump
Highest Scores	⬇ ⇩	N/A	⬌ ⬄	⬌ ⇩	⬆ ⇧	N/A ⇩
Lowest Scores	⬆ ⇧	⬇ ⇩	⬇ ⇩	⬆ ⇧	⬆ ⬌	⬇ ⬌ ⇩

N/A = not applicable to a specific body segment

■ = Males

▭ = Females

⇧ Upper Body Segment

⇩ Lower Body Segment

⬄ Mid-body Segment

Table 5.00 Critical Elements by Body Segment movements and the greatest difficulty in lower body movements. In the case of jumping from a height, girls had the greatest and least difficulty in lower body movements. However, the lower body movements which were the least difficult corresponded to the landing phase of the jump whereas the lower body movements which were the most difficult corresponded to the take-off phase of the jump. In some cases, such as jumping from a height in girls, children's difficulties were not according to body segment. Rather, they were according to the temporal sequence of the skill (e.g., take-off versus landing). It may be the case that children's activity programs place a greater emphasis on the performance of certain temporal sequences over others. For example, children's gymnastics programs place a great deal of emphasis on the performance of correct landing movements when dismounting equipment in order to help prevent injuries. Likewise, instruction may also focus on the development of certain body segments over the development of other body segments. In running, many activities centre on leg rather than arm movements such as high-knee drills and seat kicks. There may also be developmental reasons for the difficulties seen in movements according to body segment. In the present investigation, stationary hopping was examined rather than hopping over a distance. Stationary hopping involves minimal arm movements and for this reason, upper body movements played a lesser role than lower body movements in the performance of this skill. Therefore, children may have been developmentally more capable of performing upper body movements than lower body movements. While the precise reason(s) for these trends cannot be determined by the present investigation, the results suggest that there are specific body segments for each movement skill which require a greater degree of attention. These findings could be used to inform children's physical activity and education programs. In addition, they may also serve as important baseline measurements for future investigations.

In each skill, a number of children scored zero on one or more critical elements. Children were given a score of zero for a number of possible reasons (see Tables 3.00 through 3.05). In general, when a child received a score of zero in running and hopping, it was most frequently attributed to the performance of unusual movements in males and gross movement inconsistencies in females, which were likely related to behavioural issues. In skipping, the reason for a score of zero in both males and females was solely the result of performing an unrelated skill, whereby the child was unable to perform any aspect of the required skill. Zero scores in vertical and horizontal jumping were listed as being the performance of unusual and precursor skills in both males and females. Zero scores for jumping from a height in males was described as being the result of unusual movements while in females it was the result of performing precursor skills. The performance of precursor skills suggests children were not misbehaving or attempting to draw attention away from their inability to perform the skill proficiently (as would be the case for unusual movements). Rather, the performance of precursor skills suggests that this was an accurate portrayal of the child's ability.

5.2 Gender differences

Results from the investigation did not support the hypotheses that gender differences would emerge for the performance of FMS. These results are contrary to previous literature out of Australia which has shown boys as being more proficient than girls in most FMS with the exception of skipping and hopping [11, 16, 19].

The reason girls did not demonstrated greater degrees of proficiency than boys in skipping and hopping due to a lack of statistical power. Skipping and hopping were higher in girls than in boys at a significance level of $p < .05$. The fact that results were not significant at the level of $p < .01$ could be due to inadequate sample size causing a reduction in the amount of statistical power for the detection of differences between genders.

Boys did not exhibit greater proficiency than girls in running, or the remaining jumping skills. There are several explanations for these results. First, while gender differences in FMS proficiency are prevalent throughout the literature, significant differences between boys and girls generally emerge at the onset of puberty and become increasingly salient with increasing age until adulthood [33]. The children in the present investigation were 8 to 11 years of age and thus it is possible that potential gender differences between children have yet to emerge.

Second, differences in male and female movement skill performance have been attributed to both biological and environmental factors [33]. The onset of puberty explains some of the divergence between the skill of boys and girls starting from approximately 11 years of age and continuing throughout adolescence. Yet, the impact of environmental factors should not be overlooked as it too offers an explanation for the increased skill divergence between boys and girls. There are different expectations imposed on boys and girls coupled with differences in how boys and girls are treated while they learn and perform tasks involving motor skills. When provided equal encouragement and opportunities to practice, Thomas [33] asserts that trends in the data will begin to reflect a greater degree of gender similarity rather than gender difference in FMS. Third, investigations showing boys' FMS to be significantly greater than girls' have investigated skills involved in historically male dominated sports/activities. Okely et al. [11] postulated a gender bias (favoring boys) in the skills they examined (i.e., sprint run, vertical jump, overarm throw, catch, forehand strike and kick) resulting in boys displaying significantly higher FMS scores than girls. They also noted that activities classified as traditionally feminine involving FMS which depend on balance, flexibility and rhythm (e.g., dance and gymnastics) were not represented in the skills tested. With the exception of skipping and hopping the FMS investigated were arguably more gender neutral than those investigated by Okely et al. [11]. While Okely et al. [11] investigated skills (e.g., overarm throw, catch, kick and forehand strike) linked to traditionally male dominated activities (e.g. baseball and soccer), the present investigation examined running and three forms of jumping (vertical jump, horizontal jump and jumping from a height) which are involved in both traditionally male and female dominated activities. For example, dance and gymnastics are female dominated activities and involve various forms of jumping. Likewise, a sport such as basketball also involves jumping yet is historically male dominated. Collectively, the inclusion of skills involved in both male and female dominated activities provided a more gender equitable battery of tests.

5.3 Indicators of Health and Fitness

The results support the hypothesis of a relationship between FMS proficiency and indicators of health and fitness. Correlation analyses found several significant relationships between FMS and indicators of health and fitness. However, only one FMS variable showed a significant and independent relationship to our indicators of health and fitness.

5.3.1 Indicators of Health and Fitness Status

While the majority of boys and girls were classified by BMI as being of a normal weight, the results indicated that up to 33.3% of boys and 16.6% of girls were overweight. An additional 18.8% of boys and 5.5% of girls were classified as obese.

These findings are important because studies have shown that being overweight or obese as a child increases the risk of CVD and early mortality regardless of adult weight status [62]. Findings also showed that 6.6% of girls and 4.3% of boys presented with high systolic BP. While these percentages are low, BP measurements were taken from a supine position and would be consequently higher had they been taken from a seated position. Moreover, in combination with the overweight and obesity results, a portion of children in this investigation have multiple indicators of health risk.

5.3.2 Regression Analyses: Blood Pressure, Arterial Compliance and FMS

For females, there was a significant relationship (p = .008) between diastolic BP and vertical jump. Vertical jump proficiency in females accounted for 4.5% of the variance in diastolic BP after having controlled for possible covariates. The combined male and female data also showed a significant (p = .002) relationship between vertical jump and diastolic BP with vertical jump accounting for 4.0% of the variance in diastolic BP. The direction of the relationship between diastolic BP and vertical jump (for both the combined male and female data and for the female only data) was positive. This was contrary to the hypothesized results. FMS proficiency was expected to increase as diastolic BP decreased because lower BP measurements are usually indicative of healthier vasculature [52, 54]. As children mature physically, their BP measurements increase [27] therefore, the direction of the relationship between diastolic BP and vertical jump is likely a product of increased maturational age. As we do not have an accurate assessment of maturation at our disposal, the impact of this factor cannot be determined.

Our results offer a nominal degree of support for our hypothesis that FMS proficiency is related to BP in school-aged girls. In boys however, our hypothesis was not supported as no relationships between FMS, BP or arterial compliance were found. As this was the first investigation of its kind to evaluate the relationship between FMS proficiency, BP and arterial compliance, further investigation is warranted.

5.3.3 Regression Analyses: Weight Status and FMS

Significant relationships between BMI values and proficiency were not found. This is in contrast to results demonstrated in previous investigations which show youth who had BMI values classified as overweight to be less proficient than normal-weight youth [16]. Also not supported by the results of the present investigation, Okely et al. [16] found waist circumference measurements to be negatively related to proficiency in various FMS for both boys and girls. These discrepancies may be explained by having controlled for several health and fitness covariates which were not controlled for in Okely et al's [16] investigation. For example, regression analyses controlled for WC when examining the relationship between BMI and FMS. This was done to determine how much of the variance in BMI could be accounted for by FMS beyond that which was accounted for by other factors such as WC. In the bivariate correlations results indicated several relationships between FMS proficiency and weight status indicators. Body mass index was related to skipping in males and to vertical jump in the male only, female only and combined male and female data. Waist circumference was correlated to vertical jump in all three data sets and to running in the male only and combined male and female data sets. It was upon controlling for potentially confounding health and fitness variables that the significance of these relationships decreased.

5.3.4 Regression Analyses: Physical Fitness and FMS

Physical fitness variables were not found to be independently related to proficiency in FMS and was not in with the available literature regarding adolescent FMS and cardiorespiratory fitness in males and females [11]. Once again, this is likely the result of including health and fitness data as confounding variables in the analysis. The spearman correlation analysis found that running, hopping, vertical and horizontal jump were related to cardiorespiratory fitness in females. For males, cardiorespiratory fitness showed significant correlations with running, skipping, hopping and vertical jump. However, for both males and females the relationships between FMS and cardiorespiratory fitness disappeared after controlling for other health and fitness variables.

5.4 Future Directions

The present research indicates the need for greater emphasis on the development and refinement of FMS during childhood. Physical education classes are an appropriate setting for such development to take place. Recently, the British Columbia Ministry of Education introduced a new PE curriculum set for optional implementation by September 2008 and for full implementation by September 2009

[122]. The curricular update places movement skills among the central components in its organizational structure. The expressed goal of PE is to, "...provide opportunities for all students to develop knowledge, movement skills, and positive attitudes and behaviours that contribute to a healthy, active lifestyle." [122]. Specific non-locomotor (stability), locomotor and manipulative movement skills are emphasized in the prescribed learning outcomes from kindergarten to grade four with grades five to seven addressing these skills in more complex contexts (e.g., the performance of skills in combination with each other). The individual teaching and evaluation of FMS in primary grades (grades K-4) provides a foundation for subsequent sport and game activities which are taught and assessed in the intermediate grades (grades five to seven). This has created a clear developmental progression throughout the curriculum. Achievement indicators are provided for each prescribed learning outcome and are categorized as emerging, developing, acquired or accomplished [122]. This is a marked extension from the vague evaluation tools provided in the 1995 resource package and as a result the assessment of FMS has become substantially more comprehensive and objective in nature. The establishment of achievement indicators also provides the PE teacher with considerably more information regarding the classes' level of individual and collective movement skill proficiency. The direct focus on teaching and assessing FMS skills within the curricular update is an important step towards providing children the opportunity to participate in a wide range of physical activities.

It is our recommendation that research continues to investigate the specific role movement skill education plays in the acquisition and maintenance of health beyond the role of physical activity alone. Additional research into teacher knowledge and effectiveness in delivering movement skill education should be explored. Meanwhile, initiatives to improve the movement skill and physical activity levels of children, such as the revised BC PE curriculum should continue to be undertaken throughout the education system.

5.5 Limitations

The assessment tools developed specifically for this investigation served to be a major strength for the primary purpose of determining the relationship between indicators of health and fitness and FMS proficiency. Yet, they were a limitation when determining our subject's proficiency level in relation to previous literature. While this investigation was not designed to be a comparative study, the ability to categorize proficiency levels according to previously established standards would have lent support to the interpretation of children's proficiency levels. In regards to movement skill assessment, the literature lacks consistency in which skills are assessed, the test used to assess the skills and the testing methods employed. Alone or in combination, inconsistencies such as these make direct comparisons between results challenging. Typically however, results are reported according to classification as initial, elementary or mature movement patterns or in terms of those who have achieved mastery (a mature movement pattern) and those who have not. While the assessment tools used in this investigation were partially based on those used to classify skills as initial, elementary or mature movement patterns they were also based on other categorizations of developmental sequences and biomechanics research [22, 24, 34, 35, 93, 117-121]. As a result, mastery (as defined in the literature) was not able to be determined and thus direct comparisons between the proficiency results observed in this investigation and those observed in other investigations were not possible. However, general observations were made regarding the proficiency exhibited by our participants. As previously stated, this investigation was not designed to be a comparative study and the gains received from having developed our own assessment tools which contain a detailed scoring system and utilize objective measurements along with videotaped recordings outweigh these potential costs.

The relationship between FMS proficiency and indicators of health and fitness partially relies on our ability to accurately determine each child's skill level. While the employed assessment tools had several benefits, there were a few unavoidable difficulties due to our subject population which made FMS assessment difficult. Our FMS assessment was based on children performing skills to the best of their ability. In some cases this was complicated by various factors. First, some children may have misunderstood the directions. Children who did not speak English or who spoke English as a second language may have not clearly understood the skill they were being asked to perform. Consequently, their performance may not reflect their true ability. Second, as is the typical nature of children, there were times when a child would behave in a silly manner while performing a skill. The first of these factors could have been greatly reduced (if not eliminated) by providing the children with a demonstration of the skill. However, this would have led to a different problem. A demonstration could have caused an indeterminate amount of learning to occur which would influence the child's proficiency level. The second of these factors is largely unavoidable in children. Having children perform each skill more than once may have increased the chances of at least one serious (i.e., not silly) performance which could then be used for data analysis. However, a similar problem to demonstrating the skills would have occurred. Having children perform a skill several times provides them with the unintentional opportunity to practice and would thus influence their proficiency. In addition, there were time constraints during the data collection period which eliminated this possibility as an option.

Finally, the inability to determine the physical maturation level of the participants may have also been a limitation. The inclusion of maturational level among covariates may have offered some insight into the reasons we found a positive (rather than negative) relationship between vertical jump and diastolic BP.

5.6 Conclusion

This novel investigation has demonstrated proficiency in FMS to be significantly ($p < .01$) related to several indicators of health and fitness. Correlation analyses found running and hopping to be significantly ($p < .01$) related to musculoskeletal and cardiorespiratory fitness tests. A significant ($p < .01$) relationship between vertical jumping and weight status, musculoskeletal and cardiorespiratory fitness was also found by the correlation analyses. Regression analyses were also performed to determine the independent relationship between health and fitness indicators. Vertical jump accounted for the variance in diastolic BP beyond that accounted for by other health and fitness variables (i.e., systolic BP, small artery compliance and cardiorespiratory fitness). The direction of the relationship between vertical jump and diastolic BP was positive. It was hypothesized that this relationship would be negative and therefore the positive relationship between diastolic BP and vertical jump was unexpected. Additional analysis is warranted to determine the reasons for this discrepancy and to further establish the relationship between FMS proficiency and health indicators.

This investigation also examined possible gender differences among select FMS in addition to determining the current state of FMS proficiency. While results did not reveal significant ($p < .01$) gender differences among movement skills, proficiency for all FMS was exceptionally low for both boys and girls.

In light of findings demonstrating a relationship between FMS proficiency and indicators of health and fitness, combined with the evaluation of very low proficiency levels among elementary aged children, the creation of educational strategies designed to develop children's FMS are supported. The provision of adequate physical activity time is also encouraged to provide children with the opportunities to practice movement skills, therein furthering skill development. These are essential steps to grant children the skills necessary for lifelong physical activity pursuits. In closing, we have established that through their relationship to indicators of health and fitness, movement skills are an aspect of children's health that warrants greater attention.

CHAPTER VI: REFERENCES

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Appendix A: AS!BC Consent and Ethics Forms

Principal Investigators
Heather McKay PhD, 604.875.5346 and Patti-Jean Naylor PhD, 250.721.7844

Co-investigators
Joan Wharf-Higgins PhD, Ryan Rhodes PhD,
Stephen Manske PhD, Darren Warburton PhD, Shannon Bredin PhD

Research Coordinator
Sharon Storoschuk 604.875.4111 extension 62005

Information for Families:

We are pleased to invite you and your child to be a part of Action Schools! BC (AS! BC) Research Study. Your child's school has agreed to be a part of the AS! BC Research Study and we now invite you and your child to read the following information on this exciting initiative!

The Action Schools! BC Program

The goal of AS! BC is to "make healthy choices the easy choices" to improve the health and well-being of all children. The program was developed in response to the reality that many Canadian children are physically inactive and as a result are at a greater risk of developing chronic diseases such as heart disease, obesity, Type II diabetes and osteoporosis. AS! BC helps schools to provide more physical activity to students and encourage healthy lifestyles. The success of this program was recently tested in schools in the Lower Mainland. As a result of participating in more physical activity, students had improvements in heart and bone health. You can learn more about Action Schools! BC and the results of the research study on our website at www.actionschoolsbc.ca. We are now offering the AS! BC Program to schools across the province and with funding from the Canadian Institutes of Health Research we are conducting a second research study to see if the program will be successful in different areas of BC.

The Action Schools! BC Research Study

We will be conducting a 3-year study to determine if the AS! BC Program can positively change physical activity and eating behaviours, self-esteem and heart health in students across BC. To see if such changes occur as a result of the program, it is important for us to compare the AS! BC Program with regular school routines of physical activity. For this reason, schools who chose to participate in the AS! BC Research Study will be randomly assigned to one of two groups; intervention or usual practice. The intervention schools will receive the AS! BC Program and the usual practice schools will continue with their regular program of physical activity. Students from all schools will be invited to participate in the research study. Therefore, if your child's school is a usual practice school (not doing the AS! BC Program) we would still like to ask them to participate in the research study. At the end of the study period the AS! BC Program will be offered to all schools.

During the first year of the research study, there will be two measurement sessions between September 2005 and June 2006 (Fall and Spring). Each session will require your child to be absent from class for a minimum of 70 minutes. Detailed information about all measurements that will occur during these sessions is provided in the attached consent form.

In addition, your child may be asked to wear an accelerometer twice during the school year. Accelerometers are 'motion sensors' that work using the same technology as the motion sensor lights for houses and carports. The purpose of the motion sensor is to get an idea of your child's physical activity patterns. The accelerometer is small and lightweight and is worn on a belt around the waist.

At this time we would ask that you please consider you and your child's participation in the AS! BC Research Study. We invite you to read, complete and sign the attached consent form and Health History Questionnaire. Once you have completed the forms, please place them in the attached envelope, seal it and place it in the mail. Please note that should you and your child choose not to participate in the research study, your child will still be able to participate in AS! BC.

We are excited to expand AS! BC to schools throughout the province and we look forward to working with the students, parents and teachers in your region. You and your child's participation will be important in helping us determine if AS! BC is an effective means to provide physical activity and encourage healthy living in schools. If you have any questions please contact Sharon Storoschuk (Research Coordinator) at 604.875.4111 ext 62005 [Sharon.storoschuk@ubc.ca], Dr. Heather McKay (Principal Investigator) at 604.875.5346 [heather.mckay@ubc.ca] or Dr. PJ Naylor (Principal Investigator) at 250.721.7844 [pjnaylor@uvic.ca].

Sincerely,

Dr. Heather McKay,
Professor,
University of British Columbia,
Department of Orthopaedics,
VGH Research Pavilion 5th Floor
828 West 10th Avenue
Vancouver, BC V5Z 1L8

Action Schools! BC Consent Form for Families

Please read the following with your child, and if you and your child would like to participate please sign the attached form and return the signed form in the stamped, addressed envelope provided. You may keep the other pages for your records.

Procedures. Your child's participation in the Action Schools! BC (AS! BC) Research Study will involve two in-school testing sessions in the Fall and Spring of the next two school years. All children will participate in the Anthropometry and Questionnaire components and a smaller random sample of students will participate in the Cardiovascular Health and Musculoskeletal Fitness, Fundamental Movement Skills and Accelerometer components.

1. **Anthropometry:** Measures of height, weight and calf and waist circumference will be taken. Total Time - 10 minutes: Fall and Spring.

2. **Questionnaires:** Your child will be assisted in the completion of questionnaires that will assess their physical activity, nutrition, self-esteem and attitudes and perceptions about physical activity. A trained research assistant will discuss the importance of these assessments with the children. Total Time – 1 hour: Fall and Spring.

3. **Cardiovascular Health and Musculoskeletal Fitness**: We will evaluate aerobic fitness using a shuttle run in which students repeatedly run 20 meter laps in time with a clearly audible "beep" until they become tired and choose to stop. Musculoskeletal fitness (i.e. muscle strength and power) will be assessed using a hand held dynamometer. A research assistant will provide clear instructions for each procedure to the students. Resting blood pressure and heart rate will be recorded before all fitness procedures. Only a subset of students (25%) will be recruited for this portion of the study.
Total Time - 45 minutes: Fall and Spring.

4. **Accelerometers**: We will monitor children's physical activity with accelerometers. Children will wear the accelerometer (on a belt around their waist) from the time they get up until the time they go to bed (approximately 12 hours) for 5 consecutive days. A research assistant will provide clear instructions for how to wear the accelerometer. A small group of students (25%) who participate in the cardiovascular component (item 3 above) will be recruited for this portion of the study. Accelerometers will be worn for 5 days in the Fall and Spring. Total time – 45 minutes in the Fall for a session on accelerometer instructions.

5. **Fundamental Movement Skills**: Your child will be asked to perform seven fundamental locomotor skills. These include: running, vertical jumping, horizontal jumping, jumping from a height, hopping, galloping, and skipping. These skills will be videotaped from two separate cameras recording motor performance from the front and from the side. Performance of each motor skill will be videotaped so that motor skill proficiency can be assessed. A small group of students (20%) that are

participating in the cardiovascular component (item 3 above) will be recruited to participate in this portion of the study. Total Time 10 minutes: Fall and Spring.

Health History Questionnaire:
If you and your child agree to participate in the AS! BC Research Study, you will be asked to complete the attached Health History Questionnaire to determine if there are any health reasons to exclude your child from the research study and to identify any conditions or medications that may affect study outcomes.

Possible Harms:
None.

Benefits:
If you and your child choose to participate in the AS! BC Research Study, you and your child will learn more about how physical activity and healthy eating can contribute to improved health. At the end of the study you and your child will receive a summary of the results indicating the general findings of the study and your child's personal performance. It is our hope that through this program, your child will achieve the many health benefits that accompany an active lifestyle.

Rights and Welfare of the Individual:

You have the right to refuse your child's participation in this research study. It is understood that you are free to withdraw your child from any or all parts of the study at any time without penalty. If you and your child choose not to participate in the study this will not prevent them from participating in AS! BC. If your child's teacher chooses to stop participating in AS! BC we would like to still involve your child in the research study.

Confidentiality:

Your child's identity will remain confidential as all individual records and results will be analyzed and referred to by number code only. Files are kept in locked cabinets at the Vancouver General Hospital – Research Pavilion, Centre for Clinical Epidemiology and Evaluation. Only those directly involved in the study (namely, the AS! BC Research Team) will have access to your child's records and results. Your child will not be referred to by name in any program reports or research papers. Your child's results will remain confidential and they will not be discussed with anyone outside the research team. Videotapes of locomotive skills will be stored for five years at which point they will be demagnetized and destroyed.

Please be assured that you and your child may ask questions at any time and we welcome your comments and suggestions. We will be glad to discuss your child's results when they become available. Should you have any concerns about this program or wish further information please contact Sharon Storoschuk (Research Coordinator), 604.875.4111 extension 62005, Dr. Heather McKay (Principal Investigator), 604.875.5346 or Dr. PJ Naylor (Principal Investigator) at 250.721.7844. If you have any concerns about your child's rights or treatment as a research subject, you may contact the Director, Office of Research Services at the University of British Columbia at 604.822.8598.

Compensation for Injury:

Signing this consent form in no way limits your legal rights against the sponsors, investigators or anyone else.

Consent Form

Please fill out both sides of this form and return it in the stamped, addressed envelope provided.
Please keep the other pages for your records.

Parent's Consent Statement:

I/We ____ the
(Please print the name of one or both parents/guardians)

parents/guardians of ______________________________ have received and read all
(Please print child's first and last name)

7 pages of the information letter and consent form and understand the purpose and procedures of the Action Schools! BC Research Study as described.

Please check (✓) one.

___I agree to have my child participate in the 3-year Action Schools! BC Research Study (anthropometry, questionnaires) with the understanding that my child may or may not be randomly selected to participate in the cardiovascular health, accelerometer and movement skills portions of the study.

___ I do not agree to have my child participate in Action Schools! BC Research Study.

Please check (✓) one.

___I give permission to the Department of Orthopaedics, as agent of the University of British Columbia, to take videotape recordings of my child participating in the Fundamental Movement Skills component of the Action Schools! BC Research Study. I understand that such videotape recordings may be used by the Principal Investigator or nominees and will become property of the University of British Columbia.

___I do not give permission to the Department of Orthopaedics to take videotape recordings of my child.

(Continued on other side)

I understand that at any time during the 3-year Action Schools! BC Research Study we will be free to withdraw without jeopardizing any medical management, employment or educational opportunities. I understand the contents of all six pages of this form and the proposed procedures. I have had the opportunity to ask questions and have received satisfactory answers to all inquiries regarding this program.

Signature of Parent or Guardian

Date

Printed name of the Parent or Guardian signing above

Child's Statement:

I have talked with my parents/guardians about the Action Schools! BC Program and Research Study and I understand what I will be asked to do. I understand that if I want to I can stop being in the research study at any time and I will still be able to participate in activities at my school. I have had the chance to ask questions and have received satisfactory answers to all of my questions.

Signature of Child

Date

Printed name of child

School Name

Grade and Division

The University of British Columbia
Office of Research Services
Clinical Research Ethics Board – Room 210, 828 West 10th Avenue,
Vancouver, BC V5Z 1L8

ETHICS CERTIFICATE OF EXPEDITED APPROVAL: RENEWAL

PRINCIPAL INVESTIGATOR:	**DEPARTMENT:**	**UBC CREB NUMBER:**
Heather A. McKay		H02-70537

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:
N/A
Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):
Kate Reed
Darren Warburton
Patti-Jean Naylor
Karim Miran-Khan
Ryan Rhodes
Heather Macdonald

SPONSORING AGENCIES:
Provincial Health Services Authority - "Action Schools! BC: Hormones & Lipids in Action Schools! BC Children" - "Action Schools! BC"
UBC Start-up Funds - "Action Schools! BC"

PROJECT TITLE:
Action Schools! BC

EXPIRY DATE OF THIS APPROVAL: December 4, 2007 **APPROVAL DATE: December 4, 2006**

CERTIFICATION:
In respect of clinical trials:
1. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations.
2. The Research Ethics Board carries out its functions in a manner consistent with Good Clinical Practices.
3. This Research Ethics Board has reviewed and approved the clinical trial protocol and informed consent form for the trial which is to be conducted by the qualified investigator named above at the specified clinical trial site. This approval and the views of this Research Ethics Board have been documented in writing.

The Chair of the UBC Clinical Research Ethics Board has reviewed the documentation for the above named project. The research study, as presented in the documentation, was found to be acceptable on ethical grounds for research involving human subjects and was approved for renewal by the UBC Clinical Research Ethics Board.

Approval of the Clinical Research Ethics Board by one of:

Dr. Bonita Sawatzky, Associate Chair

Appendix B: AS!BC Testing Instructions

BLOOD PRESSURE

Position of child

- Please sit quietly on a chair with your feet flat on the floor and your legs uncrossed.
- Please uncover the upper part of your left arm and place your left elbow and forearm on the table.
- Your left arm should be relaxed with the palm of your hand facing up towards the ceiling.

Instructions

- For this measurement please stay still and try not to talk while we take the measurement.
- You are going to feel the cuff squeezing your arm and you might feel your hand tingling a little.

Note to Researcher:

*Ensure the blood pressure cuff is the appropriate size for the child. Use a manual cuff if two error readings are displayed by the automatic cuff. Excessive movement and incorrect placement of the cuff are the most common reasons for error readings.

*Record two measurements for SBP, DBP and HR.

*If the resting BP is above 120/80 a third measurement will be taken after a 5 min rest period.

*If the third measurement is still above 120/80 then the child will not perform the cardiovascular fitness assessment.

CURL-UPS

Position of Child

- Please lie on your back with you knees bent to 90° and feet flat on the floor. Mark the position of the child's heals with masking tape.
- Please stretch your hands down towards your feet until the tips of your middle fingers are touching the marker.

Instructions

- You will be doing Partial Curl-ups to the sound of the metronome (set to 40 bpm), you can also listen to me telling you to curl 'up', and then 'down'.
- When I tell you to start, you will curl your head, neck and shoulders up off of the mat until you feel the end of the marker with *both* of your fingers (10 cm).
- Then you will curl back down until your head touches the mat again.
- Try to do as many curl-ups as you can.
- Any questions?
- Listen to the metronome…
- Please get ready and start when I say go.

Note to Researcher:

*Child is corrected if they perform incorrect technique.

*Child is stopped if they perform more than two consecutive curl-ups with incorrect technique.

*Record the total number of *correct* curl-ups performed by the child.

PUSH-UPS

Position of Child

- Please lie on your stomach with you legs straight.
- Your feet should be together.
- Place your hands just outside of your shoulders with your fingers pointing forward.

Instructions

- You are going to start with your elbows straight and your body off of the ground.
- When I tell you to start, you will bend your arms and lower your body until your elbows are at 90°, --Make sure you keep your body really straight like a board.
- Then use your arms to push your body back up until your elbows are straight.
- Try to do as many as you can.
- Any questions?
- Please get ready and start when I say go.

Note to Researcher:

*Child is corrected if they perform the incorrect technique.

*Child is stopped if they perform more than two consecutive push-ups with incorrect technique.

*Record the total number of *correct* push-ups performed by the child.

GRIP STRENGTH

Position of Child

- Please stand holding the dynamometer 45° out from the side of your body.

Instructions

- When I say to, you are going to breathe normally while squeezing as hard as you can.
- You will do this twice with each hand, alternating between hands.
- Any questions?
- Ready… squeeze.

Note to Researcher:

*Ensure that the grip is set to an appropriate size for each particular child.

*Child performs two on each hand alternating hands for each trial.

*Record two measurements (to the nearest kilogram) from each hand.

SIT & REACH

Preparation

- Please remove your shoes for this measurement.
- Sitting with one leg straight in front of you the other bent and stretch forward for at least 15 seconds.
- Please stretch each leg twice.

Position of Child

- Please sit facing the Sit & Reach box with your legs straight in front of you.
- Your feet should be placed flat on the Sit & Reach box just slightly wider than the width of the sliding block.
- Place your hands on top of each other and reach out towards your feet.

Instructions

- When I tell you to start, you are going to stretch as far forward as you can, pushing the measuring block with the tips of your fingers.
- As you stretch forward, please keep your knees really straight and breathe out slowly.
- Try not to bounce during the test.
- Hold this stretch for 2 seconds and then you can sit up and relax.

Note to Researcher:

*Record two measurements to the nearest 0.5 cm.

*If a child is able to reach beyond the scale length, have the child relax, while you re-adjust the ruler to start at 0 cm (at the edge of the box). In this position, you will need to add 26 cm to their score for the final measure.