

THE PHYSICAL ACTIVITY
AND SKILLS STUDY

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This thesis is submitted in fulfilment of the requirements for the Doctor of Philosophy. The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

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2009

Signature:.....

Date:.....

Structure of thesis

This thesis is submitted by publication. Therefore the thesis starts with an overall abstract, then provides a summary of the main findings in each paper, and follows with six chapters:

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methods

Chapter 4: The Sample

Chapter 5: Results

Chapter 6: Discussion and Recommendations

Chapter 3 is not a complete methods chapter as the data analysis pertaining to each research question in this study is outlined in the published papers which are referred to in Chapter 5. However, Chapter 3 does include more information on sample selection and instrumentation than is provided in the respective papers. Likewise, Chapter 4 includes more detail about the sample than that provided in the respective papers.

Supervisors

Professor John Beard (University of Sydney)

Dr Eric van Beurden (North Coast Area Health Service)

Associate Professor Philip Morgan (University of Newcastle)

Preface

All papers submitted for examination in this thesis have contributing authors.

These authors include:

(a) my three supervisors - Professor John Beard, Dr Eric van Beurden and Associate Professor Philip Morgan who guided the PhD from conception to completion,

(b) two statisticians - Dr Lyndon Brooks who gave statistical advice on four papers and Doug Lincoln who gave advice on one paper,

(c) and my former colleague from the Move It Groove It (MIGI) study - Avigdor Zask, who contributed to data interpretation for two of the six papers.

I was responsible for instigating the research questions, gaining ethics approval, acquiring funding, recruiting and training staff, school liaison, data collection, analysis of data, interpretation of results, overseeing the writing of papers and acting as corresponding author. All co-authors have signed to the effect of their contribution. See Appendix 1 (not included).

Abstract

Purpose

The aims of this study were to i) investigate the relationship between childhood motor skill proficiency and adolescent physical activity participation, cardiorespiratory endurance (fitness) and perceived sports competence, ii) assess the long-term impact of a one year primary school intervention to improve motor skills on physical activity and motor skill proficiency and iii) determine whether the observed relationships varied according to gender.

Methods

The Physical Activity and Skills Study (PASS) followed up participants of a primary school intervention (Move It Groove It - MIGI) to improve motor skill proficiency. Participants were initially assessed in 2000 as part of the intervention. In 2006/07, they were re-assessed for motor skill proficiency and also measured for physical activity level (Adolescent Physical Activity Recall Questionnaire), cardiorespiratory fitness (Multistage Fitness Test) and perceived sports competence (Physical Self-Perception Profile). Composite object control (kick, catch, throw) and locomotor (hop, side gallop, vertical jump) skill scores were constructed for analysis.

Linear regressions examined relationships between childhood skill proficiency and adolescent: i) time in physical activity intensities and type, controlling for gender and school grade and ii) cardiorespiratory fitness, controlling for gender. Structural equation modelling was used to determine whether perceived sports competence mediated between childhood object control skill proficiency and subsequent adolescent physical activity and cardiorespiratory fitness. A general linear model examined the relationship between being an intervention/control student and time in physical activity adjusting for childhood skill and gender.

Results

From 928 original participants in 2000, 481 were located in 28 schools and 276 (57%) were assessed with at least one follow-up measure in 2006/07. Slightly more than half were female (52.4%) with a mean age of 16.4 years (range 14.2 to 18.3 yrs). Childhood object skill proficiency significantly impacted on later skill proficiency, physical activity and fitness, for both genders. Furthermore, perceived sports competence acted as a mediator between childhood object control skill proficiency and subsequent adolescent physical activity and fitness. Locomotor proficiency was not predictive of any outcome variable. Six years after the intervention, participants from the intervention schools still performed better than controls in one object control skill, but were no more active.

Conclusion

Childhood proficiency in object control skills is an important influence on subsequent positive health-related behaviours and outcomes. Childhood interventions to improve object control skills may have a lasting impact. Results may inform intervention designs to promote physical activity and fitness in youth.

Collection of papers for examination

This thesis is presented as a collection of peer reviewed papers. Each research question is addressed in one or more papers. The order of papers presented represents the importance of the papers in terms of the research questions, not the order they appear in the thesis.

1. Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Childhood motor skill proficiency as a predictor of adolescent physical activity. *J Adolesc Health*. 2009;44(3):252:259.
2. Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Does childhood motor skill proficiency predict adolescent fitness? *Med Sci Sports Exerc*. 2008;40(12):2137-2144.
3. Barnett LM, Morgan PJ, van Beurden E, Beard JR. Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. *Int J of Beh Nut and Phys Act*. 2008;5(40).
4. Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Zask A, Beard JR. Six year follow-up of students who participated in a school-based physical activity intervention: a longitudinal cohort study. *Int J Beh Nut Phys Act*. 2009;6(48).
5. Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Differences in motor skill proficiency from childhood to adolescence according to gender: A longitudinal study. *Res Q Exerc Sport*. Accepted February 2009.
6. Barnett LM, van Beurden E, Morgan PJ, Lincoln D, Zask A, Beard JR. Interrater objectivity for field-based fundamental motor skill assessment. *Res Q Exerc Sport*. 2009;80(2)363-368.

Following is a summary of the main findings in each paper:

PAPER 1:

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Childhood motor skill proficiency as a predictor of adolescent physical activity. *J Adolesc Health*. 2009;44(3):252:259.

Major findings

This is one of few studies to longitudinally examine the relationship between childhood motor skill proficiency and adolescent physical activity. FMS proficiency in elementary school predicted adolescent physical activity behaviour. In particular, childhood object control proficiency predicted subsequent time spent in both moderate-to-vigorous physical activity (MVPA) and organised activity. Also, childhood object control proficiency increased the probability of whether an adolescent will participate in *any* vigorous activity but not the probability of participation in *any* organised activity.

PAPER 2:

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Does childhood motor skill proficiency predict adolescent fitness? *Med Sci Sports Exerc.* 2008;40(12):2137-2144

Major findings

This is the first study to examine the relationship between childhood motor skill proficiency and adolescent cardiorespiratory fitness. Object control skill proficiency in primary school predicted subsequent fitness levels in adolescence. Predicted values from the final model showed that children of either gender with good object control skills achieved on average six more laps on the Multistage Fitness Test (MFT) than those with poor childhood object control skills. Childhood locomotor skill proficiency did not predict subsequent fitness levels.

PAPER 3:

Barnett LM, Morgan PJ, van Beurden E, Beard JR. Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. *Int J of Beh Nut and Phys Act.* 2008;5(40).

Major findings

This is the first longitudinal study to demonstrate that perceived sports competence mediates the relationship between childhood object control skill proficiency and adolescent physical activity or fitness. The respective structural equation models explained 18% of the variation in adolescent physical activity and 30% of the variation in adolescent fitness. Childhood locomotor proficiency did not predict perceived sports competence, physical activity or fitness. Whilst boys scored higher than girls in terms of object control skill proficiency, perceived competence, physical activity and fitness, gender did not moderate the relationships between these variables.

PAPER 4:

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Zask A, Beard JR. Six year follow-up of students who participated in a school-based physical activity intervention: a longitudinal cohort study. *Int J Beh Nut Phys Act.* 2009;6(48).

Major findings

In 2006, we undertook a follow-up of motor skill proficiency and physical activity in adolescents who had participated in a one year primary school intervention. Logistic regression models were analysed for each skill to determine whether the probability of children in the intervention group achieving mastery or near mastery was either maintained or had increased in subsequent years, relative to controls. In these models the main predictor variable was intervention status, with adjustment for gender, grade, and skill level in 2000. A general linear model, controlling for gender and grade, examined whether former intervention students spent more time in moderate-to-vigorous physical activity at follow-up than control students. Half (52%, n = 481) of the 928 MIGI participants were located in 28 schools, with 276 (57%) assessed. 52% were female, 58% in Grade 10, 40% in Grade 11 and 54% were former intervention students. At follow-up, intervention students had improved their catch ability relative to controls and were five times more likely to be able to catch: $OR^{catch} = 5.51$, CI (1.95 - 15.55), but had lost their advantage in the throw and kick: $OR^{throw} = .43$, CI (.23 - .82), $OR^{kick} = .39$, CI (.20 - .78). For the other skills, intervention students appeared to maintain their advantage: $OR^{jump} = 1.14$, CI (.56 - 2.34), $OR^{gallop} = 1.24$, CI (.55 - 2.79). Intervention students were no more active at follow-up. More longitudinal research is needed to explore whether gains in motor skill proficiency in children can be sustained and to determine the intervention characteristics that translate to subsequent physical activity.

PAPER 5:

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Differences in motor skill proficiency from childhood to adolescence according to gender: A longitudinal study. *Res Q Exerc Sport*. Accepted February 2009.

Major findings

This is one of few longitudinal studies to assess youth motor skill proficiency with a process-oriented motor skill assessment battery at two time points: childhood and adolescence. Students' proficiency in three object control and three locomotor skills were assessed in 2000, in New South Wales, Australia ($M = 10.06$ years, $SD = 0.63$), and in 2006/07 ($M = 16.44$ years, $SD = 0.64$). In 2006/07, 266 students, 138 female (51.9%), and 128 male (48.1%), had at least one skill re-assessed. Males were more object control proficient than females. Childhood object control proficiency significantly predicted ($p = .000$) adolescent object control proficiency ($r^2 = .39$), and while gender was significant ($p = .000$), it did not affect the relationship between these variables ($p = .53$). Because childhood object control proficiency is predictive of subsequent object control proficiency, developing skills in childhood is important.

PAPER 6:

Barnett LM, van Beurden E, Morgan PJ, Lincoln D, Zask A, Beard JR.
Interrater objectivity for field-based fundamental motor skill assessment. *Res Q Exerc Sport*. 2009;80(2)363-368.

Major findings

This is the first study to examine the interrater reliability of a process-oriented instrument to assess the motor proficiency of adolescents by live observation in a field setting. We found that the overall interrater weighted objectivity coefficient, for the six motor skills assessed, was $\kappa = .70$. For separate skills the kappa coefficient was highest for the side gallop and catch and lowest for the hop. Future studies assessing the motor skill proficiency of children and adolescents should aim to assess interrater objectivity both overall and for each skill tested. If some skills are harder to assess, then training for these skills may need to be more extensive or their method of assessment may need to change.

Acknowledgements

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And last but not least, the students, for without them there would be no study.

Glossary

APARQ	Adolescent Physical Activity Recall Questionnaire
FMS	Fundamental Motor Skill/s
MET	Metabolic Equivalent
MFT	Multistage Fitness Test
MIGI	Move It Groove It
MPA	Moderate Physical Activity
MVPA	Moderate-to-Vigorous Physical Activity
NSW	New South Wales
PE	Physical Education
PDHPE	Personal Development, Health and Physical Education
PSPP	Physical Self-Perception Profile
RA	Research Assistant
SES	Socio-Economic Status
VPA	Vigorous Physical Activity

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1 INTRODUCTION

1.1 Background and Context

The evidence is overwhelming that physical activity¹⁻¹² and fitness¹³⁻¹⁶ are important for health. Being active has many important short-term health benefits for youth in physical and psycho-social domains¹⁷. But as children get older they become less active¹⁸ and less fit¹⁹. In one Australian state in 2004, 40% of girls and 22% of boys in Grade 10 did not meet current physical activity recommendations²⁰ and 33% of boys and 37% of girls²⁰ did not reach recommended standards of fitness²¹. Since physical activity behaviours²² and fitness^{23, 24} track to some degree from youth to adulthood, there is concern that inactive youth will become inactive adults.

Strategies to increase physical activity levels and fitness in youth need to be devised and evaluated but must be based on an understanding of key determinants. Being able to perform basic fundamental motor skills (FMS), such as throwing, kicking and jumping, is considered to be an important prerequisite to sport and physical activity participation²⁵⁻²⁷. In the last ten years there has been accumulating cross-sectional evidence of the importance of FMS proficiency to physical activity and sport participation²⁸⁻³¹ and fitness^{27, 32, 33} in children and adolescents. As there is some evidence that motor skills track through childhood³⁴⁻³⁶, childhood motor skill proficiency may be a potentially important determinant of physical activity and fitness.

How children feel about themselves is also important because children who have a positive physical self image and believe they are competent at sporting activities do tend to be more active³⁷ and fit³⁸. It has been proposed that motor skill proficiency or actual competence precedes perceived competence and that perceived competence more directly effects motivation to participate than actual competence³⁹. We might then assume that children who are motor proficient will develop a positive feeling about their own ability and therefore become active adolescents.

Despite emerging evidence regarding motor skill proficiency as a key correlate of physical activity and fitness, and perceived sports competence as an important psycho-social correlate of physical activity behaviour, there has been very limited longitudinal research to test causality in these relationships. We do not know whether fundamental motor skill proficiency in childhood predicts adolescent physical activity participation or fitness or how perceived competence relates to these variables.

If childhood motor skill proficiency is a determinant of subsequent physical activity behaviour then motor skill development in childhood becomes important. Yet, the long-term impact of childhood motor skill interventions has not been explored. Reviews of evidence-based strategies to promote physical activity amongst young people recommend more long-term follow-up studies^{40, 41}.

It might also be expected that any effect on physical activity or fitness as a result of childhood motor skill proficiency may differ according to gender. Motor skill research on youth have generally found that males are more proficient in object control skill performance (involving object manipulation i.e. catching or kicking)^{21, 42-47}. Few studies are longitudinal, but those that are show that gender differences in motor skills also track to different degrees, depending on the skill^{34, 48}.

In the absence of other longitudinal research, the current study known as the Physical Activity and Skills Study (PASS) investigates the nature of the relationship between childhood motor skill proficiency and adolescent physical activity participation and cardiorespiratory endurance, including the potential associations with perceived sports competence. In addition, it examines the long-term impact of the Move It Groove It (MIGI) Intervention; a one year Australian school-based physical activity intervention (1999-2000) that improved motor skill proficiency in primary school students. This study also explores the impact of gender on these relationships and in particular on the change in motor skill proficiency from childhood to adolescence.

1.2 Purpose of Study

The aim of this study is to investigate the nature of the relationship between childhood motor skill proficiency and adolescent (measured six years later) physical activity participation, cardiorespiratory endurance and perceived sports competence and to explore the impact of gender on these relationships. A secondary aim was to assess the long-term impact of the MIGI Intervention.

1.2.1 Major research questions

1. What is the nature of the association between fundamental motor skill proficiency during childhood and physical activity participation (MVPA, vigorous, organised, non-organised) in adolescence?
2. What is the nature of the association between FMS proficiency during childhood and cardiorespiratory fitness in adolescence?
3. Does perceived sports competence mediate between childhood motor skill proficiency and adolescent physical activity?
4. Does perceived sports competence mediate between childhood motor skill proficiency and adolescent cardiorespiratory fitness?

1.2.2 Secondary research questions

5. Are children who completed a FMS intervention during childhood more proficient at FMS in adolescence than control group children?
6. Are children who completed a FMS intervention during childhood more physically active in adolescence than control group children?
7. Does gender moderate the relationship between childhood motor skill proficiency and any of the variables posed in this study i.e. adolescent physical activity, fitness, perceived sports competence and/or motor skill.

1.3 Hypotheses

The prime study hypothesis was that children with greater motor skill proficiency would become more active adolescents with higher levels of cardiorespiratory fitness. It was also hypothesised that children with higher skill proficiency would develop a higher perception of their competence in sports which would influence and lead to greater adolescent participation in physical activity and higher cardiorespiratory fitness. The secondary study hypothesis was that intervention children who participated in a successful motor skill intervention would become adolescents who were more skill proficient and more physically active than their former control counterparts. It was proposed that these relationships might vary by gender.

In particular it was hypothesised that:

1. FMS proficiency during childhood predicts a) Moderate-to-Vigorous Physical Activity (MVPA) participation in adolescence and b) participation in organised physical activity in adolescence.
2. FMS proficiency during childhood predicts adolescent cardiorespiratory fitness.
3. Perceived sports competence mediates between FMS proficiency during childhood and adolescent physical activity.
4. Perceived sports competence mediates between FMS proficiency during childhood and adolescent cardiorespiratory fitness.
5. Children who completed a FMS intervention during childhood would perform FMS as an adolescent more proficiently than control group children.
6. Children who completed a FMS intervention during childhood would participate in more MVPA as adolescents than control group children.

7. Gender will moderate relationships between childhood motor skill proficiency and adolescent physical activity, fitness, perceived sports competence and motor skill proficiency.

1.4 Study Significance

Increasing physical activity is a major national and international public health priority because participation in physical activity is associated with extensive health benefits. Investigating potential determinants of adolescent physical activity and fitness is crucial because the adolescent age period is associated with the greatest decline in activity¹⁸, yet there is limited longitudinal research to test causation.

The PASS may provide helpful information that will contribute to our understanding of physical activity determinants. The PASS is the only longitudinal study to follow children from primary to high school to assess the contribution childhood skill proficiency makes to subsequent physical activity and fitness. Our approaches to increasing youth physical activity may be informed by knowing if childhood motor skill proficiency impacts on adolescent physical activity participation and cardiorespiratory fitness.

Knowing whether skilled children become active and fit adolescents will be useful for policy makers, curriculum planners, and teachers, in that it could inform the planning and delivery of physical education (PE) lessons and ensure that teaching strategies are appropriately selected. Understanding the importance of perceived sports competence in this relationship as a potential mediating variable will help the design of interventions to promote physical and fitness among youth.

The PASS is also one of the few studies to conduct a long-term follow-up of a school physical activity intervention. Knowing whether improvement in motor skill proficiency gained through a childhood intervention lasts beyond the intervention end point, and if this has translated into physical activity participation may also help to inform our approaches to school PE for

children. Furthermore, knowing how gender might impact on all these relationships will help us to tailor interventions to the needs of each gender.

The PASS findings are thus important and will be beneficial for schools, teachers, health professionals, parents and all those in the community interested in ensuring our youth are physically active and healthy.

1.5 Overview of Study Design

The PASS comprised the longitudinal follow-up of students who had previously participated in MIGI, a one year school-based physical activity intervention (1999-2000) in primary school students. Those who participated in the MIGI program during 1999 and 2000 were approached for assessments during 2006/07 for the PASS. The PASS examined changes in skills and physical activity behaviour between these two assessment periods: childhood (mean age 10 years - 2000) and adolescence (mean age 16 years - 2006/07).

MIGI aimed to increase motor skill proficiency and physical activity amongst elementary school students⁴⁹ with the expectation that intervention children would become more involved in sports, and remain more active than their lesser skilled peers⁵⁰. In-school interventions included: 'buddying' of pre-service teachers with each of the schools for in-class work with teachers and students, professional development of classroom teachers, collaborative planning with the schools project team and resource allocation in the form of a web-site and funding for equipment purchase⁴⁹.

A total of 1045 children participated in MIGI from 18 randomly selected and stratified primary schools (nine schools participating in the intervention and nine serving as controls) in an area comprising 24,555 sq kilometers in New South Wales, Australia. Motor skills of children were assessed between February and June 1999 (MIGI baseline) and August to December 2000 (MIGI post-test)⁵⁰. Of these students, 1021 had first and last initials noted on their motor skill assessments. The battery of motor skills included the catch,

kick, overhand throw, hop, side gallop, vertical jump, sprint run, and static balance ⁴⁹.

At post test in 2000, intervention children's motor skill proficiency had improved by 17% overall, relative to control students in the battery of FMS ⁴⁹. The mean age of the sample at post-test was 10.1 (range 7.9 to 11.9 yrs). In 2006/07, the list of original MIGI participants (of the 1021, 929 (91.0%) matched by full name and gender to class role) was sent to all consenting high schools in the original study district (97.6%, $n = 41/42$) to identify adolescent students for follow-up as part of the PASS. Students' names were identified on the high school register, and consenting students from 28 high schools were included in the PASS sample. These students were reassessed in six motor skills (catch, kick, overhand throw, hop, side gallop, vertical jump), and also assessed for physical activity behaviour, cardio-respiratory fitness and perceived sports competence. Linear and structural equation modelling was used to examine relationships between childhood skill proficiency and adolescent physical activity and cardiorespiratory fitness. A general linear model examined the relationship between being an intervention/control student and subsequent physical activity.

1.5.1 Operational definitions

Childhood: The time for a boy or girl from birth until the onset of puberty.

Adolescence: The definition of adolescence varies by program, need and funding source. It is generally accepted that it is the time from puberty until adulthood. The Centre for Disease Control definition for adolescence is from age 10 until 24.

Fundamental motor skills: FMS, either locomotor (also known as movement skills e.g. running) or object control (involving manipulation of an object e.g. kicking), are usually perceived as occurring after a stage (or stages) that involves birth reflexes ²⁷. Mastery of FMS is seen as providing the foundation for the development of more sports-specific skills ²⁷.

Physical activity: Physical activity is a behaviour that can be defined as “..any bodily movement produced by the skeletal muscles and resulting in a substantial increase over the resting energy expenditure” (Page 126) ³⁷

Physical activity in daily life can be regarded as occupational, sports, conditioning, household, or other activities ⁵¹

Participation in physical activity: Physical activity with a MET value (metabolic equivalent; 1 MET=3.5mL of oxygen per kilogram of body weight per minute) of 3.0 or greater and up to and including 6.0 were considered moderate, and those activities greater than 6.0 were considered vigorous ⁵². The total number of MVPA minutes spent in physical activity during a usual week over the year (averaged between a usual summer week and usual winter week) was calculated from the self-report physical activity instrument.

Organised sports and games: Physical activities involving regular classes, training or competition that were somewhat structured or formal and have a coach, instructor or teacher.

Non-organised physical activity: Physical activities which are not structured or formal with no regular training/competition and no coach, instructor or teacher.

Physical fitness: Physical fitness is a set of attributes that are either health-or skill-related ⁵¹. Cardiorespiratory fitness, sometimes called endurance fitness aerobic fitness, or aerobic capacity, is a health-related component of physical fitness and is the type of fitness referred to in this study. It relates to the ability of the body's cardiovascular (circulatory) and respiratory systems to function together to supply fuel during sustained physical activity and to eliminate fatigue products after supplying fuel ⁵¹.

Perceived sports competence: Perceived sports competence refers to the perception of one's own competence ³⁹ in the sport and physical activity arena.

1.6 Ethics

Ethics approval for the PASS was gained from the University of Sydney (07-2006/9243), the Department of Education (06.296), and the local Catholic Diocese.

2 LITERATURE REVIEW

2.1 Introduction

This chapter is divided into three sections. The first section outlines the rationale for promoting physical activity and cardiorespiratory fitness in adolescence. The importance of physical activity and fitness to health and how adolescent physical activity contributes to adult health will be discussed. The epidemiology of adolescent physical activity participation and fitness and current recommendations for activity and fitness will also be outlined.

The second section presents an overview of physical activity behaviour including relevant theories of behaviour change and determinants of adolescent physical activity participation. Motor skill proficiency will be examined closely as a potentially key physical activity determinant in this study. Perceived sports competence is explored as a possible mediating factor in the relationship between childhood motor skill proficiency and adolescent physical activity and fitness. Relevant theoretical frameworks for understanding motor skill proficiency and perceived sports competence are outlined. Gender differences in motor skill proficiency and perceived sports competence will also be described.

Finally, relevant literature which explores the impact of interventions targeting children's motor skills is introduced under the premise that if motor skill is a determinant of physical activity behaviour and fitness levels then improving motor skill proficiency becomes important. Lastly, the case for further research is outlined and the review summarised. Figure 1 shows a diagrammatic representation of the literature review.

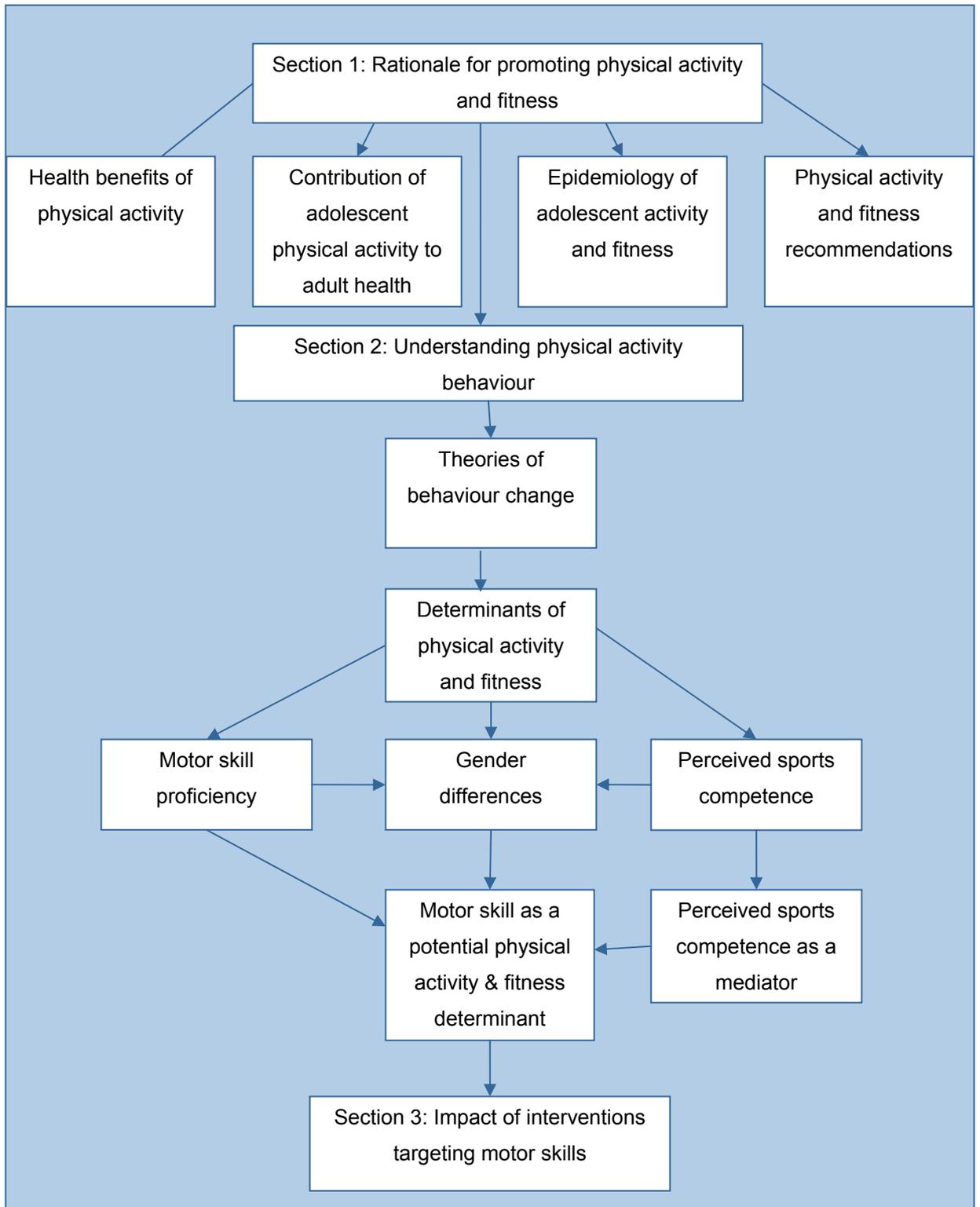


Figure 1: Schematic Diagram of Literature Review

2.2 Rationale for Promoting Physical Activity and Fitness

2.2.1 Health benefits of being active and fit

Physical inactivity was identified as a major public health concern 20 years ago ¹. Since that time, evidence of the many protective benefits of physical activity has continued to accumulate. The strongest evidence is in the prevention of cardiovascular disease and reducing overall mortality in adults ²⁻⁶.

Physical activity also has preventative effects for non-insulin dependent diabetes ^{2, 3, 6}, with the risk of Type 2 diabetes substantially reduced with MPA ⁷, especially when combined with weight loss and a balanced diet ⁵. Physical activity also helps to improve glucose metabolism in patients with Type 2 diabetes ⁸.

There is also strong evidence that physical activity prevents cancer ⁶, including: colon ^{1-3, 5, 9} and breast cancer ^{9, 53}. Evidence is weaker, but still likely, for prostate and lung and endometrial cancers ^{9, 10}. Regular physical activity also helps in obesity prevention and treatment ⁶, the management of hypertension ^{3, 6, 54}, bone development ¹¹, and arthritis and osteoporosis ².

Furthermore, physical activity has a beneficial effect on psycho-social health ¹². A review of psycho-social (defined to include psychological and social-psychological outcomes) health benefits due to exercise (habitual physical activity, fitness training, exercise, and sport), noted that exercise had a small to moderate effect on anxiety, a moderate to large effect on depression, a consistent moderate relationship with measures of mood and self-esteem and small to moderate effects in cognitive functioning ¹². Another review note that although available evidence suggests there are benefits to mental health from physical activity participation, most research in this area is cross-sectional and on small samples and needs to be updated with better designed studies ⁵. In adolescents, cross-sectional studies suggest weak positive associations between physical activity and less anxiety and

depression symptoms, whereas quasi-experimental studies show a strong positive influence between physical activity and improvement in anxiety and depression ¹⁷.

It has been shown that physical activity has a strong dose relationship to fitness ⁵⁵, therefore the nature and relative importance of fitness determinants may also be important ¹³. Figure 2 presents a model illustrating relationships between physical activity, health-related fitness and health for adults ⁵⁶. The model shows physical activity impacting on fitness, which in turn affects physical activity participation. With greater fitness, people tend to become more physically active, with those who are fittest tending to be the most active. Fitness is also seen to influence health, but health status also influences both physical activity and fitness ⁵⁶. This model may also be useful in understanding the relationship between physical activity and fitness in adolescents except that adolescent physical activity behaviour would be less likely to include occupational pursuits and also arguably, other chores.

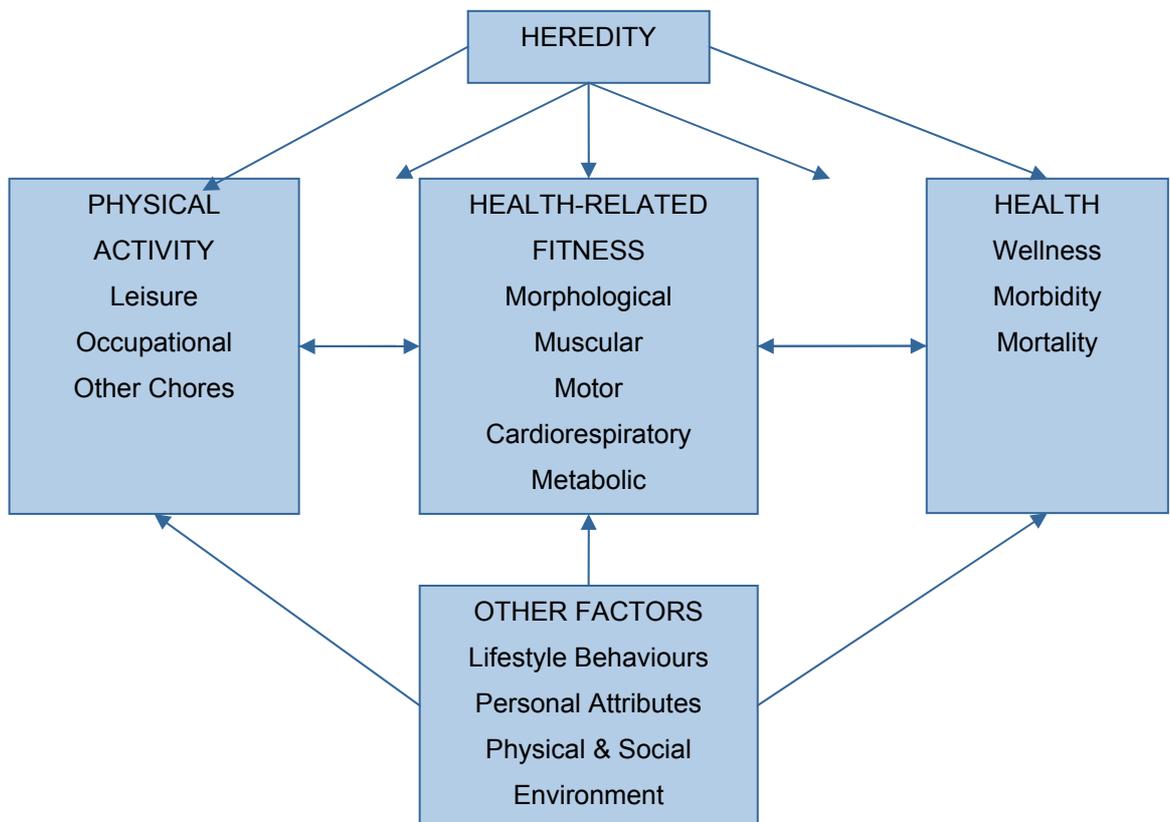


Figure 2: A model describing the relationships between physical activity, health-related fitness and health ⁵⁶

A recent review suggests that cardiorespiratory fitness or endurance is associated with both obesity and cardiovascular disease factors ¹³ and there is also a significant relationship between adolescent cardiorespiratory fitness and later body fatness ^{57, 58}.

In fact, cardiorespiratory fitness is emerging as a factor that may even deserve more attention than physical activity. Exercise capacity has been found to be a stronger predictor of mortality in adult men than activity patterns ¹⁵, and cardiovascular risk factors appear to relate more strongly to cardiorespiratory fitness than components of physical activity in children and adolescents ¹⁶.

2.2.2 Adolescent physical activity and fitness contributes to adult health

Four pathways have been proposed to explain how adolescent physical activity may contribute to adult health: i) the *tracking* of physical activity from adolescence to adulthood, ii) *direct influence* of adolescent physical activity on adult morbidity, iii) role of physical activity in *treating* adolescent morbidity and iv) *short-term benefits* of physical activity in adolescence on health ⁵⁹.

Tracking refers to the maintenance of relative rank or position over time. The strongest findings for tracking in relation to risk factors for cardiovascular disease is physical inactivity ⁶⁰⁻⁶². In one study, children's (Kindergarten to Grade 3) physical activity was monitored with accelerometers and tracked over a three year period, with sedentary behaviour (such as television viewing, and inactive minutes) more predictable (i.e. tracking more strongly) than overall physical activity ⁶³. Likewise in a review article, sedentary behaviour and poor physical fitness were both found to be associated with poor health outcomes in adulthood ⁵⁹.

Even though evidence of the tracking of physical activity behaviour across the lifespan has been limited ⁶⁴ and unclear ⁶⁵, there is some evidence for the tracking of physical activity behaviour in the short to medium term. Studies show tracking at low to moderate levels in early childhood ^{63, 65}, during adolescence ^{36, 60, 66}, and from adolescence into adulthood ⁶⁴. There is also some evidence to suggest physical activity behaviour tracks from childhood to adulthood, if the child has participated in competitive sport and PE ^{67, 68}, although the correlations were weak ⁶⁹. Generally speaking, as the time span increases, the correlation between measurements reduces ³⁶.

In a review of studies from 2000-04 focusing on the period from adolescence to adulthood, there was a consistent moderate effect of physical activity during adolescence on adult physical activity ⁵⁹. In this review, studies that defined physical activity participation in terms of participating or not participating, rather than the extent of participation, tended to find stronger effects ⁵⁹.

Tracking for health-related components of physical fitness tends to have higher inter-age correlations than for physical activity behaviour^{64, 66, 70, 71}. Fitness in adolescence is associated with fitness in adult years^{23, 24} and tracking of cardiovascular fitness from childhood to adulthood in terms of VO² max also shows moderate correlations⁶⁶. Perhaps correlations are higher for health-related fitness components because such components may be easier to measure as they are generally assessed with observational methods and not dependent on self-report. However, with more studies using data from pedometers and accelerometers, we may see better tracking of physical activity in future studies. Another factor that influences the ability to find higher tracking correlations for both physical activity and health-related fitness is that maturation and growth vary during childhood and adolescence⁶⁶.

In terms of the direct influence of adolescent physical activity on adult morbidity, evidence is limited as there are very few long-term follow-up studies available⁵⁹. The adolescent physical activity and health review mentioned previously⁵⁹, found support for the consistent long-term protective effect of physical activity in adolescence on future bone health. There was also mainly positive support for the long-term protective effect of physical activity on breast cancer⁵⁹. However, support for physical activity in adolescence on the risk factors for cardiovascular disease was not found⁵⁹.

An early study also found little evidence for a significant relationship between physical activity and risk indicators of cardiovascular disease in children⁷². However, a recent review found the association with physical activity and fitness is weak when risk factors for cardiovascular disease are analysed in an isolated fashion, but when analysed in a cluster, the association is strongly related to low physical activity/fitness⁷³. There is also some evidence that high density lipoprotein cholesterol (HDL-C) concentrations in adolescents are enhanced by physical activity⁷⁴, showing that current physical activity behaviour can impact directly on future health. In addition, physiological risk factors that can arise from lack of physical activity, such as

atherosclerotic lesions, high blood lipids, body mass index^{2, 71}, hypertension², and cholesterol levels^{75, 76} track from childhood to adulthood.

A review by Twisk and colleagues concludes that short-term benefits of physical activity to morbidity risk in adolescence can include cardiovascular health, bone health and emotional health⁷⁷. No effect was found for lipid levels, blood pressure or glucose levels in adolescence but HDL-C was positively associated with cardiorespiratory fitness and negatively with body fatness. Physical activity was also associated with improved bone mass⁷⁷.

In contrast to this review, the more recent adolescent physical activity and health review by Hallal and colleagues, found evidence that exercise did lower blood pressure⁵⁹, as did another recent study of mildly hypertensive adolescents¹⁷. Similarly to the Twisk review, others have also found there is a role for physical activity in treating adolescent morbidity with evidence strong for components of cardiovascular health¹⁷.

The above review by Hallal and colleagues did confirm the Twisk findings; that physical activity is associated with improved bone mass⁵⁹. Others have also found evidence strong for the beneficial effects of physical activity on musculoskeletal health¹⁷.

Hallal and colleagues also found evidence that physical activity was associated with less depression and reduced anxiety sensitivity⁵⁹. Twisk reported evidence for positive influence of self-esteem and stress levels⁷⁷. This is consistent with a study of adolescent girls in which Schmalz and colleagues found that participating in physical activity led to positive self-esteem, particularly for younger girls and those at greatest risk of overweight⁷⁸. Higher physical activity at ages nine and eleven years predicted higher self-esteem two years later (at ages 11 and 13 years respectively), controlling for family socio-economic status (SES) and body mass index⁷⁸.

2.2.3 Epidemiology of physical activity behaviour and fitness and associated recommendations

As children move through adolescence, physical activity participation rates^{18, 79-81} and cardiorespiratory endurance levels decline^{19, 82} with the decline in activity throughout adolescence especially marked for girls^{83, 84}. Boys tend to be more active and more fit than girls⁸⁵ in both childhood and adolescence^{81, 86, 87}.

Over ten years ago, the NIH (National Institutes of Health) Consensus Development Panel on Physical Activity and Cardiovascular Disease Health established a recommendation for physical activity of 30 minutes per day for both children and adults⁸⁸. The recommendation at that time for adolescents, from the International Consensus Conference on Physical Activity Guidelines for Adolescents, was that they should be active every day as part of their daily life and in addition engage in another three sessions per week of MVPA lasting 20 minutes or more. Daily physical activity requirement was not quantified, as the data at that time did not support such a specific recommendation¹¹. However, a recent literature review based on current evidence emphasised that school age youth should participate daily in 60 minutes or more of MVPA that is developmentally appropriate, enjoyable and involves a range of activities. This can be achieved in a cumulative manner in a variety of settings including PE, sport, recess, before and after school programs and recreational¹⁷.

A recent state wide survey in New South Wales (NSW), Australia found that more students met these physical activity recommendations in 2004 than in 1997, indicating an improvement in general physical activity participation, particularly in the summer school terms²⁰. Nevertheless, 40% of girls and 22% of boys in Grade 10 still did not meet current recommendations²⁰. In terms of fitness, 37% of girls and 33% of boys in the same study did not reach criterion standards⁸⁹ of cardiorespiratory fitness associated with health benefits²¹.

2.3 Understanding Physical Activity Behaviour

2.3.1 Theories of behaviour change

In terms of health behaviour, theories relating to a particular problem or health issue help to describe and identify why a problem exists, whereas theories of action help to guide the development of interventions⁹⁰. In health promotion and education it is important to understand behaviour in both of these contexts. Likewise, in attempting to understand what facilitates adolescent physical activity participation and fitness, relevant theoretical frameworks help to conceptualise research design and to interpret findings. In the current study, an understanding of behaviour change theories is necessary as theories of behaviour change will be referred to in Section 2.3.2 when motor skill is posed as a potential determinant of adolescent physical activity, fitness and perceived sports competence. It must be noted that the theories which are described, whilst often used to explain behaviour in children and adolescence, stem from work with adults in the physical activity arena.

During the 1990s, the Health Belief Model, Social Cognitive Theory, and the Theory of Reasoned Action were widely used in health promotion and education, with the Transtheoretical Model, diffusion of innovations, the empowerment model and ecological models, also well used⁹⁰. A more recent review (1999/2000) further identified Social Cognitive Theory and The Transtheoretical Model as the most widespread of all the theories⁹¹.

Physical activity is a complex behaviour, and attempting to understand what factors may contribute to increasing participation and the somewhat reciprocal relationship⁵⁶ between physical activity and fitness may be too complex to be explained by a single theory⁹². Bauman (2002) looked at consistently documented positive correlates of physical activity in adults which had been evaluated in multiple studies⁹³ and noted the behavioural theories connected with the variables⁹². The main theories identified were the Theory of Planned Behaviour, the Health Belief Model, Social Cognitive Theory, and the Transtheoretical Model.⁹²

As there is considerable confusion between theoretical perspectives and how they might be applied,⁹⁰ it can be helpful to categorise theories in terms of those which focus on individual factors, compared to those which focus on the environment, or those which encompass models for community change⁹¹. The Health Belief Model, Theory of Planned Behaviour, and the Transtheoretical Model all focus on individual factors affecting health behaviour whereas Social Cognitive Theory emphasises environmental factors. None of these commonly cited theories fall under the category of models for community change.

The Theory of Planned Behaviour suggests that intentions and behaviours result from rational decision making⁹⁴. A central factor in the Theory of Planned Behaviour is the intention to perform a particular behaviour⁹⁵. In this context intentions are the motivational factors influencing behaviour, with behaviour more likely if intention is strong. A person's intentions are based on their beliefs, which are formed from 'attitudes' (how we think about a psychological object or behaviour e.g. whether we think it is 'beneficial' or 'not beneficial') and subjective norms (i.e. social pressure to perform or not perform that behaviour). It is also purported that 'actual' environmental factors, such as opportunity and resources, as well as 'perceived' factors i.e. how an individual perceives their own environment, also influence behaviour. Thus, motivation (intention), ability (behavioural control) and perceived behavioural control influence attitudes towards a given behaviour⁹⁵.

Generally a person will engage in a particular behaviour if s/he: believes the advantages of success outweigh the disadvantages of failure, is motivated and has control over relevant internal and external factors⁹⁶.

The Theory of Planned Behaviour is an extension of the Theory of Reasoned Action, with the difference being that perceived behavioural control was included to allow for factors affecting behaviour that are not within an individual's control. Otherwise, the two theories are similar, both purporting that an individual's intention is the most important behavioural determinant, with intention arising from attitude towards engaging in the behaviour and a subjective perspective of 'norm' associated with the behaviour⁹⁴.

The Health Belief Model has been used to explain the change and maintenance of health behaviour and also as a framework to guide interventions ⁹⁷. Like the Theory of Planned Behaviour, it is a value expectancy theory which means that mental processes play a critical part in the theory. The concept when looked at in a health framework is that there is a desire to get well or to avoid illness and a belief that a particular action would prevent an illness i.e. perceived susceptibility and seriousness and perceived benefits and barriers are the four factors that operate and interact to guide behaviour ⁹⁷. Thus, an individual may take health action if they regard themselves as susceptible, if they perceive there are serious consequences for not taking action and if they believe they can take action which would benefit them ⁹⁷.

The Transtheoretical Model is another model used to understand health behaviour ⁹⁸ and is based on behavioural 'stages of change' which are drawn from across theories ⁹⁴, such as the Theory of Planned Behaviour and Social Learning Theory ⁹³. Stages are seen as both dynamic and stable in nature, meaning that while stages can last over time they also have potential to change ⁹⁸. 'Stages of change' are the steps people move through as they make changes, with the 'process of change' the ways people use to alter their experiences and environments. The notion is that people in different stages use different processes in order to move to the next step ⁹⁸.

Stages of change can represent a way of understanding behavioural risk factors and give a directional focus to change ⁹⁹. People in the 'precontemplation' and 'contemplation' stages are seen as needing to change their thinking to progress from being sedentary to being physically active. People in the 'preparation' and 'action' stages are seen as wanting to be physically active but needing behaviour change skills. Those in the 'maintenance' stage rely on cognitive and behavioural techniques to ensure they remain physically active ⁹⁹. See Figure 3 for an outline of the different stages.

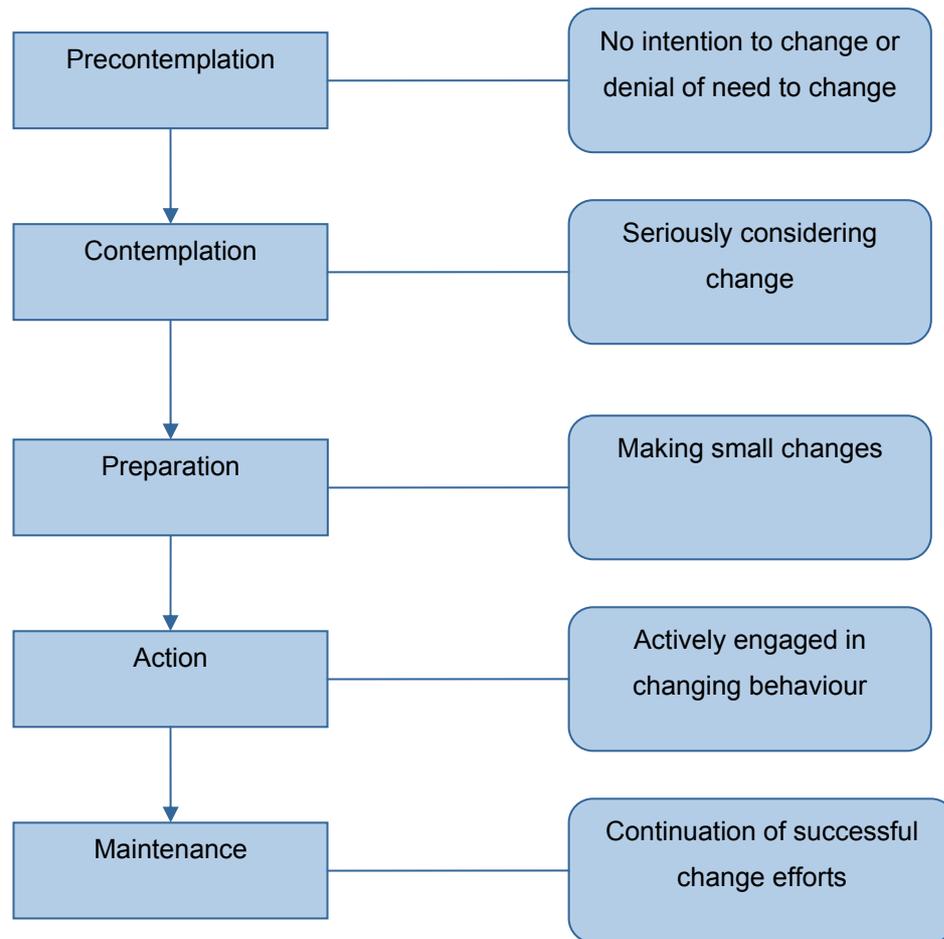


Figure 3: Stages of Change – Transtheoretical Model ⁹⁸

The concept of self-efficacy is incorporated within the Health Belief Model ⁹⁷, the Transtheoretical Model and the Theory of Planned Behaviour ⁹¹. Self-efficacy has been described by several theorists with an early interpretation of motivation in terms of competence or ‘effectance’. In this model, motivation is the concept that behaviour leads the organism to find out how the environment can be changed and what would be the consequences for the changes, leading to ‘effectance’ or a ‘feeling of efficacy’ ¹⁰⁰. The central argument is that the motivation needed to attain competence cannot only come from drives and instincts but from being involved in activity which is motivating in its own right, producing a feeling of efficacy. Therefore, competence refers to the capacity of an organism to interact effectively with the environment and is attained slowly through feats of learning ¹⁰⁰. Competence as a motivational concept behaviour is not random but ‘directed, selective and persistent’ because it satisfies an intrinsic need to deal with the

environment. Competence or 'effectance motivation' is thus seen as an intrinsic drive towards dealings with the environment with the drive developing slowly through ones own actions with the surroundings ¹⁰⁰. Competence motivation can therefore be described as the desire to engage in and be successful at achievement related tasks, and in doing so, perceive that one has been successful.

Motivation when defined as 'achievement' motivation or an 'expectation of success' is similar to perceived self-efficacy as described by Bandura ⁹⁵. Bandura describes perceived self-efficacy under a social cognitive theoretical framework which suggests that there are multiple influences on behaviour from multiple directions that include both cognitive and social factors. Behavioural, cognitive, personal and environmental factors are all seen to operate and interact together to influence behaviour ¹⁰¹. Self-efficacy is one aspect of Social Cognitive Theory relevant to physical activity and refers to a decision about how well one can take action to deal with a particular situation ¹⁰². Expectations of mastery, i.e. how much people believe in their own effectiveness, is seen as affecting both the start and the maintenance of behaviour. Mastery expectations are likely to affect whether an individual will try in a particular situation, with individuals becoming involved in activities and behaving with confidence when they see themselves as capable ¹⁰². Whilst self-efficacy is seen as a major determinant of choice of activity, it is acknowledged that the amount of effort also rests on having appropriate skills and incentives ¹⁰². Expectations of efficacy are described as being based on four aspects: performance accomplishments, vicarious experience, verbal persuasion, and physiological states ¹⁰². Performance accomplishment refers to experiences of success which raise personal expectations, thus contributing to efficacy towards a particular endeavour. Vicarious experience refers to the role modelling of others as being an important factor, i.e. 'someone else can do it, so I can too'. Verbal persuasion is the feedback from others that 'you can or should do it' and emotional arousal refers to anxiety around an action which effects an individuals belief in being able to act ¹⁰². Thus, both environmental events and information pertaining to the individual contribute to an individuals self-efficacy ¹⁰². So for behaviour

change to happen, each of these aspects, need to be addressed. This may mean increasing awareness around the behaviour, addressing the formation of behavioural skills needed to enact the behaviour and creating a supportive environment for the behaviour to occur ¹⁰².

Other achievement motivation theorists with a social cognitive approach to motivation and behaviour also suggest that in 'achievement' settings, individuals strive towards the demonstration of competence. When an individual believes they have demonstrated competence, they see themselves as successful and when they feel they have not demonstrated competence they perceive themselves as unsuccessful. This can be termed a mastery goal orientation. Mastery oriented individuals focus on developing new skills and believe that effort will lead to personal progress and mastery in turn, improving their own competence ¹⁰³.

2.3.2 Factors associated with adolescent physical activity and fitness

Relevant theoretical frameworks can help to identify and test potential factors that may be associated with physical activity participation. Identifying such factors and how they may interact is important in developing strategies to increase youth physical activity participation. Since physical activity can have a strong dose relationship to fitness in adults ⁵⁵, the nature and relative importance of factors associated with fitness may also be important ¹³.

Use of the term 'determinant' is often used in the physical activity literature in relation to associations found in cross-sectional studies of which causation can not be applied ⁹². A determinant is appropriately defined as a causal factor, which when varied, results in systematic variations in physical activity behaviour ⁹². Thus in the following section, *correlates* of physical activity or fitness are referred to when describing cross-sectional evidence, rather than *determinants*, as most evidence is not based on cause and effect study designs.

Physical activity is a complex behaviour and has multiple correlates. Physical activity correlates have been classified into three broad categories: (i)

physiologic/developmental (including maturation and growth) (ii) environmental (such as the school, seasonal influences and safety), and (iii) psychological/social/demographic (self-efficacy, personal beliefs about health behaviours, attitudes and knowledge, parents and role modelling, education and SES) ¹⁰⁴. This model of correlates was reclassified by Lindquist and colleagues into the four categories of i) physiological, ii) psychological, iii) sociocultural and iv) ecological. In this classification model, psychological correlates are separated from socio-demographic correlates and the category of environment has been termed ecological ¹⁰⁵. Ecological includes such factors as availability of facilities, physical safety and climate ¹⁰⁵. Others have also included 'body mass' and 'stage of puberty' as physiologic/developmental factors, 'self-efficacy' and 'attitudes to exercise' (including achievement orientation, perceived competence and intention to be active) as psychological correlates, 'gender', 'ethnicity', 'rurality', and 'SES' as socio-demographic factors, and 'features of the built environment' and 'seasonal weather effects' as environmental factors ¹⁰⁶. Correlates have also been classified as 'social', including factors such as 'support and help from parents', 'parent role modelling', and 'sibling activity', and 'behavioural and skills' including factors such as 'sensation seeking', 'participation in sports', 'sedentary behaviour' and 'motor skill proficiency' ⁸¹.

A systematic review identified that factors consistently related to adolescent physical activity include demographic factors such as age (a negative association), ethnicity (favouring European American) and gender (male). Other factors consistently related to adolescent physical activity include psychological factors such as: achievement orientation, intention to be active, perceived competence and depression, and behavioural factors such as: sensation seeking, previous physical activity and participation in community sports, sibling activity, support from significant others, sedentary behaviour, parental support and opportunities to be active ⁸¹. Notably, in the last ten years there has been accumulating cross-sectional evidence of the importance of FMS proficiency a behavioural factor, to physical activity participation ^{28-31, 107} and fitness ¹⁰⁸.

Motor skill proficiency

Discussion around motor skill development has traditionally focused on maturation as opposed to learning¹⁰⁹. Maturation approaches to motor skill development describe the process of gaining motor skill proficiency as progressive sequences of coordination¹⁰⁹. This cumulative and sequential pattern of developing motor skills²⁷ has been described as ‘the mountain of motor development’¹¹⁰. The ‘fundamental pattern’ period is where children achieve basic motor patterns, ideally then progressing ‘up the mountain’ to obtain more specific sports skills¹¹⁰. Motor skills associated with locomotion (involving movement; such as jumping), object control (involving manipulation of an object; such as a ball) and postural control (ability to maintain body posture and to move the body voluntarily into a particular position)¹¹¹ are usually perceived as occurring within the fundamental pattern period, after a stage (or stages) involving birth reflexes. These early periods are termed the ‘reflexive’ and ‘preadapted’ periods in Clark and Metcalfe’s ‘mountain of motor development’ model¹¹⁰. The model clearly illustrates that whilst all children are expected to progress through to the fundamental pattern period, fewer are expected to progress to the context specific and finally the skilful stage. The different sized mountain peaks in the model represent different possible end points for individuals. Please see Figure 4 for a visual representation of the mountain of motor development.

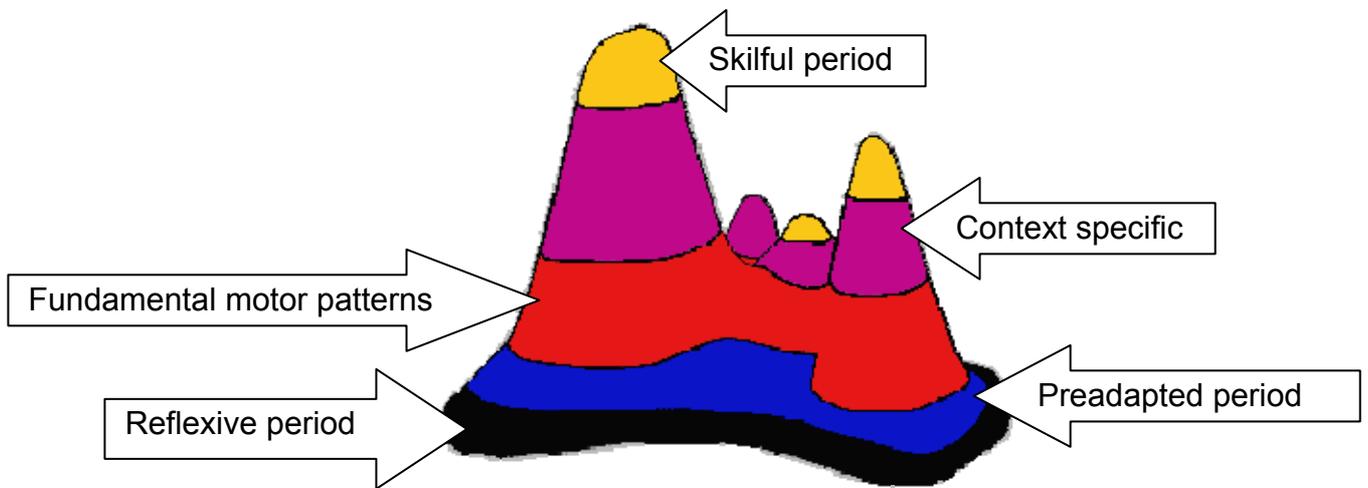


Figure 4: A possible representation of the mountain of motor development ¹¹⁰ Note: The developmental periods are demarcated by shading

Despite general agreement about this sequence of motor skill progression, there is much individual variation. Individual variation is not inconsistent with this sequential maturational approach so long as the order of development is maintained, but when exceptions in movement sequences occur it can imply other factors aside from maturation are at work ¹⁰⁹. A dynamic systems theory explains the motor development process as one in which changing constraints, originating from the interaction between organism, environment (external constraints) and task ¹⁰⁹, define behavioural opportunities at each point in the lifespan ¹¹⁰. The constraints perspective suggests that the order of motor skill development is due to similar constraints placed on children and young people rather than a common set of genetic prescriptions ¹⁰⁹. The Theory of Planned Behaviour also has a constraints perspective in that motivation (intention), ability, and perceived behavioural control (based on the perception of environmental constraints and opportunities) all influence an individual's aptitude to develop motor skills ⁹⁵.

White's ¹⁰⁰ argument of competence as the capacity of an organism to interact effectively with the environment could also help explain motor skill

development. In this context, the motivation needed to attain motor skill competence does not only come from drives and instincts but from being involved in activity which is motivating in its own right, producing a feeling of efficacy.

Social Learning Theory may also be applied to the understanding of motor skill development. Expectations of mastery¹⁰² in this context refer to a child becoming involved in activities requiring motor skills and behaving with confidence when they see themselves as capable. Seeing others engage in motor skills through vicarious experience¹⁰² also gives a firm message to a child that 'someone else can do it, so I can too'. Verbal persuasion¹⁰² also plays a part, with the role modelling and encouragement via teachers and parents important to developing a child's self-efficacy in motor skill performance. Emotional arousal or anxiety¹⁰² around motor skill performance could also feasibly effect an individual's motivation.

Regardless of the theoretical perspective used to explain motor skill development, FMS mastery is considered a pre-requisite to the development of more sports-specific skills^{112, 113} and also considered important to sport participation²⁵⁻²⁷. Therefore, FMS proficiency has the potential to be a determinant for physical activity behaviour.

Motor skill proficiency as a physical activity and fitness determinant

The relationship between motor skill proficiency and physical activity or fitness has not been extensively studied. The existing studies are difficult to compare due to the different ways of measuring and assessing the constructs of interest and the different age groups and settings which have been studied.

Physical activity is not an easy behaviour to measure as it varies daily and in this sense is not a stable behaviour¹¹⁴. Physical activity can be measured via direct observation, objective measures such as accelerometry, or by diary or self-report. Each method has both advantages and associated limitations¹¹⁵,

¹¹⁶. Studies therefore measure physical activity in terms of total time, time in various intensities, step count, or degree of participation (i.e. active versus sedentary). There can also be a distinction made in type of physical activity i.e. organised versus non-organised or 'free play'.

Fitness measures focus either on health-related or skill-related physical fitness ¹¹⁷. Health-related fitness includes cardiorespiratory endurance, body composition, muscular strength, muscular endurance and flexibility ¹¹⁷. Cardiorespiratory endurance measured directly, involves the analysis of expired air whilst exercise is performed on a machine (such as a treadmill) in a laboratory to assess maximal aerobic power ¹¹⁷. A common measure used in field studies is the mile run/walk ¹¹⁷. Endurance fitness is commonly measured by the Multistage Fitness Test (MFT) ¹¹⁸ although there are also many other fitness testing protocols such as the FITNESSGRAM ⁸⁹.

Other aspects of health-related fitness, such as muscle strength and endurance, are also commonly measured in a laboratory setting with specialised equipment, with sit-ups and pull-ups used as indicators in field settings ¹¹⁷. Flexibility can also be measured by specialised equipment in a laboratory setting, with the sit and reach test used in field settings to assess forward flexion of the trunk ¹¹⁷.

Skill-related fitness includes components of agility, balance, coordination, speed, power and reaction time ¹¹⁷. Motor skill assessment can be performed via either product or process assessment. Product assessment is motor skill assessment conducted in order to rate the outcome of skill execution such as time, distance or number of successful attempts ³⁵. In contrast, process assessments are concerned with *how* the skill is performed ³⁵, rather than the outcome of the skill. Process-oriented assessment has been used more recently in assessing motor skill proficiency ³⁵ and provide a more detailed way of assessing motor development ³⁴ allowing for accurate identification of specific skill components that may need improving ¹¹⁹. Motor skills can also be categorized into types, for instance as object control (e.g. catch) or locomotor (e.g. vertical jump), and analysed accordingly.

Cross-sectional motor skill and physical activity studies of pre-school children

Studies examining the relationship between motor skills and physical activity have been conducted in a range of age groups and settings. In pre-school aged children, the focus has tended to be on physical activity rather than fitness. Table 1 provides a summary of studies in pre-school children examining the relationship between physical activity and motor skill performance.

Fisher and colleagues (2005) found significant but weak cross-sectional relationships for both genders between fundamental movement skills and physical activity (total and MVPA) in pre-school children, but not with light intensity physical activity. The product-oriented Movement Assessment Battery assessed motor tasks including: jumps, balance, skips, and ball exercises, and time spent in physical activity was assessed via a uniaxial accelerometer worn for six consecutive days. The relationship with each subcategory of skill (locomotor, manipulative and balancing) and physical activity was also investigated, with similar results as when the total motor skill score was used. Those in the upper motor skill quartile participated in significantly more MVPA than those in the lowest motor skill quartile ²⁹.

Butcher and Eaton (1989) hypothesised that time spent in gross motor free play activities would relate positively to gross motor skills. Physical activity was measured via a mechanical motion recorder and motor proficiency assessed using the product-oriented Bruininks-Oseretsky Test of Motor Proficiency. They found that children who participated in what they categorised as 'high active/gross motor' activities in a free play situation, as opposed to 'sedentary', or 'fine motor' activities, were more likely to have good running skills, however there were no relationship with other motor skills, such as catching. As there were few opportunities for the children to practice upper limb coordination (for example catching) in the pre-school setting the authors thought this may have limited the ability to find a relationship between such items and physical activity ¹²⁰. Saakslähti and colleagues (1999) also investigated the relationship between FMS and

categories of physical activity behaviour in this age group. Physical activity was observed by parents using a diary and motor skills were assessed using a product-oriented assessment. Their 'APM Inventory' assessed walking and running speed, standing broad jump, agility, throwing and catching, balancing, clapping and walking and kicking. Whilst the combined category of high level play (including very active indoor and outdoor play) correlated with running and very active indoor play correlated with throwing, the correlations were low ¹²¹. Another study in pre-school children found no relationship with physical activity participation (assessed via direct observation), however only one skill was assessed (a bunny hop), using a product-oriented assessment ¹²².

Unlike other studies of pre-schoolers, O'Neill and colleagues, investigated the relationship between engagement in various types of physical activities and motor skill ability including six locomotor and six object control skills, but used a process-oriented instrument (modified Test of Gross Motor Development – TGMD) ¹²³. Only 13% of time was spent in gross motor activities as opposed to activities such as lying down, sitting/squatting, standing and walking. The percent of intervals children spent jumping/skipping was associated with total motor skill score and object control score and also approached significance for locomotor score. The percent of intervals children spent walking was negatively associated with total and locomotor score ¹²³. The percent of intervals children spent throwing was not associated with object control score, but children hardly spent any time in throwing activities.

Overall the findings for the cited studies in pre-school children are very mixed. Positive associations were found between total physical activity, MVPA, and motor skill scores in one study ²⁹, and between types of activity and particular motor skills in two studies ^{121, 123}. Negative associations were found in two studies between physical activity and items such as balance, visual motor control and upper limb speed/dexterity ¹²⁰, and with motor skill total scores ¹²³. One study found no association with the skill tested and activity ¹²². The mixed findings most likely reflect the variation in

instrumentation for both motor skills and physical activity. All the motor skill assessments used different instruments and measured a wide variety of skills, although most were product assessments (n = 4/5). Physical activity was measured in three different ways (objective measures, observation, and diary) with different constructs of physical activity within these measures, in terms of type of activity. Although, findings that were negative or with a lack of association, were generally found for lighter physical activity^{29, 123}, and for fine¹²⁰ or obscure motor skills, for example, the bunny hop¹²².

Table 1: Summary of cross-sectional studies of pre-school children examining the relationship between physical activity and motor skill performance

MOTOR SKILLS				PHYSICAL ACTIVITY		ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of Assessment	Outcome of interest	Negative (-) Positive (+)
Butcher and Eaton 1989	Product	Bruininks-Oseretsky Test of Motor Proficiency	Eight subtests (running speed and agility, strength, balance, bilateral limb coordination, upper limb coordination, response speed, visual motor control, and upper limb speed and dexterity)	Mechanical motion recorder (actometer) and observation of children's play using constructed instrument (sedentary, fine motor 1, fine motor 2, active, gross motor)	Activity level	Balance (-) visual motor control (-)
					% of time in high active/gross motor free play	running speed and agility (+) visual motor control (-) upper limb speed/dexterity (-)
Sallis 1993	Product	Based on Ulrich 1985	Bunny hop test	Observation using BEACHES activity codes (i.e. lying, sitting, standing, walking and very active)	Physical activity (each activity code transformed into caloric expenditure expended per kilogram of body weight and then	No association

MOTOR SKILLS				PHYSICAL ACTIVITY		ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of Assessment	Outcome of interest	Negative (-) Positive (+)
					summed to indicate calories expended per kilogram per minute of observation at home)	
Saakslanti 1999	Product	APM-Inventory	Walking and running speed, length of standing broad jump, agility (when jumping sideways), throwing and catching, balancing, clapping and walking in rhythm, galloping, somersault and kicking	Physical activity diary. Time spent in 5-min units in different activity categories, (sleeping, indoor play, very active indoor play, outdoor play, very active outdoor play, unattended play) over one weekend observed by parent and noted.	Very active indoor play	Throwing (+)
					High level of play (very active indoor plus very active outdoor)	Running (+)
Fisher 2005	Product	Movement Assessment Battery	15 tasks including jumps (vertical jump, running jump and standing jump),	Uniaxial accelerometer	Total physical activity	total score (+)
					MVPA	total score (+)

MOTOR SKILLS				PHYSICAL ACTIVITY		ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of Assessment	Outcome of interest	Negative (-) Positive (+)
			balances, skips, and ball exercises (kicking, catching and throwing)		Light physical activity	No association
O'Neill 2008	Process	Test of Gross Motor Development modified	6 locomotor (running, jumping, sliding, galloping, leaping and hopping) and 6 object control (throwing, rolling, kicking, catching, dribbling and striking)	Observation System for Recording Instruction Time in Children - Pre-school version	% intervals jumping/skipping	total motor skill score (+) object control score (+)
					% of intervals walking	total motor skill score (-) locomotor (-)
					% of intervals throwing	No association with object control

Cross-sectional motor skill and physical activity studies of primary school children

Most studies of primary school aged children have also investigated the relationship between motor skill proficiency and physical activity, rather than fitness. Refer to Table 2 for a summary of studies in primary school aged children exploring the relationship between physical activity and motor skill performance.

An early study (1979) found performance of three measures of perceptual motor tasks (static balance, manual dexterity and arm-hand speed accuracy) using a product-oriented assessment was not different for those that were or were not involved in sport¹²⁴. In contrast, Ulrich did find a relationship between participation in organised sport (parent reported of son/daughter participation in an organised sport in the last year) and movement competence in primary school aged children (5-10 years)³¹. Items assessed were classified as motor ability items (broad jump, flexed arm hang, sit-up test, side step test and shuttle run) and motor or sport skill items (playground ball dribble, soccer ball dribble, softball repeated throw, soccer ball throw)³¹. Performance on the soccer ball dribble was the most powerful item in the relationship to sport participation and soccer also was the sport of participation for 66% of participants. In general, performance on the sport skill items better reflected group differences (between either participating or not participating in organised sport) than performances on the motor ability items³¹. Graf and colleagues (2004) also found that children who participated in more activity (club and regular sport activity and irregular physical activity) had the highest motor skill results (tests involved four items concerning balancing and jumping)¹²⁵. Physical activity participation in all three of these studies was measured via self-report.

Ulrich suggested in her study that future research include choosing motor items relevant to physical activities with which children are engaged, to provide a more meaningful profile of competencies³¹. In fact, the idea of skill items relating specifically to skill performance was suggested many years ago¹²⁶. Raudsepp and colleagues (2006) studied types of outside school

activity in primary school children and the relationship with particular FMS. They found that developmental levels of throwing and jumping were both related to activities that involved throwing and jumping respectively, whereas physical activity (measured by the Caltrac accelerometer) was not related to either jumping or throwing skills. Unlike previous studies, overhand throwing and standing long jump were measured using a process-oriented instrument¹⁰⁷.

In a recent study, physical activity was measured with accelerometers and the Bruininks-Oseretsky Test of Motor Proficiency assessed children's (range eight - ten years) motor proficiency³⁰. Motor proficiency was associated with both activity counts and percentage of time in moderate physical activity (MPA) and MVPA (explaining 8.7% of variance)³⁰. Children in the highest motor proficiency quartile were also the most physically active compared with children with lower levels of motor proficiency who had similar levels of physical activity³⁰. Children involved in extra curricula organised activities had better motor fitness compared with children who did not (measured by standing broad jump). In terms of the individual gross motor skill items, the authors reported that both running speed and agility and the broad jump, were positively associated with total activity counts, MPA, vigorous physical activity (VPA), and MVPA³⁰.

In summary, most studies in primary school children (n = 4/5) have found positive associations between skills and participation in activity (n = 2)^{31, 125}, types of activity (n = 1)¹⁰⁷, and total activity, MPA and MVPA (n = 1)³⁰. Similar to the studies in pre-school children, the study which found no association with activity participation assessed fine motor skills and balance¹²⁴. Studies of primary school children, like pre-school children, also varied considerably in instrumentation. All used different motor skill instruments and assessed different combinations of skills, although all were product assessments (with one also using a process assessment). In terms of physical activity assessment, three used self-report, two used objective measures and one used observation.

Table 2: Summary of cross-sectional studies of primary school aged children exploring the relationship between physical activity and motor skill performance

MOTOR SKILLS			PHYSICAL ACTIVITY			ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of Assessment	Outcome of Interest	Negative (-) Positive (+)
Magill 1979	Product	Perceptual motor instruments chosen to assess speed and accuracy of arm movement including the tapping test, the Minnesota manual dexterity test and the stabilometer.	Static balance, manual dexterity & arm-hand speed & accuracy	Self-report	Involved or not involved in organised sport	No association
Ulrich 1987	Product	Chosen from a review of the literature and reviewed by three content experts	9 items altogether including 5 motor ability items (broad jump, flexed arm hang, sit-up test, sidestep test & shuttle run) & 4 sport skill items (soccer ball dribble, playground ball dribble, softball throw, soccer throw)	Self-report	Participation in organised sport	Sport skill items particularly with soccer ball dribble (+)

MOTOR SKILLS			PHYSICAL ACTIVITY			ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of Assessment	Outcome of Interest	Negative (-) Positive (+)
Graf 2004	Product	Koperkoordinationstest fur Kinder; KTK	Four items concerning balancing & jumping	Self-report	Participation in club sport & regular sport	Motor quotient (+)
Raudsepp 2006	Product & Process	Instrument name not specified	Overhand throw & standing long jump	Modified Children's Physical Activity Form (MCPAF) to observe outside school activity & Caltrac Accelerometer	Activities involving throwing	developmental levels (+)
					Activities involving jumping	developmental levels (+)
					Total activity (Caltrac)	No association with jumping & throwing
Wrotniak 2007	Product	Bruininks-Oseretsky Test of Motor Proficiency	Eight subtests (running speed & agility, strength, balance, bilateral & upper limb coordination, response speed, visual motor control & upper limb speed & dexterity)	Accelerometer	Moderate	(+)
					MVPA	(+)
					Total activity	(+)
					All activity measures	running speed, agility & broad jump (+)

Cross-sectional motor skill and physical activity studies of adolescents

Fewer studies have been conducted in adolescence. Table 3 provides a summary of studies in adolescents. Okely (2001) extended previous research by using a process-oriented assessment battery to assess the cross-sectional relationship between six FMS and both non-organised and organised physical activity in Grade 8 (mean age 13 years), and Grade 10 (mean age 15 years) students. A significant relationship between fundamental movement skills and self-reported participation in organised physical activity was found, although only a small proportion (3%) of variance was explained by fundamental movement skills. The relationship between movement skills and organised activity was stronger for girls with the very low quintile of girls spending significantly less time in activity than the very low quintile of boys. Two locomotor skills and four object control skills²⁸ were assessed, but the effect of these sub categories of skills on physical activity participation was not explored. Movement skills had no effect on non-organised physical activity²⁸ which is similar to Butcher and Eaton's findings, where free play in pre-school children was only found to relate to running¹²⁰.

Reed (2004) examined the relationship between physical activity as measured by pedometer steps (over three full consecutive school days) and tests of motor skill such as balance and agility passing a ball, using a product-oriented assessment in Grade 6, 7 and 8 students. There were some associations between the passing test and daily step count (in Grade 6 students and Grade 8 boys) but overall these skills only weakly related to physical activity. There were also significant negative correlations between physical activity and the motor skill tests between girls in Grades 6 and 7¹²⁷.

In these two studies, two different motor skill assessments were used, one product and one process with different skills assessed in each. Also physical activity was measured in two different ways (self-report and diary).

Nevertheless, positive associations in both studies were found between skills and organised activity²⁸, and among skills and step count¹²⁷.

Table 3: Summary of cross-sectional studies in adolescents exploring the relationship between physical activity and motor skill performance

MOTOR SKILLS				PHYSICAL ACTIVITY		ASSOCIATION
Authors	Product or process	Instrument	Skills	Method of assessment	Outcome of interest	Negative (-) Positive (+)
Okely 2001	Process	Get Skilled Get Active	6 skills (run, vertical jump, catch, overhand throw, forehand strike and kick)	Self-report; Adolescent Physical Activity Recall Questionnaire	Organised physical activity participation	(+)
					Non-organised physical activity participation	No association
Reed 2004	Product	Bass stick Balance test (lengthwise), Side-Step Agility Test and the AAHPERD passing test	Balance, and agility and passing a ball	School Physical Diary used to record pedometer steps (Digi-Walker)	Daily step count	Passing test (+)
					Steps taken in PE	Agility test (+)

Cross-sectional motor skill studies using fitness as an outcome

Only three studies were located that used fitness as an outcome and all found a relationship with motor skill proficiency. Please refer to Table 4 for a summary of studies that have explored the relationship between fitness and motor skill performance. One study of primary school aged children (kindergarten) assessed the relationship between motor proficiency and various fitness components, including the PACER endurance fitness test. Motor proficiency was assessed using the Bruininks-Oseretsky Test product-oriented battery which includes eight subtests. Strength, balance, and bilateral coordination were significantly related to the half mile run, with strength the only subset of the motor skill test related to the PACER endurance test ¹²⁸.

Okely (2001) also investigated the relationship between cardiorespiratory fitness and FMS proficiency in adolescents, as part of the previous study described, finding that all six skills and the composite skill score related to the number of laps completed on the MFT ¹⁰⁸. Stodden and colleagues (2007) also examined the association between measures of health-related fitness (e.g. push-ups, sit-ups, curl-ups, PACER test) in adolescents and motor skill competence (using a product assessment) finding that the physical fitness measures all contributed to the amount of variance explained in kicking and throwing velocity and also distance jumped ³³.

The three studies located that used fitness as an outcome, all found an association between motor skill proficiency and endurance fitness. All identified endurance fitness as the outcome measure. Product motor skill assessment were used in two of the studies ^{33, 128} and these studies can therefore be described as looking for association between health-related fitness measures and endurance fitness.

Table 4: Summary of cross-sectional studies exploring the relationship between fitness and motor skill performance

MOTOR SKILLS				FITNESS		ASSOCIATION
Authors	Product or process	Instrument	Skills	Instrument	Outcome of interest	Negative (-) Positive (+)
Reeves 1999 (kindergarten children)	Product	Bruininks-Oseretsky Test of Motor Proficiency	Eight subtests (running speed and agility, strength, balance, bilateral limb coordination, upper limb coordination, response speed, visual motor control, and upper limb speed and dexterity)	Half Mile run		Strength, balance, bilateral coordination (+)
				PACER Endurance Test	Number of laps	Strength (+)
Okely 2001 (adolescents)	Process	Get Skilled Get Active	6 skills (run, vertical jump, catch, overhand throw, forehand strike and kick)	Multistage Fitness Test	Number of laps	Total score and each skill (+)
Stodden 2007 (adolescents)	Product	JUGS radar gun to measure velocity	Kicking, throwing and distance jumped	FITNESSGRAM testing protocols and PACER test	Kicking, throwing velocity & distance jumped	Six fitness measures(+)

Longitudinal evidence

A major limitation of the previously described studies is the cross-sectional design used to describe the relationship between motor skill proficiency and physical activity and fitness. Many of these studies suggested that future research include longitudinal studies^{28-30, 107, 120}. There is only one published longitudinal study, by McKenzie and colleagues (2002), which examined the relationship between childhood motor skills and subsequent physical activity⁴². This study examined early childhood (ages 4-6 years) motor skills (lateral jumping, catching a ball, and balancing on one foot) and early adolescent (12 yrs) physical activity participation measured via the seven day Physical Activity Recall questionnaire. Motor skills were assessed using a product oriented battery. For example, the number of times jumping over a tape, the number of successful catches, and the time stability was maintained. No relationship was identified between these three motor tasks and subsequent physical activity⁴².

Several explanations were suggested by the authors as to why a relationship between motor skills and activity was not found. Firstly, there may be no connection between childhood movement skill proficiency and subsequent physical activity because of other factors influencing physical activity⁴². Secondly, there may be a relationship between motor skill proficiency and subsequent physical activity, but either the motor skill assessment or the physical activity assessment precluded finding this relationship⁴². Physical activity was assessed via self-report which may have limited accuracy⁴². Only three motor skills were assessed with two of these skills having what the authors termed a restricted range of measurement; 0-2 for balancing and 0-6 for catching⁴². Okely found cross-sectional associations with physical activity and motor skill proficiency using a composite score for the six skills assessed²⁸.

Also, the skills were measured before the children had had a chance to participate in school PE and in out-of-school PE and sport programs. The potential for motor skill ability to predict subsequent activity may have been limited because ability was measured at such an early stage⁴². It may be

that measuring motor skill proficiency in early childhood is too early to detect relationships with subsequent physical activity⁴². Perhaps assessing motor skills at an age when most should have experienced opportunities to learn and practise skills will lead to more accurate predictions of future activity.

Summary of evidence for motor skill as a determinant

Even though the one longitudinal study located did not show a relationship between motor skill proficiency and physical activity, cross-sectional research, particularly in those of school age, suggests that motor skill proficiency is positively associated with physical activity^{28-31, 107} and fitness^{33, 108, 128} in youth. This is despite the use of different measures and constructs of motor skills, physical activity and fitness.

Of the studies using product assessments to investigate the relationship between motor skills and physical activity that found no association, only a limited skill range was measured^{122, 124}. Of the few studies that used process-oriented instruments^{28, 107, 108} to assess motor skills, a relationship between motor skill proficiency and time in physical activity was found in adolescents²⁸ but not in primary aged children¹⁰⁷. However, Raudsepp and colleagues did find a relationship with particular motor skills and physical activity, involving the use of the specific activity related motor skill¹⁰⁷. Of the three studies investigating the relationship between motor skills and fitness, a relationship was found in each study regardless of the type of motor skill assessment.

Perceived sports competence

The notion of perceived competence is central to the self-esteem model proposed by Harter³⁹ and comes from social cognitive approaches to motivation and behaviour drawing from the competence or 'effectance' model of motivation¹⁰⁰. Harter describes self-esteem as a multidimensional and hierarchical construct with the 'self' composed of different domains (i.e. social, physical, cognitive) that sit under a construct of global self-esteem. Harter identified a number of self-esteem sub-domains that children can differentiate between: scholastic competence, athletic competence, peer/social acceptance, behavioural conduct, and physical conduct^{39, 129-131}.

Harter's model proposes that the outcome of mastery attempts affect perceived competence, with perceived competence therefore more directly effecting motivation than actual competence³⁹. Harter also specifies that self-esteem is influenced by perceptions of competence in particular achievement domains that are perceived to be important¹³². This model was extended for the physical domain¹³³ with Figure 5 illustrating how physical activity behaviour as an outcome stems from pathways through self-esteem and enjoyment which originate from perceived competence. Griffin (1982) also suggested that actual competence influences perceived competence in turn affecting physical activity participation¹³⁴. Perceived competence is therefore thought to be an important motivator of sports participation³⁹.

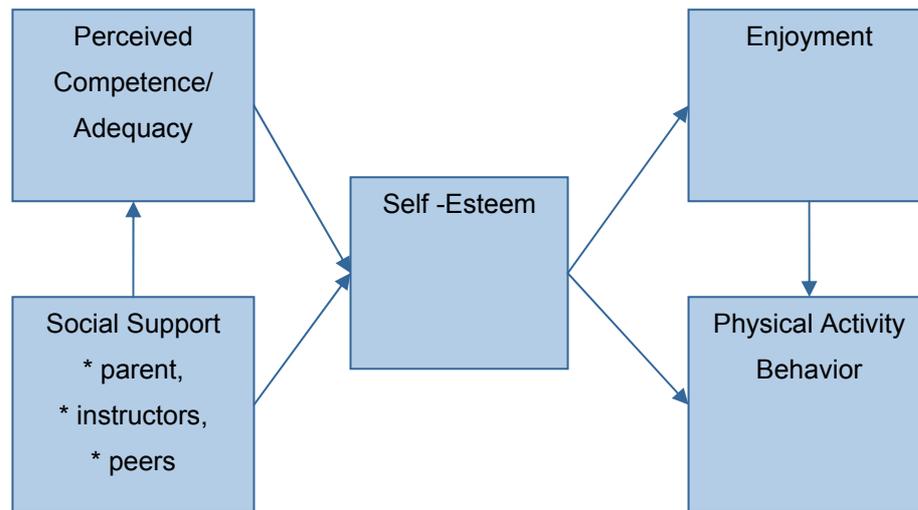


Figure 5: Harter's mediational model of global self-worth ¹³² customised for the physical domain ¹³³.

In the early 1980's few studies had assessed the role of perceived sports competence in sport motivation ¹³⁵. In 1981, Roberts tested Harter's model by investigating the relationship of sport participation to perceived ability and showed that children's selection and motivation to participate in sporting activities were related to their perceived competence ¹³⁶. Children who participated in organised sport were found to have higher levels of perceived ability and persisted more in sport contexts with higher expectations of success ¹³⁶. Another early study found that sport participants compared to drop-outs had higher levels of perceived physical competence ¹³⁵.

Studies since this time have built an evidence base around the importance of perceived sports competence to youth physical activity and sport participation and to fitness levels. Many of these studies have focused on a profile approach to measuring the different aspects of self-esteem, following on from Harter's model. The Physical Self-Perception Profile (PSPP) ^{137, 138} is one such instrument that measures physical self-perception in terms of the different sub-domains of the physical self. Fox and Corbin (1989) found that the perceived sports competence, condition and strength sub-domains could discriminate between active and non-active students in a University sample. Furthermore, each sub-domain was associated with the physical activity that

it logically related to, i.e. perceived sports competence was related to ball sport activities ¹³⁷.

The sub-domain of perceived sports competence has been further identified as an important psycho-social correlate of physical activity in youth. In a review of correlates of physical activity of children and adolescents ⁸¹, perceived physical competence was found to have a positive association with physical activity based on studies reviewed from 1970-1998 ^{139, 140}.

In a 10-14 year old Canadian sample, Crocker and colleagues (2000) found that physical self-perceptions, especially perceived conditioning and sports competence, were significant correlates of physical activity ³⁷. In another study, of the four sub-domains of physical perception tested in structural equation models, perceived sports competence and conditioning had the most parsimonious pathway to physical activity ³⁷. In one adolescent cross-cultural sample, the sub-domains of the PSPP-C were able to differentiate between high-active and low-active adolescents with around 60-70% of cases for both genders correctly classified ¹⁴¹. In the British sample, perceived sports competence and strength were the most important discriminators for both genders, and in the Russian sample, perceived physical conditioning and sports competence were the most important discriminators for both genders ¹⁴¹.

In terms of the relationship between perceived sports competence and fitness, Raudsepp and colleagues demonstrated in another adolescent sample that perceived sports competence and overall physical self-worth were predictors of MPA and physical fitness ¹⁴². In young adolescents, performance in an endurance run moderately correlated with physical perceptions of sports competence, physical conditioning and physical self-worth ¹⁴³. Also in this age group, physical self-perceptions of sports competence and other aspects have also been related to several indicators of physical strength ¹⁴⁴.

Thus, perceived competence has an important relationship to participation in sport ^{135, 136} and physical activity ¹³⁹⁻¹⁴² and fitness ¹⁴²⁻¹⁴⁴, but it should not be

considered a determinant of participation; although cross-sectional findings are consistent with this interpretation ¹³⁶. Longitudinal data are needed to assess whether sports participation influences perceptions of competence ^{135, 142} and to determine the causal links between physical activity and perceptions of self-esteem ³⁷.

Perceived sports competence as a mediator

Bauman (2002) proposed that consistent correlates of physical activity can be considered as potential mediating variables ⁹². Since perceived sports competence is a consistent correlate of physical activity ^{135, 136, 139-142} and fitness ¹⁴²⁻¹⁴⁴, and also associated with motor skill proficiency ^{38, 145}, it may be able to be considered as a mediating variable. Griffin (1982) suggested that actual competence influences perceived competence which in turn affects physical activity participation choices and proposed that 'movement confidence' could act as a mediator ¹³⁴. 'Movement confidence' is defined as a feeling of adequacy in a situation requiring movement, arising from the process of evaluation an individual makes of experiences related to moving. The product of this evaluation process is the interaction between what is further defined as MOVCOMP (MOVement COMPetence) and MOVsense (personal expectations of sensory experiences related to moving). The concern is to maintain a 'positive spiral', i.e. that an individual is more likely to choose to participate and perform ¹³⁴. Therefore, movement confidence has the potential to act as both a consequence and a mediator.

It is plausible then, that children who are skill proficient may develop a high perception of sports competence leading to greater subsequent participation in physical activity and higher fitness levels. Conversely, children with poor proficiency may develop low perceived competence resulting in less engagement in physical activity in adolescence. In this sense perceived sports competence would be acting as a mediator in the relationship between childhood skill and adolescent physical activity and/or fitness.

The idea of a mediating variable has stemmed from psychological research ¹⁴⁶. Woodworth in the 1920's introduced the generic mediation model or

stimulus-organism-response (S-O-R) model ¹⁴⁷. The model proposed that effects of stimulus (environmental factors) on behaviour are mediated by internal processes of the organism. The processes of the individual which can influence the response to a stimuli were termed by Woodworth as: 'structure'; permanent bodily structure or anatomy, 'state'; state of being in a given moment (e.g. drowsiness), and 'activity'; the activity with a particular goal that an individual is presently engaged in. The idea being that different individuals respond differently to the same stimulus and the same individual will not necessarily respond in the same way each time they are stimulated ¹⁴⁷.

Mediators can be seen as "intervening causal variables" that are necessary to complete a cause effect pathway (page 7) ⁹². Any variable that represents a way through which an independent variable is able to influence the dependent variable of interest can be termed a 'third' variable ¹⁴⁶. Thus mediators are one kind of third variable and can help to explain how or why effects occur ¹⁴⁶.

Mediators are often confused with another kind of third variable, the moderators. These affect the direction and/or strength of the relation between independent and dependent variables. Independent variables can be divided into subgroups by moderator-levels and these subgroups can each be tested in relation to the dependent variable ¹⁴⁶. For example, gender is a potential moderator variable in that the effect of being male and female on the dependent variable due to a particular independent variable could be tested.

Figure 6 shows a diagrammatic representation of the basic causal path after inclusion of a mediator variable. The idea of a mediating variable can be seen in terms of having two predicting paths to the outcome variable; the direct prediction from the independent variable (path c) and the indirect prediction from the mediator (path b). Another path is also specified from the independent variable to the mediator (path a). A variable is said to be a mediator if: 1. there is a significant relationship between the independent variable and the mediator (path a), 2. there is a significant relationship between the mediator and the dependent variable (path b) and 3. when paths

50

a and b are controlled, a relationship between the independent and dependent variables that was significant is no longer significant ¹⁴⁶.

Even though absolute mediation occurs when the independent variable has no significant effect on the dependent variable after controlling for the mediator, the mediator can still be seen as a mediator, if the relationship between the independent and dependent variables diminishes when controlling for the mediator ¹⁴⁸. Others have also specified that for a variable to mediate it does not have to explain the whole causal pathway, as some of the effect may still be from a direct effect ⁹².

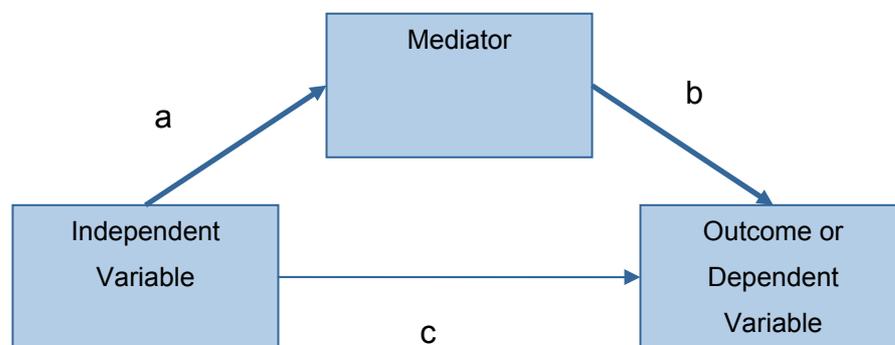


Figure 6: The basic causal chain of mediation ¹⁴⁶

One further kind of 'third' variable' that needs brief consideration here in relation to the mediator is the 'confounder'. A confounder is a predictor of the outcome that is also associated with the independent variable but unlike the mediator it is not part of the causal chain. See Figure 7: The role of a confounder in a causal relationship. Whether a factor is considered to be a moderator, mediator or confounder depends on how the study question is defined and theoretically conceptualised.

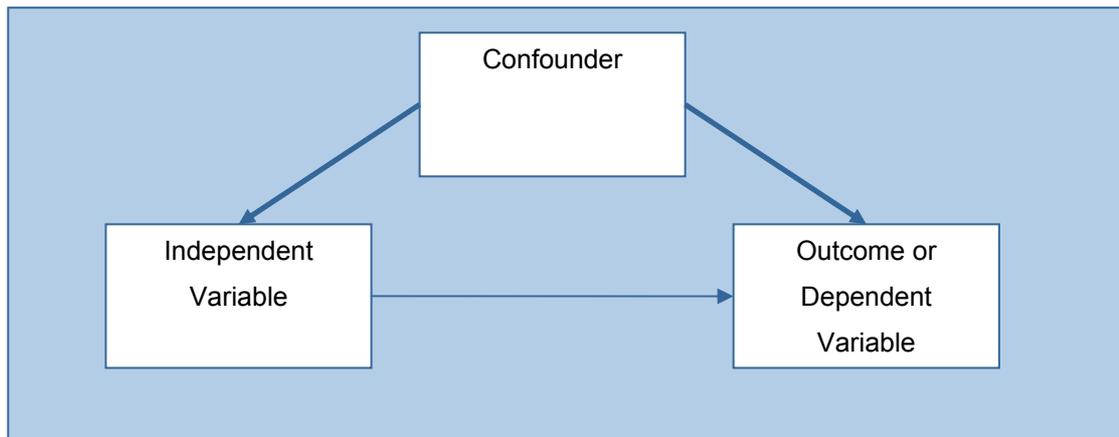


Figure 7: The role of a confounder in a causal relationship ¹⁴⁶

Of the existing physical activity studies that include mediators, two common theoretical frameworks are Social Cognitive Theory and the Transtheoretical Model ¹⁴⁸. The most common mediators studied include: behavioural process of change, cognitive processes of change, self-efficacy, decisional balance, social support and physical activity enjoyment ¹⁴⁸.

Whilst more studies recently in physical activity research have investigated the potential role of mediating variables, few studies have looked at whether mediators influence physical activity behaviour ^{148, 149}, although this does appear to be increasing. A review summary published in 2002 only located two studies in youth which examined the influence of an intervention on both physical activity and mediators ¹⁴⁸. A more recent review found seven additional studies that examined the direct effect of physical activity interventions on hypothesized mediators and the relationship between mediators and physical activity in youth ¹⁴⁹.

Ulrich (1987) did not look specifically at the mediating role of perceived sports competence but did examine the relationship between: 1) children's perceived physical competence and participation in organised sport, 2) children's actual competence and organised sport and 3) children's perceived physical competence and actual motor competence. Her findings showed that perceived physical competence was not related to participation in organised sport but was related to demonstrated motor competence, and that actual competence and physical activity participation were related ³¹. Figure

8 shows the possible relationships proposed by Ulrich in 1987 amongst the three elements of the sport participation/motivation paradigm (actual competence, perceived competence and participation) for children ³¹.

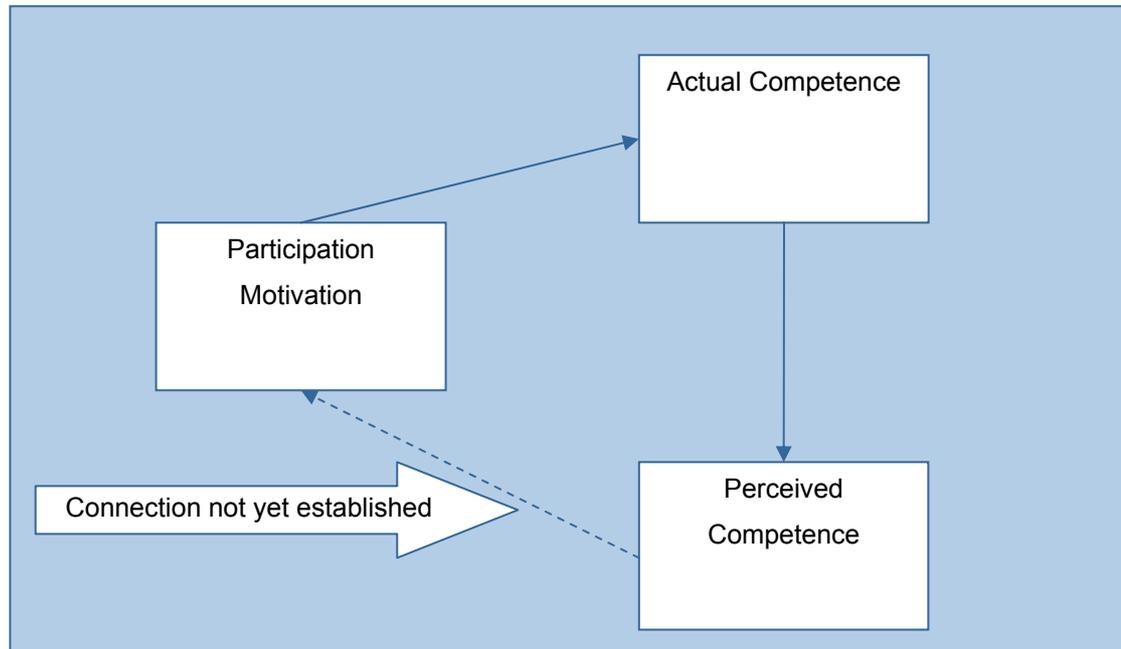


Figure 8: Possible relationships amongst three elements of the sport participation/motivation paradigm for children as proposed by Ulrich in 1987 ³¹

Ulrich proposes several reasons for why a relationship between perceived sports competence and participation was not found. The children in this study were young (Grade 4 were the oldest participants) and perhaps were more motivated by social reasons to pursue sport. Less than a third of children rated 'not being good at sports' or 'not enjoying sports' as important reasons for not participating, with other reasons such as distance to activity, and expense of programs reported more commonly. Also, a dichotomous variable was used for participation possibly limiting the ability to find a relationship. Lastly, perhaps the sort of motivation to participate, based on a perception of competence, develops as children become older ³¹.

Summary of evidence for perceived sports competence

Perceived competence has an important relationship to participation in sport^{135, 136} and physical activity¹³⁹⁻¹⁴² and fitness¹⁴²⁻¹⁴⁴. It is plausible that children who are skill proficient may develop a high perception of sports competence leading to greater subsequent participation in physical activity and higher fitness levels. In this sense perceived sports competence may act as a mediator in the relationship between childhood skill and adolescent physical activity and/or fitness.

Gender as a potential moderator

It might be likely than any effect on physical activity or fitness as a result of motor skill proficiency may differ according to gender. Gender differences in motor proficiency have been found using both product and process (qualitative) motor skill assessments. In both childhood and adolescence, males are generally more proficient than females in object control skill performance (involving object manipulation i.e. catching or kicking)^{21, 43, 45-47, 150}. In locomotor skill performance, some studies report no gender differences^{43, 45, 150, 151}, while others report males¹⁵²⁻¹⁵⁴ or females⁴³ as more proficient.

Gender differences in motor skills also track to different degrees, depending on the skill^{34, 48} with existing studies finding the disparity between males and females' performance in object control skills widens over time⁴⁸. Yet few of these studies are longitudinal, limiting the determination of consistency or stability of performance across developmental time³⁴ and how this may differ according to gender.

It might also be expected that the potential mediating relationship between childhood skill and adolescent physical activity and fitness by perceived sports competence, may differ according to gender. Boys tend to score higher than girls on physical self-perception sub-domains such as perceived sports competence^{135, 137, 142, 144}. However, this is not always the case, for instance, Biddle (1993) found no gender differences in levels of perceived

sports competence ¹⁴³. In the cross-cultural study described earlier, Russian boys scored higher than Russian girls on perceived sports competence and three other sub-domains but in the British sample, boys only scored higher than girls in one sub-domain ¹⁴¹. Crocker (2000), when looking at the relationship of PSPP domains to self-reported physical activity amongst younger adolescents, found there was no moderating effect for gender ³⁷.

2.4 Impact of Interventions Targeting Motor Skills

If childhood motor skill proficiency is a predictor of subsequent physical activity and/or fitness then improving motor skill proficiency in children may be important. Many of the studies investigating motor skill and physical activity suggested that future research include intervention studies ^{28-30, 107, 120}. However, there is limited research demonstrating how motor skill proficiency can be improved in children without developmental delay.

There are several studies in pre-school children that illustrate the effectiveness of motor skill programs. In a Scottish sample, intervention children had significantly higher performance in movement skills tests (using the Movement Assessment Battery) than control children at six month follow-up after adjustment for gender and baseline performance ¹⁵⁵. Kelly and colleagues reported gains in intervention children in six motor skills after a 12-week program, using a process-oriented instrument ¹⁵⁶. Connor-Kunz and colleagues also found significant motor skill gains in pre-school children after an eight week program ¹⁵⁷. Significant improvements in locomotor and object control subscales were reported after a 12-week motor skill intervention in pre-school children (using the process-oriented TGMD) ¹⁵⁸. Additionally, a recent study reported that an 18 week intervention could improve fitness (sit-ups, sit-n-reach, shuttle run, 3 minute run) and gross motor skill (Peabody Development Motor Scales) in normal pre-school aged children ¹⁵⁹.

The few studies that have focused on school aged children without developmental delay also indicate that motor skill improvement is possible

beyond that expected through normal growth and development. In 2000 MGI increased children's motor skill proficiency by 17% overall in a battery of motor skills⁴⁹. Halverson and Robertson demonstrated the positive effects of instruction on throwing¹⁶⁰. The CHILT project administered the product-oriented body coordination test for children and found significant improvement after a four year intervention in two of the four items assessed - balancing backwards and lateral jumping¹⁶¹. Another study also found lateral jumping ability in primary school children after 20 months to be greater in the intervention group¹⁶². Children who participated in a nine week after-school multiskills club performed significantly better in the static balance following the intervention¹⁶³. The 'Switch Play' intervention, of which one goal was to improve motor skills, found after one school year no significant intervention effects for FMS z-scores overall, however girls in intervention groups recorded significantly higher motor skill z-scores¹⁶⁴.

Even less is known about the long-term impact of school-based motor skill interventions. Tracking children longitudinally allows the influence of interventions on lifelong motor development to be determined¹⁵⁸.

Unfortunately, there are no motor skill and very few school-based physical activity interventions with a long-term follow-up. Reviews of evidence-based strategies to promote physical activity amongst young people recommend more long-term follow-up studies^{40, 41}. 'Switch-Play' found a significant improvement in fundamental skill z-scores for girls after a short-term follow-up (six and 12 months) and longer term effects reported on physical activity for intervention students¹⁶⁴.

Only three school-based physical activity interventions with long-term follow-ups were located: CATCH - three year follow-up¹⁶⁵, the Class of 1989 - twelve years¹⁶⁶ and the Oslo Youth Study - seven years⁴¹, all reporting significant intervention effects on self-reported physical activity that declined over time⁴¹. None of these three studies included a motor skill component.

2.5 The Case for Further Research

The present study will expand upon the only other longitudinal study located⁴², by assessing children in motor proficiency at a time when all would have experienced a number of years of PE, and half had participated in the MGI motor skill development program. Also, a larger number and variety of motor skills are assessed and even though the physical activity measure is self-report, it was administered in late adolescence when accuracy of self-report approaches that of adult levels of recall¹⁶⁷.

The PASS therefore will further test whether there is a relationship between motor skill proficiency and subsequent physical activity. There is some evidence that motor skills track through childhood³⁴⁻³⁶, so greater motor proficiency in youth may be predictive of subsequent physical activity. Childhood motor skill proficiency may thus be an important factor in subsequent adolescent physical activity. The somewhat reciprocal relationship between physical activity and fitness⁵⁵ is not investigated in the current study; rather, both physical activity and fitness are hypothesised in terms of being potential outcomes of childhood motor skill proficiency.

No longitudinal studies could be located that have investigated whether perceived sports competence mediates between childhood skill proficiency and subsequent physical activity behaviour and fitness in adolescence. The current study therefore also investigates whether childhood skill proficiency will not only directly predict subsequent physical activity participation and fitness levels but also be mediated through perceived sports competence. This will extend the work of others in this area by providing the first mediation analysis of this type with these particular variables. Unlike Ulrich's study³¹, a relationship between perceived sports competence and physical activity participation may be more likely as the participants are older (at follow-up) and therefore more likely to have developed a motivation based on perceived competence. Furthermore, unlike Ulrich's study, the current study uses continuous measures of physical activity participation and fitness levels. See Figure 9 for a pictorial representation of this hypothesis.

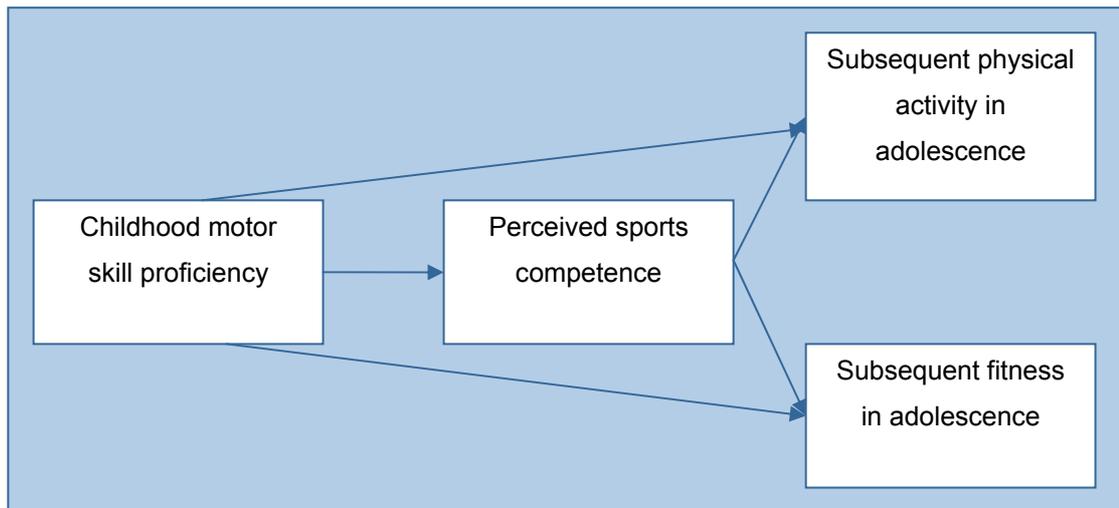


Figure 9: Hypothesised model of perceived sports competence as a mediator between childhood skill proficiency and adolescent physical activity and fitness

Identification of a key mediating variable, such as perceived sports competence, could help inform the design of interventions to promote physical activity and fitness among youth⁹² and in doing so, give a more systematic approach to increasing the effectiveness of physical activity interventions¹⁶⁸.

In addition, the current study will describe any gender differences in motor proficiency, physical activity participation, fitness levels and perceived sports competence. Also, the PASS will investigate i) whether the relationship between childhood skill proficiency and subsequent physical activity participation and fitness levels vary by gender and ii) if the proposed mediated pathway through perceived sports competence varies according to gender.

Lastly, if childhood motor skill proficiency is a predictor of subsequent physical activity and/or fitness then improving motor skill proficiency in children may be important. Thus, the PASS will also investigate the long term impact of the MIGI intervention, a one year Australian intervention (1999-2000) that improved motor skill proficiency in primary school students, on motor skill proficiency and physical activity participation.

2.6 Summary

Investigating potential adolescent physical activity and fitness determinants is a public health priority. Physical activity provides immediate short-term benefits, has a role in the treatment of adolescent morbidity and there is some evidence of the tracking of physical activity behaviours through childhood and adulthood with some physiological risk factors for cardiovascular heart disease also tracking through this period. Unfortunately many adolescents are not currently meeting physical activity or fitness recommendations, and as a result inactive adolescents are more likely to become inactive adults and thus be more prone to resulting lifestyle diseases.

Childhood motor skill proficiency may be a key determinant of adolescent physical activity and fitness, and perceived sports competence may mediate in these potential relationships. Because gender differences in motor skill performance and perceived sports competence exist, it might be expected that the potential longitudinal relationship between motor proficiency and physical activity and fitness may differ according to gender. If childhood motor proficiency is a determinant of adolescent physical activity, then improving childhood motor skill proficiency becomes important.

In the absence of other longitudinal research, this study will investigate the nature of the relationship between childhood motor skill proficiency and adolescent physical activity participation and cardiorespiratory fitness, including the role of perceived sports competence. In addition, the long-term impact of the MIGI Intervention will be investigated.

3 METHOD

3.1 Introduction

As each paper representing the results for each research question has a methods and analysis section, data analysis is not repeated or expanded in this chapter. However, this chapter does provide more detail than the respective papers on the sample and instrument selection, and also on data collection and management.

This chapter is divided into four sections. Firstly, the sample selection is described including sample size calculations, the feasibility of locating students, the data matching process, school selection, and student recruitment. The second section outlines the measurement instruments used in the PASS and gives the background and validity and reliability information for each instrument. This section starts with the self-report instruments, followed by the physical tests. The third section provides the published interrater reliability assessment for the motor skill instrument in the PASS sample population (Paper 6). This final section covers the PASS data collection and data management procedures.

3.2 Sample Selection

3.2.1 Sample size calculations

The original MIGI evaluation involved 1045 Year 3 and 4 children (aged 7 to 10 yrs) from 18 primary schools; nine intervention and nine control^{43, 49}. For the PASS, sample size was calculated with a two-tailed α of 5% and power of 80%. VPA was used as a reference point for the dependent variable, rather than MVPA intensity, so that standard deviations and mean minutes per week could be taken from the NSW Schools Fitness and Physical Activity Survey 1997⁴⁴ (which used the same self-report instrument in a similar study population), to calculate the sample size. Therefore, two calculations

were made with the resulting sample size ranging from 353 – 439 (see below).

1. To detect a 20% difference in the mean time spent doing non-organised physical activity at vigorous intensity, between those who six years earlier, demonstrated mastery of FMS and those who did not, the required sample size was 353.

2. To detect a 20% difference in the mean time spent doing organised physical activity at vigorous intensity, between those who six years earlier, demonstrated mastery of FMS and those who did not, the required sample size was 439.

3.2.2 Likelihood of achieving follow-up sample

Feasibility of locating MIGI students

Considering some of the original MIGI students would have migrated out of the Northern Rivers area and some would no longer be at an educational institution, a mini tracking study was undertaken to assess whether it would be feasible to find the required numbers of MIGI students for follow-up as part of the PASS.

Four primary school samples, situated within three Northern Rivers regional town locations, were used to determine potential follow-up numbers. Firstly, school Principals were telephoned and advised about the study and whether they would be interested to help provide tracking information for feasibility purposes. For two of the locations (Town 1 and Town 2), all potential feeder high schools in the same town were approached. For Town 3, only one out of six potential high schools was approached.

If Principals agreed, a list of matched MIGI students was faxed through to a school liaison contact to identify former MIGI students presently enrolled at their respective high school. The list of matched MIGI students faxed to the high schools were only those students from the particular feeder schools in each regional location – not the whole list of 929 matched students.

All schools contacted agreed to help with the feasibility study. This included four state schools and five independent schools. Based on this endeavour it seemed likely that more than half the original sample (56 - 62%) could be tracked when approaching all possible schools in a town. In the location in which only one possible school was approached, the potential follow-up figure was considerably lower (17%). Please see Table 5 for the numbers and percentages located in this mini tracking study. All schools contacted were cooperative.

Table 5: Number and percentage of students tracked in feasibility study

	MIGI FEEDER SCHOOLS N	MIGI STUDENTS N	POTENTIAL HIGH SCHOOLS N	HIGH SCHOOLS APPROACHED N	STUDENTS IDENTIFIED N	OF MIGI SAMPLE %
Town 1	1	164	5	5	102	62.2
Town 2	1	117	3	3	65	55.6
Town 3	2	112	6	1	19	16.9
TOTAL	4	393	14	9	186	47.3

Other factors affecting potential follow-up

Several additional factors were taken into consideration in attempting to calculate whether the PASS would be feasible to undertake. It was thought that some schools may not agree to their school's involvement; (9% of high schools did not agree to be part of the NSW Schools Fitness and Physical Activity Survey in 1997)⁴⁴. However, in the current study, a higher consent rate was envisaged, as consent for schools tends to be higher in rural areas (personal communication Dr Michael Booth). Also, it was thought that testing in many of the schools would only involve a few children and so would not be a burden for schools.

It was also anticipated that after finding the cohort, some parents would not consent for their child to participate. In the Schools Physical Activity and Nutrition Study (SPANS) 2004, consent for FMS testing was 63% for Grade 8 and 50% for Grade 10 students²¹. The consent rate for Grade 10 students was thought to be lower because blood samples were also asked for²¹. Thus, the consent rate of 63% was used as an indicator estimate for the likelihood of finding the cohort for the PASS. Finally, absence on the day was 2.8% in the SPANS²¹.

After consideration of school consent, parent/student consent, and absence on the day, the study coordinator anticipated that recruiting 355 students would be possible which is close to the required sample size necessary ($n = 353 - 439$). (See Table 6 for calculation details).

Table 6: Calculation of likely follow-up sample

START SAMPLE	1045	REDUCE SAMPLE BY N STUDENTS	REDUCE SAMPLE BY %	EXPLANATION
Migration out of area & no longer in education	679	366	35	Estimate based on mini tracking study
School non-consent	579	100	25 students x 4 schools	Based on SPANS ²¹ in which 9% of school sample did not consent. With the PASS school sample of 42; 4 schools with approximately 25 students per school are likely to not consent. (Based on original sample of 1045 children, assuming equal numbers of students in each school).
Parent non-consent	365	214	37	Based on SPANS ²¹
Absent on day	355	10	2.8	Based on 2.8% in SPANS ²¹
Likely sample	355			

3.2.3

3.2.4 Matching MIGI records to names

MIGI records

All 1999 baseline data records for MIGI were entered by school, school year, tester, skill tested and gender. Individuals were not identified. Rolls for each class within each year group and a record of who was absent or present on the day of testing were filed alongside the data records. This meant that children who participated in testing could be identified as a class group but that individual children's testing records could not be identified.

Children who were on the roll at this time, whether or not they participated on the day of testing were considered to have taken part in either the MIGI intervention or acted as a control. As it was not possible to identify individual

children's results, it was considered satisfactory (in terms of answering the main research questions for the PASS) to know whether they had been part of the sample that had either received the intervention or acted as control.

All 2000 data records from MIGI (post-test: the completion of the intervention) were grouped by school, school year, tester, skill tested, and gender. In addition, a new variable consisting of first and last initials was added. Rolls for each class within each year and a record of who was absent or present on the day of testing were filed alongside the data. This meant it was possible to attempt to match the test scores with the respective child listed on the roll as present for that day.

Data matching

Of the 1045 MIGI records, 1021 were tested at MIGI post-test and had initials stored with their motor skill assessments. These were manually checked against class rolls and all who matched on school, gender, class year, tester, and first and last initials were considered a match.

The manual process was used to check matches that were not obvious due to issues with phonetics and spelling. For example the child's name may have been Kate Smith but the tester may have written down 'CS', interpreting the name as 'Cate'. Another example is having only the first or second initial of a 'double barrelled' surname recorded such as 'J' instead of 'SJ'. for 'Smith - Jones'. These mistakes could be identified quite easily once all other obvious matches had been made for that school, class year and tester. If there was any uncertainty that this child was not the same child then the record was omitted, but if all other records matched and the error seemed a feasible and logical mistake these children were included.

The list of children identified through the manual matching process and the original data set of unmatched data from the 1021 initialled records were then imported into SAS (version 9.1) and a merge was conducted. The merge was set up to check what had been performed manually. In a couple of cases the

computer matching process matched records that should have been identified and matched during the manual process but were missed.

Two of the ten testers failed to note down the children's initials for much of the testing. This meant there was no way of matching these records and therefore these 68 students (7.3 % of sample), were excluded. This meant four of the eighteen schools were missing a fifth to half of their data.

The MIGI testers were instructed that if there were two children in their testing group that had the same first and last initials and gender that they were to take a date of birth from both children. If this had been done, these children were included but the match was left until the children had been recontacted and the birthdates established. Sometimes in these instances the tester had written the child's first name on the data sheet; if this was the case the records could be identified at this point and these children were also included. If date of birth or first name had not been noted there was no way of matching the record and these records were excluded. A further 12 students (1.3 % of sample) were excluded due to duplicate initials in the data that could not be matched.

On seven occasions (0.8% of sample) one initial matched with either the first or last initial of one of the names remaining on the roll but the other initial did not match and did not seem to have occurred from a logical phonetic or spelling mistake. These students were also excluded. On five occasions (0.5% of the sample) the initials recorded by the tester could not be matched to any record on the roll and were therefore excluded.

A total of 92 (9.01%) students were not able to be matched leaving a matched sample of 929. Thus the final list that could be used for follow-up purposes had 929 children, which is 90.9% of the original sample of 1021. When the schools were divided by control and intervention, 61 of the unmatched 92 were from intervention schools whilst 31 were from control schools.

3.2.5 School selection

School selection for MIGI

The original primary schools were situated in the Northern Rivers region of NSW, which is a rural region of 24,555 sq kilometres bounded by Grafton in the south to Tweed Heads in the north and west to Bonalbo. Potential participating state primary schools were divided into small, medium and large schools and then randomised within these categories. This process resulted in eighteen participating schools across the Northern Rivers^{43, 49}.

Approaching schools for the PASS

Original MIGI participants still residing in the Northern Rivers may at the time of the current study have been: at the particular high school that their primary school 'feeds' into; at another high school in the same town; at a high school in a different town; at an independent school; or not attending school.

MIGI participants in 2000, at post-test, were in Grades 4 or 5, therefore in 2006 they would be in Grades 10 or 11 unless they had been repeated or accelerated. To capture as many of the original sample as possible, all schools in the region with students in Grades 10 and 11 were approached directly to take part in the PASS.

Principals of schools were mailed an information package describing the study, how it was to be conducted, a guarantee of confidentiality, contacts for further enquiries and the name and contact details of a member of the University of Sydney Human Research Ethics Committee for complaints about unethical behaviour. Attached to the letter was a form to return by fax that indicated whether or not the principal agreed for the school to participate in PASS. If they agreed, they were asked to provide the name of a school staff member to act as liaison officer. School Principals, who did not respond within two weeks of information being sent, were contacted by telephone as a reminder to respond.

3.2.6 Student recruitment

Identifying students

For schools that consented, the liaison officer was then contacted by telephone to inform them of the purpose of the study and to outline how the identification of students was to occur. The list of 929 MIGI students was then either faxed or emailed to the school for them to check if any of the students on the list were currently at their school.

The list included the students first and last name, gender, school year in 2000, and school attended in 2000. The liaison contact was instructed to go through the list and look at the students name and compare this to the students they have on the rolls for Grade 10 and Grade 11. They were specifically instructed to *not* look only for their feeder schools. The school attended during 2000 was included only as a check for them to make sure once they had identified the student by name and gender that it was in fact the same student. This meant that students who had repeated and were in Grade 9 may have been missed unless the teacher recognised their name as they were going through the list. Schools were only asked to look at Grades 10 and 11 to make the task easier and quicker and therefore more acceptable for the school.

Liaison contacts were asked to fax back the list of names with identified students marked on the list as at their school. If no students were identified, the school was thanked for their time and that was the end of their involvement.

Consent

If students were identified, the liaison contact was telephoned to arrange the consent process. Active signed consent from parents/guardians and from students was required for students to participate in the PASS. Information sheets and parental/participant permission forms for schools to send to parents were developed.

In the first instance, a talk to explain the study purpose and an article for the school newsletter were offered to the contacts as ways to inform the students about the PASS. If the school was willing to organise a talk, parent information letters addressed to each student and their parents/guardians, and consent forms, were given to students at this occasion. If not, letters were posted to the school liaison contact to give directly to students.

Liaison contacts were asked if they wished for the consents to be returned to them or school administration, or direct to the researcher using postage paid envelopes. If the liaison teacher wished for the consent forms to be returned to them, they were asked for the consent forms once completed to be kept at the school. Contacts were called at fortnightly intervals to remind them to hand out the consents (if applicable) and to remind students to return the consents.

In the second instance, to boost consent rates, parent information letters in stamped envelopes were addressed (using school records that were not removed from the school) and stamped at the school by the study coordinator and mailed from the school directly to parents/guardians. Parents/guardians were asked to either return consent forms directly to the researcher by a reply paid envelope or to return the form to the liaison contact at their school.

This process ensured that the researcher did not have access to home address details of students and that the researcher did not directly approach parents and students.

3.3 Measurement

3.3.1 Self-report measures

Demographic variables

Information on school year, gender, date of birth, language spoken at home, Aboriginal and Torres Strait Islander background and postcode, was gathered through the first page of the survey.

Physical activity

The issues involved in assessing physical activity levels accurately are complex. No one instrument is perfect in terms of validity, reliability, practicality, and expense. The main ways measurement of physical activity has been undertaken are via monitoring, direct observation or behavioural observation and self-report. Monitoring is performed by either mechanical or electronic devices and physiological measurements¹⁶⁹. Direct observation entails recording the behavioural aspects of physical activity using a coding framework¹⁷⁰. Self-report includes diaries, logs, recall surveys, retrospective quantitative history, and global self-reports (recall surveys in which participants rate their behaviour in relation to others).

Self-report is the method that was chosen to assess physical activity participation in the PASS. In large cohort studies of children and adolescents, self-report is the most practical and cost effective way to assess physical activity¹⁷¹. However self-report does have disadvantages, therefore it is important to select an instrument that attempts to combat known limitations. The self-report instrument used in the PASS, the Adolescent Physical Activity Recall Questionnaire (APARQ), does meet current evidence regarding efficacy associated with physical activity self-report instruments.

One issue with existing self-report physical activity measures is that none of the measures have been used widely, so there is no standard measure in the field¹¹⁴. Another issue, is that level of physical activity varies seasonally¹⁷² and adolescents tend to overestimate time spent in activities with high seasonal variability. The use of questionnaires where each activity is reported by season possibly helps to improve accuracy¹⁷³.

In terms of cognitive recall issues¹⁷⁴, one week recalls generally perform better than two week self-report recalls of activity¹¹⁴. In addition, recall with older youngsters has better validity^{115, 175} with Grade 11 students having test- retest reliability coefficients that were similar to adults¹⁶⁷.

The recall of vigorous physical activity is generally better than recall of MPA¹⁷⁶ with assessments for vigorous activity having higher validity than for lower intensities of activity¹⁷⁷. Although, there can be some difficulty in distinguishing between vigorous and moderate activity¹⁷⁶. Questions concerning recall of physical activity should also target the specific physical activity domains in the contexts in which people usually perform the target activity and in the jargon used for that activity¹⁷⁸. Type of activity (i.e. leisure, occupational, household) frequency, duration within a time frame and intensity¹⁷¹ are all important to include.

The APARQ has been used widely in Australia and reflects current knowledge in that it: asks for activity by season, is concerned with a 'usual' week, will be used with older adolescents, has the classification of moderate or vigorous applied by the researcher not the student, and asks for activity recall within both 'organised' and 'non-organised' contexts.

The APARQ has been assessed for test-retest reliability and validity by looking for agreement on a three category ('vigorous', 'adequate', 'inactive') and also a two category ('active', 'inactive') measure within organised and non-organised activity. In Grade 10 students, for both the three-category and two-category measures, the values of percent agreement exceeded 70%, and all values of kappa were 0.50 or higher. In terms of validity, for the three-category measure, mean laps on the MFT were higher in the 'adequate' and 'vigorous' categories than the 'inactive' category for girls. For boys, the mean laps in the 'vigorous' active and 'inactive' categories were significantly different. For the two-category measure, mean laps were higher in the 'active' category than the 'inactive' category for both boys and girls. The correlation coefficients between energy expenditure and MFT laps in Grade 10 students were 0.14 for boys and 0.39 for girls¹⁷⁹.

Students were asked to specify all physical activities in which they participate in a usual week, in both summer and winter, and the frequency and duration of participation in each activity. Students were also asked to indicate date of birth, gender and language spoken at home.

Perceived sports competence

The PSPP^{137, 138}, designed to measure physical self-esteem and developed from responses from college-aged American students, has a scale that specifically looks at sports competence and was therefore selected to measure perceived sports competence. As the students in the PASS were in the upper years of high school (mean age 16 years) and close to college age, it was considered inappropriate to use the modified PSPP-CY¹⁴⁴.

The PSPP and the PSPP-CY (modified and designed for children) have been well used and overwhelmingly well validated in the literature^{143, 144, 180-187}. An exception is one study which validated the PSPP with an Australian high school sample and found when examining construct validation, that the PSPP appeared to be weaker when compared to the Physical Self Concept scale (PSC) and the Physical Self Description Questionnaire (PSDQ)¹⁸². However, one of the issues raised was with a subscale of the PSPP that is not used for the current study; the condition subscale. Another concern was that the PSPP not be used with younger adolescents due to the non-standard response scale (i.e. a pair of statements to be agreed or disagreed with). Since only one subscale was to be focused on for the current study (that of sports competence), and because the sample was to be older adolescents, it was still considered appropriate to use the PSPP. Furthermore, the PSC has not been published (Richards 1987, 1988 cited by¹⁸²) and the PSDQ has been validated in few other populations^{188, 189}.

The main purpose of the PSPP was to construct and validate (based on Harter's model of motivation^{39, 129, 130}) a physical self-perception profile that reflected self-perception content and allowed for the hierarchical structure of self-esteem¹³⁷. There are five, six-item scales that measure perceived physical self-perception: *sports competence*, *physical condition*, *strength* and *body attractiveness* and overall *physical self-worth*. The profile uses a 4-point structured alternative format in which the student must first decide which of two statements best describes them and then must choose whether the statement is 'sort of true' or 'really true' for them. Two examples of item statements in the sports competence subscale are: 1. "*Some people feel that*

they are not very good when it comes to playing sports' BUT "Others feel that they are really good at just about every sport" and 21. "Some people are sometimes a little slower than most when it comes to learning new skills in a sports situation" BUT "Others have always seemed to be among the quickest when it comes to learning new sports skills". Each item can be scored from 1 (low self-perception) to 4 (high self-perception).

Fox and Corbin ¹³⁷ found, through both exploratory and confirmatory factor analysis with a sample aged 19 years (mean), that all items of the PSPP contributed well to the functioning of each subscale. Corrected item total correlations for the subscale of sports competence ranged from $\alpha = .70$ to $.90$ for females and $\alpha = .60$ to $.90$ for males ¹³⁷. Subscales were sensitive to a wide range of individual differences, did not appear susceptible to social desirability and were stable over a three week period ¹³⁷. The sensitivity, reliability and stability of subscales were supported for both genders ¹³⁷.

3.3.2 Physical tests

Conduct of the physical tests required open space approximately 30 metres in length. If possible the tests were completed indoors to avoid exposure to the sun and rain, but an outdoor space was also acceptable. Students were asked to be in clothes and shoes suitable for physical activity.

Fundamental motor skill assessments

The MIGI intervention used the Australian resource, 'Get Skilled Get Active' ¹⁹⁰, to assess students' motor skills. An earlier version of 'Get Skilled Get Active' reported test–retest reliability of the 11 motor skills over a seven day cycle on 42 primary school children, returning reliability estimates (alpha coefficient method) of $\alpha = .70$ or greater for all skills except the leap and run ($\alpha = .13$ and $\alpha = .17$ respectively) ¹⁹¹. The updated resource included eight of the 11 skills (catch, overhand throw, kick, forehand strike, sprint run, leap, dodge, vertical jump) from the original resource ¹⁹⁰ and four new additions (hop, side gallop, skip and static balance). Test-retest reliability has been assessed for this test battery with each grade (Grades 1-3) assessed for different combinations of six skills. Mean agreement percentage scores

ranged from 69 (95% CI; 60 - 87), for the hop with Grade 1 children, to 85 (95% CI; 70 -100) for the kick with Grade 3 children (Personal communication Tony Okely ¹⁹²).

Skills to be assessed

Eight skills were assessed in 2000 using the updated protocol ¹⁹⁰. These skills were chosen because they are recognised as integral to the development of more sports-specific skills (e.g. development of overhand throw for the overhead smash in tennis or overhead serve in volleyball)⁴⁹. Interrater reliability was checked on sets of 48 scores for every observer pair for all the skills combined and reported as kappa = .61 ⁴⁹.

Six of the eight FMS assessed in MIGI ⁴⁹ (static balance, sprint run, vertical jump, kick, catch, overhand throw, side gallop and hop) were reassessed in the PASS. The static balance and sprint run were not reassessed as these were only originally tested for Grade 4 in 2000 and therefore half the students did not have these two tests as part of their test battery. Most of the analysis that requires childhood motor skill level uses these six skills to create composite scores. The only exception is that the childhood assessment for the sprint run is used in one analysis in Paper 2. "Does childhood motor skill proficiency predict adolescent fitness?". *Medicine and Science in Sports and Exercise*; 40 (12):2137-44.

The skills tested and the testing method in PASS are comparable with those of the NSW Schools Fitness and Physical Activity Survey 1997 and the NSW Schools Physical Activity and Nutrition Survey 2004 ^{21, 44} apart from the forehand strike, and leap which were not tested in MIGI.

This battery of six skills includes skills that both males and females are proficient in ^{42, 43}. Each skill is made up of five or six features considered integral to the proficient performance of the skill. In teaching purposes some of these features are considered introductory. For example, the kick consists of six features, with features 1 and 3 considered introductory features: 1. Eyes focused on the ball throughout, 2. Forward and sideways swing of opposite arm, 3. Non-kicking foot placed beside ball, 4. Bend knee of kick leg

90° + during backswing, 5. Contact ball with top of foot, and 6. Kick leg follows through high towards target area.

Cardiorespiratory fitness

Cardiorespiratory endurance ('fitness') was estimated indirectly as the number of laps completed on the MFT, (also known as the 20 meter Shuttle Run Test, or PACER) ¹¹⁸. This test was selected over other field measures of cardiorespiratory endurance such as timed and distance runs as it has been shown to be more motivational and appropriate for indoor testing, and less influenced by pacing among children and adolescents ¹⁹³. Additionally, it is considered to be an appropriate and time efficient fitness test for large groups of students ¹¹⁸. Students are required to run between two lines 20 meters apart (one 'lap') starting at 8.5 km/hr and increasing by 0.5 km per hour every two minutes, in time with a recorded MFT signal with each increase corresponding with a change in level. The number of 'acceptable' laps completed is determined by the student not keeping pace with the signal from the tape for two consecutive laps, (whereupon they are withdrawn from the test) or the student withdraws themselves ¹¹⁸.

3.4 Interrater Reliability

It is important that instruments and testing methods used are valid and reliable. Reliability is the consistency of a response either across multiple trials within a single administration (internal consistency) or across days (test-retest or stability reliability) ¹⁹⁴. Reliability in physical activity self-report studies has generally been reported in a test-retest manner ¹⁹⁵. The concept of reliability assumes that the time interval between test-retest is not long enough for real change to occur in the variable of interest or that the setting is controlled so real change cannot occur. But physical activity is not controlled and many changes can be expected, therefore field settings need measures of stability - a form of reliability that captures variability and reflects measurement error of the instrument ¹⁹⁶.

An important aspect of research rigor in studies concerning motor skill proficiency is interrater objectivity (also termed interrater reliability), defined as the consistency or agreement in scores obtained from two or more raters^{197, 198}. In a training setting, interrater objectivity is commonly determined as the relative number of times raters agree with an 'expert' rating of skill proficiency (used as a gold standard for comparisons). However, during live observation (i.e. not recorded observations) in a field setting, assessment of motor skill proficiency commonly occurs with multiple raters without comparison to an 'expert' rating of motor skill proficiency. It is therefore important to examine the reliability of an overall group of raters used in a study. Additionally, examining the reliability of specific motor skills may help determine which skills may be more problematic to assess in the field.

For these reasons, interrater reliability of the motor skills assessed in the current study was determined during field observation periods in schools. Please see the following publication for details of this interrater reliability assessment.

PAPER 6 “Interrater objectivity for field-based fundamental motor skill assessment”.

3.5 Data Collection and Management

3.5.1 Staff recruitment

Potential research assistants (RA) for the PASS were recruited via student email lists from the Schools of Human Movement and Exercise Science in two universities situated in the study area and via an exercise leader network managed through the local health service.

Five expressions of interest were received, four completed the training and three were available for data collection. One RA was midway through an honours degree in exercise science, one had completed the degree and was employed in the fitness industry, and one was in their final year of study. All had experience in sports coaching (netball and soccer) and/or personal training with adolescents.

The aim was to recruit RAs from distinct geographical areas as the testing plan was for the study coordinator to do as many assessments as possible with the three RAs assisting by covering a different area (north, central and south) within the study district. This occurred, with one based in the northern location, one in the south and one centrally.

3.5.2 Staff training

Training of RAs was conducted in mid 2006 by the study coordinator and an experienced trainer from the University of Wollongong, Australia. The study coordinator had trained RAs for MIGI in both 1999 and 2000 and thus had experience with the 'Get Skilled Get Active' protocol. The trainer had trained teachers in FMS assessment and assessed the FMS proficiency of children as part of the HIKCUPs trial ¹⁹⁹.

The first day of the three day training covered background to the PASS, conduct expected, and survey administration. The second and third days were both on assessing FMS including an outline of the 'Get Skilled Get Active' protocol ²⁰⁰, practice sessions coding each other and repetitive rating, by each prospective tester of children performing each FMS on a video,

where every component of each videoed FMS performance had been previously rated by the trainer. This was followed by a practical test where the trainer performed each movement skill with common errors and the raters assessed each component of each FMS as correct or not correct. Training continued until the agreement rate between each rater's assessment and the trainer's assessment consistently approached or exceeded 85% correct for each component of each FMS.

3.5.3 Data collection procedure

The PASS self-report survey was to be completed first, followed by the physical tests as per the SPANS ²¹. Schools were asked to provide a space for the students to sit down to complete the written part of the assessments. Confidentiality was assured and research staff were available to help any students who had difficulty completing or interpreting the questionnaire.

The PASS self-report survey included the APARQ survey and the PSPP survey. For the APARQ survey, verbal examples of non-organised and organised activity were given. The protocol recommended by Fox ¹³⁸ for administering the PSPP was used in the PASS. Briefly, confidentiality was assured, and an item example was described to all students to demonstrate how to complete the survey.

The testing procedure for motor skills allowed students to observe a motor skill demonstration before being asked to perform the skill. For the catch, kick, overhand throw and vertical jump, the skill was performed five times ⁵² with a feature deemed as present if the student performed it consistently throughout the trials. For the hop and side gallop, the skill was observed as students travelled back and forth once between two points 15 metres apart. The RA assessed each feature of that skill as present or absent without any verbal feedback from the RA. Assessment was completed by observing features in the order in which they are executed (also written in this order on the data sheet). For instance with the catch, 'eyes focused' is the preparatory feature, followed by 'feet moving to place the body in line with the object', then 'hands coming to meet the object' etc.

The testing procedure for cardiorespiratory endurance involved the students being played the initial taped introduction which describes the test protocol. Briefly, students were told they must keep in time with the MFT and must place their foot on or over the line each time. Distance was marked out with a tape measure and students were run in groups of no more than 15 to ensure adequate spacing. Upon termination, each student had the level and shuttle written on their hand by the study coordinator and scores were recorded when all students finished.

3.5.4 Data entry and cleaning

All data were entered into an Access database designed for that purpose. All cleaning was performed using SAS (version 9.1).

Physical activity

Activity time

The variable that represented how many hours an activity lasted was converted to minutes and this was added to the 'minutes' variable to give the total time per activity.

A rate of energy expenditure (METS; kcal.kg⁻¹.min⁻¹) was assigned to each activity which was based on the Compendium of Physical Activities²⁰¹ and since expanded for the SPANS²⁰².

A variable for activity intensity (moderate or vigorous) was created. Moderate activity needed to be for at least 10 minutes duration with a MET value of 3.0-5.9, and vigorous activity was for activity of at least 20 minutes duration with a MET value of greater than or equal to 6.0.

As the dataset was arranged vertically rather than horizontally (each activity was listed underneath each other, with one line per activity), the data needed to be reconfigured to have each activity across the page linked to one ID number. This was done by creating several new datasets that summed the information that would be needed.

First, a dataset with the total time each student spent in activity by season and type (organised or non-organised) was created. From this dataset, four datasets were created: non-organised winter, non-organised summer, organised winter and organised summer. Second, a dataset with the total number of times each student performed an activity each week by season was created. From this dataset, two datasets were created: winter frequency and summer frequency. Third, a dataset with the total number of times each student spent in activity by season and intensity was created. From this dataset four datasets were created: moderate intensity winter, moderate intensity summer, vigorous intensity winter and vigorous intensity summer. These 10 datasets were merged to create one dataset that had totals for each season, for intensity, type of activity and activity frequency for each student.

A variable was created to identify students who met the minimum frequency per week (greater than seven times per week as per SPANS)⁵². A variable was also created to identify students who met the minimum requirements of one hour per day of physical activity⁵². Then both of these variables were used to identify which students had met both frequency requirements and time requirements for physical activity participation.

To allow for some students only doing activities for one term, students could fill in for each season whether they completed the activity for the whole season or not (i.e. 2 terms or 1 term). Then for records that specified only one term, the time in the activity was halved. This allowed for some students only doing activity for one term.

Exclusions

The exported dataset from ACCESS had 3767 entries. Entries were excluded for the following reasons (as per SPANS⁵²):

All activity with a MET value of less than 3 (453 entries),

All activity less than once per week (194 entries),

All activity less than 10 minutes duration per occasion (117 entries),

Duplicates: After manual checking of the data, there were cases of students participating in two school sporting activities each term. If the student did not make it clear that both activities were done for half a term each, there was potential for the data to be entered twice (one term for one activity and another term for another activity). So all instances of where students had specified more than one sport in one term was checked manually, to ensure there was only one term's entry. If a duplicate entry was found, 'duplicate' was written in the note field. This field was then used to delete 25 records.

Parties/clubbing: There were 16 cases of students writing 'parties' or 'clubbing' as an activity with very long lengths of time associated with it (for example 10 hours every week). Even though many adolescents may be active by dancing at parties, it is hard to quantify exactly how much time was actually spent dancing, so these records were excluded as they had the potential to skew the data. However if 'dancing' was specified as organised activity this was included, as it was likely to be a dance class.

Re-categorisation

There were many different forms of school-based instruction that students wrote down, i.e. 'Human Movement', 'Sport Science' 'Sport & Rec' 'SLR', 'sport studies', and 'PE'. So these entries were all termed 'PE (school)', as opposed to 'School Sport', in this way distinguishing PE from Sport at school.

During data entry, sometimes 'PE' was written as the activity, with the actual activity i.e. 'cricket', written in the note field. At other times, the activity i.e. 'cricket' was written in the activity field and in the note field 'PE' was written. School-based sport and school-based PE were classified into a single new variable to solve this issue.

When records were entered slightly differently, they were standardised. For instance, 'walking - power' became 'Power walking', and 'lawn bowls' became 'Bowling', 'running with dogs' became 'Play with pet', 'race/practice Motor x' became 'Motor-cross'. This meant that when the dataset was merged with

the dataset of MET values, the merge was successful, with each entry of each activity being matched with a MET value. A decision was made to call 'Sport Coaching'; 'Umpiring', as there was no appropriate MET value for coaching.

If a student misclassified organised and non-organised activity this was corrected during the data entry phase. This rarely occurred ($n = 3$).

In the SPANS, if a student gave a clearly excessive or incorrect frequency duration value or incorrect frequency this was adjusted to match that of those in the same class at the students' school⁵². This was not possible in the PASS as the students, being in upper high school, were all in different classes with very varying time tables.

Checking outliers

There were six students that recorded no time spent in the recorded activity. These records were checked and it was found that students had not completed the section of the survey that recorded time spent in the activity.

After checking the final dataset, two entries of '5' were found in the total column for time (minutes) spent in physical activity (after all activity less than ten minutes had been excluded). After checking, it was clear that this was due to activities only having been performed for one term and then in the cleaning program this time in activity was halved. So these records were not dropped as they did meet the criteria of a minimum of ten minutes in physical activity (for half of the term).

There were 72 records where each occasion was longer than 5 hrs, or the total time was greater than 14 hrs per week. These records were checked for error manually with 27 corrected for a mistake in total time. In these cases it was clear when looking at the survey that the student had written down a total time rather than a time for each activity occasion. For example, tennis; 5 times per week for 10 hours each time would be corrected to 5 times per week, for two hours per time. This error was also found in the SPANS⁵². In 10 cases, records were corrected for another error (either frequency or

misunderstanding of handwriting). For 35 cases, records were checked but left as is, as no obvious error could be found.

After corrections and checking, the program was run again and there were 40 records left that still filled the above criteria (including the 35 that were checked and not changed and five that were corrected but still fitted the criteria). Many of these records were feasible. For instance: an athletics entry (6 times per week for 150 minutes each time) was from a student who was a champion power walker, and a cycling entry (40 times for 15 minutes each time) was from a student that did many short 'bmx' trips. However, other records were less likely to be an accurate account of a student's activity. For instance, dancing seven times a week for 210 minutes each time. Even though this record was dubious, it was not clear whether an error of total time or frequency was made, or whether no error was made, so it was not excluded.

Perceived sports competence

The PSPP scores were summed as specified by Fox¹³⁸. Briefly, for the subscale of perceived sports competence, scores for each item were summed with a possible range of total scores from 6 - 24. A student was included in the analysis if they had complete scores for the perceived sports competence subscale.

Motor skills

In the MIGI motor skill dataset, if there were duplicates of last name, first name and type of skill tested, every second skill was removed. This removed 74 entries and reduced the dataset from 6518 to 6444 records. These duplicates would not have been identified at the time of MIGI as records were not linked to a name. Then a new dataset was made that excluded the records for the sprint run and static balance.

As all the skills were listed separately (i.e. one skill record per line), skills were then separated into different datasets and a skill total was created for each skill. This was followed by merging all the single skill datasets together

so one dataset remained with all skills across one line (i.e. one ID record with all skills). The following variables were then created for each skill: a mastery variable (all components achieved), near mastery (all achieved bar one), mastery plus near mastery (joining of previous two variables). For some of the analysis questions, overall object control and locomotor skill totals were constructed and this process is detailed in the respective papers.

Fitness

Scores for the MFT were based on the last level and shuttle completed by a student. This result was converted to the number of laps, using a table from the Cooper Institute⁸⁹ to create a continuous variable for analysis.

3.6 Summary

This chapter described the sample selection for the PASS, demonstrating through sample size calculations and a mini tracking study, that the study was feasible in terms of being able to locate enough original students for follow-up. It also outlined in more detail than that provided in the papers, the data matching process, school selection, and student recruitment.

The background of each of the measurement instruments used in the PASS was then described. 'Get Skilled Get Active', an objective qualitative measure, was used to assess six FMS, including the catch, overhand throw, kick, vertical jump, side gallop and hop with a seventh motor skill, the sprint run, used in one analysis only. The measurement of cardiorespiratory endurance in adolescence was also via an objective measure; The MFT¹¹⁸. Self-report measures were used for physical activity (APARQ)¹⁷⁹ and perceived sports competence (PSPP)^{137, 138}.

The third section provided an interrater reliability assessment for the motor skill instrument in the PASS sample population (Paper 6). It was demonstrated that the interrater weighted objectivity coefficient for the motor skill battery was $\kappa = .70$. For separate skills, the kappa coefficient was highest for the side gallop and catch and lowest for the hop. This final section also

outlined the data collection process which included: RA recruitment, the three day training program for RAs, and data management procedures including exclusions.

4 THE SAMPLE

4.1 Introduction

The purpose of this chapter is to provide extensive detail on the study sample. Because this study is a follow-up study it is of importance to understand detail around student and school consent and follow-up rates. The chapter begins with a description of the 2000 matched sample giving numbers and proportions of males and females overall, in each school grade and for each FMS assessment.

The remainder of this chapter covers the PASS sample, in particular: locating students, consent and follow-up for 2006/07. The number of schools that consented, the school liaison contacts, the number and whereabouts of located students, and the characteristics of located students as compared to non-located students are reported.

This is followed by information around consent which covers; student consent rates, individual school consent rates and factors that impacted on consent rates. Characteristics of consenting students compared to non-consenting students (in terms of gender, school grade and whether from an intervention or control school), are described.

Then, overall follow-up rates are reported. The follow-up sample is described and follow-up rates for each aspect of surveying/testing and reasons for non-participation are also described. The sample for each aspect of surveying/testing is also described in terms of gender and school grade. Figure 10 illustrates the follow-up sample at each point.

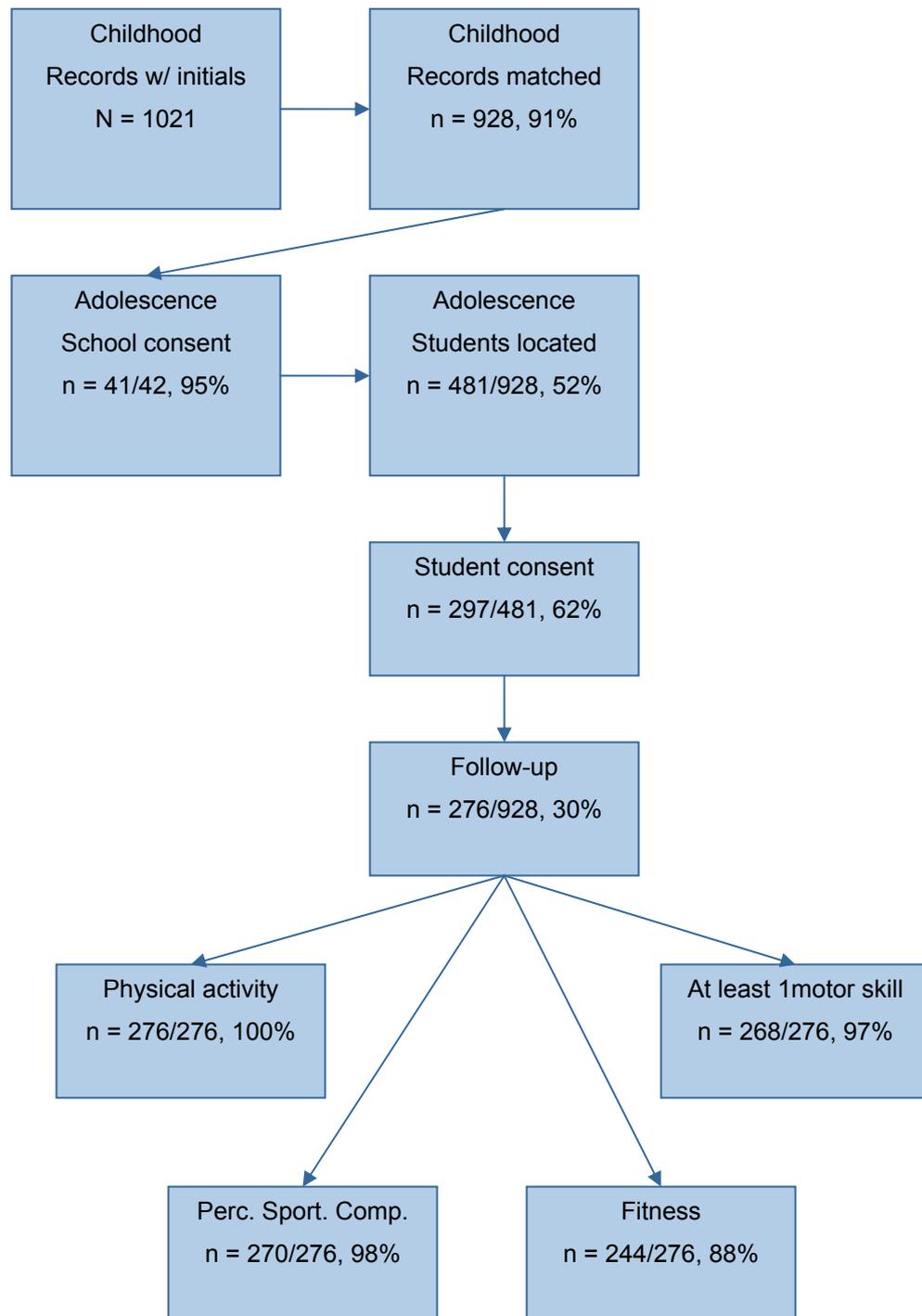


Figure 10: The follow-up sample

4.2 MIGI Sample (2000)

4.2.1 Matched students

The sample had slightly more males ($n = 480$, 51.7%) than females ($n = 448$, 48.3%) and fairly even numbers of those originally assessed in Grade 4 ($n =$

460, 49.6%) and in Grade 5 ($n = 468$, 50.4%). More than half were control students ($n = 535$, 57.7%) with 393 (42.4%), intervention students. The discrepancy between control and intervention students is in part due to the unmatched records; of which more control than intervention students were matched (see 'Data matching' in Section 3.2.3 'Matching MIGI records to names').

4.2.2 Students assessed for FMS

Percentages assessed for proficiency in each skill were; 99.6% ($n = 924$) for the kick and catch, 99.4% ($n = 922$) for the overhand throw, 98.9% ($n = 918$) for the side gallop, 99.0% ($n = 919$) for the hop and 98.3% ($n = 912$) for the vertical jump. A total of 96.3% ($n = 894$) students had all six skills tested, 28 had five skills tested, three had four skills, and three had one skill tested only.

4.3 PASS Sample (2006/2007)

4.3.1 Student location

School consent

Forty three high schools (19 state and 24 independent) in the original study area were approached to take part in the PASS. One government school had no students in the year groups of interest and therefore was not eligible. One independent school declined due to student workload. The remaining 41 schools all consented to take part. School consent rate was thus 41/42 (95.4%).

Liaison contacts

All schools were approached in the same manner (see 'School selection' in Section 3.2.4). One Principal remained the liaison contact, but in most cases Principals appointed Personal Development, Health and Physical Education (PDHPE) teachers ($n = 23$) (usually the Head of PDHPE) as liaison contacts. In the remaining five schools (all with small numbers of located students); administration staff ($n = 3$), a Deputy Principal ($n = 1$) and a Year Advisor ($n = 1$) were appointed.

Location of participating students

A list of 929 study subjects was sent to the 41 consenting schools in order to identify current students for follow-up. Students were located in 28 of the 41 schools. School liaison staff initially recognised the names of 535 students, however 35 of these students had left school before the study had commenced and one had recently passed away. A further eighteen students left school before being contacted to consent to the study. Thus, 51.8% ($n = 481$) of the original students were presently enrolled at a school and able to be asked for consent. Of these schools, 18 were government and 10 were independent.

Characteristics of located students

There were even numbers of males ($n = 241$) and females ($n = 240$) located ($\chi^2 = 1.05, p = .306$). More former Grade 4 students ($n = 272/481, 56.5\%$) were located than Grade 5 students ($n = 209/481, 43.5\%$), ($\chi^2 = 19.46, p = <.000$). More control (54.5%, $n = 262/481$) than intervention (45.5%, $n = 219/481$) students were located ($\chi^2 = 4.14, p = .0419$). The mean composite childhood FMS score of the located students was slightly higher (17.7) than those not located (16.8), ($t = -2.45, p = .014$).

4.3.2 Consent

Student consent

The overall student consent rate was 61.7% (297/481). This represents approximately a third (32.0%, $n = 297/928$) of the original sample. One consent form was unidentifiable and so could not be matched to a student or school. Of the 296 consenting students eligible for analysis, slightly more females (51.7%, $n = 153/296$) consented than males (48.3%, $n = 143/296$), however this was not significant ($\chi^2 = 2.03, p = 0.15$). More former Grade 4 students (60.1%, $n = 178/296$) consented than Grade 5 students (39.9%, $n = 118/296$), ($\chi^2 = 19.4, p = <.000$) and more intervention students (52.7%, $n = 156/296$) than control students (47.3%, $n = 140/296$) ($\chi^2 = 19.08, p = <.0001$). Intervention students were also more likely to consent (71.2%, $n = 156/219$)

than controls (53.4%, $n = 140/262$) ($\chi^2 = 15.97, p < .000$). See Table 7 for number and percentage of located students, consent rate of located students and follow-up rate of original matched sample for gender and school grade.

Table 7: Number and percentage of the sample that were: located, consenting, and followed-up of the original matched sample, for gender and school grade in 2000

	2000 MATCHED SAMPLE		2006/07 LOCATED		2006/07 CONSENTED		2006/07 FOLLOW-UP	
	n	%	n	%	n	%	n	%
Grade 4								
Male	241	52.4	141	58.5	82	58.2	77/241	32.0
Female	219	47.6	131	59.8	96	73.3	93/219	42.5
TOTAL	460	49.6	272	59.1	178	65.4	170/460	37.0
Grade 5								
Male	239	51.0	100	41.8	61	61.0	55/239	23.0
Female	229	48.9	109	47.6	57	52.3	51/229	22.3
TOTAL	468	50.4	209	44.7	118	56.5	106/468	22.7

School consent rates

Twenty six schools (of the 28 with located students) had students that consented to be part of the study. Of these 26 schools; two schools had over 30 students consent (36.5%, $n = 108/296$), six schools had between 10-30 students consent (40.2 %, $n = 119/296$), and the remaining 18 schools had under 10 students and almost a quarter of the sample (23.3%, $n = 69/296$).

Consent rates within schools with 10 or more located students varied from 33% to 90%, with six schools having a consent rate of 60% or greater, and two having a consent rate below 60%. See Table 8 for the number and percentage of students located per school, and the number and rate of those who consented in each school.

Table 8: Number and percentage of students located per school, number and rate of those who consented per school

N LOCATED	% LOCATED	N CONSENTED	% CONSENTED
107	22.2%	35	33%
81	16.8%	73	90%
45	9.4%	29	64%
45	9.4%	30	67%
33	6.9%	15	45%
24	5.0%	17	71%
20	4.2%	12	60%
19	4.0%	16	84%
16	3.3%	9	56%
15	3.1%	8	53%
13	2.7%	6	46%
13	2.7%	9	69%
8	1.7%	4	50%
7	1.5%	5	71%
6	1.2%	6	100%
5	1.0%	1	20%
5	1.0%	5	100%
4	0.8%	4	100%
3	0.6%	3	100%
3	0.6%	2	67%
2	0.4%	2	100%
1	0.2%	1	100%
1	0.2%	1	100%
1	0.2%	1	100%
1	0.2%	0	0%
1	0.2%	1	100%
1	0.2%	0	0%
1	0.2%	1	100%
		(Unidentified) 1	
N = 481		N = 297	61.7%

Factors impacting on consent

All students were approached in the same manner (see 'Student recruitment' in Section 3.2.5) and all students received a second reminder letter in the post to their home address if they had not returned a consent form after the first invitation.

There were several factors that impacted on consent as reported by the contacts. The key factor reported by liaison contacts in schools with large numbers of located students was that it was very hard to coordinate organising and asking students who were in either of two year groups and within many different classes. The feasibility of getting these students together at any one time proved to be very challenging for some schools. As the students were in the upper years of high school, some of these large schools did not always know students whereabouts as they had free periods and flexible timetables.

The other main barrier to consent, reported by the contacts, was that many students (and their parents or guardians) could not remember being in the original study. Because they couldn't remember the original study some did not see the relevance of participating in the present study. Another barrier was the MFT. Some contacts felt that having to do this test would put off some students who were not very fit. The test was considered to be unpopular amongst students.

One key factor impacting on consent, as observed by the study coordinator, was the former Department of Education ethics policy. At the time MIGI was conducted, the Department of Education policy for student consent was an 'opt off' policy, that is, if parents/guardians did not want their child to participate. Otherwise all children had effectively consented by default. At present, the policy is 'opt on'. Now, all parents/guardians who want their child to participate in such studies must fill in a consent form. The implication of this change in policy for the PASS is that parents may not have remembered that their child was in MIGI as they didn't have to explicitly consent. This may have impacted negatively on consent rates.

Other factors impacting on consent as observed by the study coordinator were the liaison contact's knowledge of students and the length of time the liaison contact had taught at the school. In two of the schools with large numbers of located students, contacts were appointed that had only been at the school for a year and so were disadvantaged by not knowing students. Also, by not knowing the students, these contacts did not appear to have much influence over the students' decision to participate or not. In one large school with a high consent rate, the contact, who had been in the school for many years, knew all the students and appeared to have a high degree of respect from students.

The greatest factor in student consent, as felt by the study coordinator, was the personal effort made by the respective liaison contacts. There were great differences between the schools in terms of the commitment of the liaison contact. Some contacts really tried to encourage the students to participate whereas others did what was required, but no more.

4.3.3 Follow-up

School visits

There were 39 visits to schools for surveying. Four school visits required three RAs to assess students (over 20 students scheduled for testing), 12 school visits required two RAs (between 10 and 20 students scheduled) and 23 school visits required one RA only (less than 10 students). Seventeen schools were visited on one occasion, seven schools on two occasions, one school three times and one school five times. The schools with the larger numbers of consenting students tended to have more visits, although this was not always the case with some schools requiring two visits to assess less than ten students.

In three cases interviews were administered to students by telephone. These interviews were for students from three different schools. One school had been visited once, one school had been visited twice, and one had been visited five times. At each of these schools, contacts were unwilling to

organise a further visit but the student had agreed to being surveyed by telephone by a PASS RA.

Rate for each assessment

Of 296 eligible consenting students, 93.2% ($n = 276$) were surveyed, leaving an overall follow-up rate of 29.7% ($276/928$). Of the 20 students not surveyed one student passed away, two had long-term illnesses, and 17 from six schools were not present at any of the scheduled survey days and the school liaison contacts concerned were unwilling to organise further dates.

The followed up sample did not differ by gender ($\chi^2 = 2.40$, $p = .12$) but were more likely to have been originally tested in Grade 4 (61.5%) than Grade 5 (38.5%), ($\chi^2 = 22.67$, $p < .0001$) and had a slightly higher (17.5 compared with 16.5) mean composite childhood FMS ($t = -2.60$, $p = .009$). More former intervention ($n = 148/276$, 53.2%) than control students ($n = 128/276$, 46.8%) were surveyed, ($\chi^2 = 19.27$, $p = .000$)

All but one were English speaking (99.6%, $n = 273/274$), and 7.0% ($n = 19/272$) were of Aboriginal and/or Torres Strait Islander background. Using home postcode of residence as a proxy for socio economic advantage/disadvantage as defined in the Australian Bureau of Statistics Index of Disadvantage²⁰³; nearly the entire sample were classified as below the New South Wales state average (50th percentile and below) (98.9%, $n = 273/276$)²⁰³. 12.3% ($n = 34$) were below the 10th percentile (916), 34.4% ($n = 95$) below the 25th percentile (950), and 52.2% ($n = 144$) below the 50th percentile (990).

A total of 31 students were either unwilling to do an aspect of the testing/surveying or left without explanation. The FMS proficiency of these students, in 2000, was compared to the rest of the surveyed students (including students who had a genuine reason for not completing some assessments). There was no difference in terms of skill proficiency in 2000, between the 31 classed as unwilling and the 245 willing to complete assessments ($t = 1.53$, $p = .13$).

Physical activity

All 276 students surveyed for the PASS completed the APARQ.

Perceived sports competence

Out of the 276 students surveyed for the PASS, six did not complete the physical self-perception section of the questionnaire. Three were not assessed as they were surveyed by telephone and this part of the survey was considered inappropriate to do by telephone (due to the personal nature of questions and the structure of the questioning). Two did not complete this section of the questionnaire (one felt sick and one had a learning disability and could not understand the questions) and one student left this section of the questionnaire blank.

Of the 270 who completed this questionnaire, a score for perceived sports competence was calculated for all students who had completed each item in this domain. All students completed items 11 and 16, 267 students completed item 1, 266 completed item 26, 265 completed item 21, and 264 completed item 6. The follow-up rate for the domain of sports competence was thus 92.8% ($n = 256/276$). Of the 256 surveyed, 52.7% ($n = 135$) were female and 47.3% ($n = 121$) male, with 59.0% ($n = 151$) in Grade 10 and 41.0% ($n = 105$) in Grade 11.

Motor skills

Of the 276 students surveyed for the PASS, 10 were not assessed for FMS skill proficiency. Of the ten who were not assessed, three completed surveys by telephone and could not attend for testing in person, and seven were not assessed due to illness or injury.

Of the 266 remaining students who were assessed for at least one FMS, 264 were assessed for the catch, 262 for the overhand throw and kick, 261 for the vertical jump, 258 for the hop and 255 for the side gallop, (see Table 9). Of those with less than six skills assessed; 11 had five skills tested, five had four skills, five had three skills and two had only one skill tested.

Of the 23 students who had less than six skills tested; 10 left early (it is unclear whether this was due to time constraints or unwillingness), six were unwilling to do particular skills, and four were injured. In one school, rain prevented the kick from being assessed for four students (one of whom was already counted as being unwilling to do two other skills). Of the 266 with at least one skill tested, 128 were male (48.1%) and 138 (51.9%) female with 157 (59.0%) in Grade 10 and 109 (41.0%) in Grade 11.

Table 9: Numbers and percentages of students assessed for at least one FMS in 2000 and 2006/07

SKILL	2000		2006/2007	
	N = 928		N = 276	
FMS	n	%	n	%
Catch	924	99.6	264	95.7
Kick	924	99.6	262	94.9
Overhand Throw	922	99.4	262	94.9
Vertical Jump	912	98.3	261	94.6
Hop	919	99.0	258	93.5
Side Gallop	918	100.0	255	92.4

Fitness

Out of the 276 students surveyed for the PASS, 84.8% ($n = 234$) completed the MFT. Of the 42 that did not complete the test 17 were unwilling, nine were unable due to rain (and were not present at the subsequent replacement test date), six had an injury, three had telephone interviews, three left with no explanation, two had appointments, one was sick, and one could not complete due to high temperature on the day.

Ten of the 42 who did not complete the test provided a result from a test undertaken in PE in the previous six month period. These scores were included bringing the total MFT scores eligible for analysis to 244 (88.4%). Of the 244 with MFT results, slightly more than half the sample were female (52.1% $n = 127$) with 60.1% ($n = 146$) in Grade 10 and 39.0% ($n = 97$) in Grade 11. All but one spoke English at home.

4.4 Summary

This chapter provided extensive detail on the study sample. In summary, the school consent rate was 41/42 (95.4%). A list of 929 study subjects was sent to the 41 consenting schools in order to identify current students for follow-up. Students were located in 28 of the 41 schools. Of these schools, 18 were government and 10 were independent. There were even numbers of males and females located. Liaison contacts, in most cases the Head of PDHPE, were appointed by the respective Principals to approach located students for study consent.

The overall student consent rate was 61.7% (297/481). Of the consenting students there were no significant differences between numbers of females and males. Consent rates within schools with ten or more located students varied considerably. The main factors affecting consent were; that students were spread between classes and year groups and thus difficult to locate and address, students not remembering MIGI which was compounded by the ethics 'opt off' policy at the time of MIGI, whether the liaison contact knew the students personally, and the effort put in to gaining consent by the respective liaison contacts.

Of 296 eligible consenting students, 93.2% (n = 276) were surveyed, leaving an overall follow-up rate of 29.7% (276/928). There were 39 visits to schools for surveying. The followed up sample did not differ by gender but were more likely to have been originally tested in Grade 4 than Grade 5 and had a slightly higher mean composite childhood FMS. More former intervention than control students were surveyed.

5 RESULTS

5.1 Introduction

As this thesis is submitted via publication, results pertaining to each research question have either been published or are in press. This chapter provides the title of each paper and identifies the specific research questions each paper sought to answer. The status of each paper is also outlined. The actual papers are not provided in the PhD for copyright reasons.

PAPER 1: “Childhood motor skill proficiency as a predictor of adolescent physical activity”

Paper status: ‘published’

Research question answered in this paper:

1. What is the nature of the association between FMS proficiency during childhood and physical activity participation (MVPA, vigorous, organised, non-organised) in adolescence?
7. Does gender moderate the relationship between childhood motor skill proficiency and adolescent physical activity?

PAPER 2: “Does childhood motor skill proficiency predict adolescent fitness?”

Paper status: ‘published’

Research question answered in this paper:

2. What is the nature of the association between FMS proficiency during childhood and cardiorespiratory fitness in adolescence?

7. Does gender moderate the relationship between childhood motor skill proficiency and adolescent fitness?

PAPER 3: “Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment”

Paper status: ‘published’

Research questions answered in this paper:

3. Does perceived sports competence mediate between childhood motor skill proficiency and adolescent physical activity?
4. Does perceived sports competence mediate between childhood motor skill proficiency and adolescent cardiorespiratory fitness?
7. Does gender moderate the relationships between childhood motor skill proficiency and adolescent perceived sports competence, physical activity and fitness?

PAPER 4: “Six year follow-up of students who participated in a school-based physical activity intervention: a longitudinal cohort study.”

Paper status: ‘published’

Research questions answered in this paper:

5. Are children who completed a FMS intervention during childhood more proficient at FMS in adolescence than control group children?
6. Are children who completed a FMS intervention during childhood more physically active in adolescence than control group children?

PAPER 5: “Differences in motor skill proficiency from childhood to adolescence according to gender: A longitudinal study.”

Paper status: ‘accepted in press’

Research question answered in this paper:

7. Does gender moderate the relationship between childhood motor skill proficiency and adolescent motor skill proficiency.

5.2 Summary

This chapter provided the title of each of the PASS publications (papers 1-5) that related to the study results. The specific reference information for each paper can be found in the introduction. Paper 6 was more appropriately presented in the methods section (see Section 3.4).

6 DISCUSSION AND RECOMMENDATIONS

6.1 Introduction

In this chapter, the overall results of the PASS as one body of work will be discussed, rather than repeating the specific discussions within each of the papers separately. The chapter starts with a summary of the main findings presented in the papers and the significance of these findings. Each hypothesis is then restated with conclusions provided as to whether it was supported, or not supported, by the findings. Study limitations are then presented and discussed. The final sections provide recommendations arising from the study and possible future research directions.

6.2 Main Findings

The prime purpose of the PASS was to investigate the nature of the relationship between childhood motor skill proficiency and adolescent physical activity participation, cardiorespiratory fitness and perceived sports competence, and to see whether these relationships varied by gender. The PASS findings confirmed that motor skill ability influenced subsequent physical activity participation. Paper 1 demonstrated that skilled children became more active adolescents and in particular it was object control proficiency that impacted on subsequent physical activity, through both time spent in MVPA and organised activity. In addition, childhood object control proficiency increased the probability of whether an adolescent will participate in *any* vigorous activity. Paper 2 demonstrated that object control proficiency impacted on subsequent fitness, with predicted values from the final model showing that children with good object control skills achieved on average, more than six more additional laps on the MFT than those with poor childhood object control skills. Paper 3 extended this work further by examining the role of perceived sports competence in the relationship

between childhood motor skill proficiency and subsequent physical activity and fitness. It was found that perceived sports competence partially mediated the relationship between motor skills and physical activity/fitness. Thus the first three study hypotheses were supported. These findings are broadly consistent with cross-sectional research which suggests that motor skill proficiency is positively associated with physical activity^{28-31, 107} and fitness^{33, 108, 128} in youth and that perceived competence has an important relationship to participation in sport^{135, 136}, physical activity behaviour¹³⁹⁻¹⁴² and fitness levels¹⁴²⁻¹⁴⁴.

Findings from the PASS suggest that object control proficiency is a more important influence on health-related behaviours and outcomes (adolescent physical activity, fitness, perceived sports competence and object control proficiency) than locomotor proficiency. Papers 1-5, when considered together, consistently confirm the impact of childhood object control proficiency. Locomotor proficiency did not predict physical activity behaviour (Paper 1), fitness (Paper 2), perceived sports competence (Paper 3) or help to explain adolescent locomotor proficiency (Paper 5). In this regard, it is noteworthy that an object control skill was the only skill which intervention children could perform better than controls six years after the MIGI intervention in which this study was nested (Paper 4).

These findings may be explained by it being more important to possess object control skill proficiency in terms of participation in many games, activities and common sports. Paper 2 showed that, of the organised activities which students participated in during adolescence, nearly all involved object control skills. As participation in organised activity has been linked to motor skill proficiency^{28, 31, 125, 204} this further confirms the importance of object control skill proficiency. Not surprisingly, it has also been shown that skill specific proficiency relates to the activity of interest, i.e. activities involving throwing are associated with developmental levels of throwing¹⁰⁷. This is also consistent with the PASS findings. Likewise, one plausible explanation for why object control skills predicted subsequent fitness is that these types of skills (kicking, throwing, catching) are often

associated with physical activity experiences of a moderate and/or vigorous intensity (such as recreational or organized sports training and competition)¹⁰⁷. Thus, students who are proficient at performing these skills may participate more in the type of activities likely to increase fitness levels. Papers 1, 2 and 3 discuss in more detail why object control proficiency may be important to physical activity participation.

Locomotor proficiency may be a less important predictor for a number of reasons. Okely and colleagues found a battery of movement skills (including four object control skills and two locomotor skills) was associated with organized activity²⁸, however the individual contribution of object control versus locomotor proficiency on physical activity was not assessed. Paper 5 suggests that childhood locomotor proficiency does not explain adolescent locomotor proficiency, implying that locomotor skill performance may not be stable over time. Locomotor skill performance may be more susceptible than object control skill performance to other factors such as weight³², (which was not measured or controlled for in the PASS). If locomotor skill performance is variable it is perhaps logical that skill performance as a child would not contribute to subsequent physical activity and fitness behaviour.

In the adolescent interrater reliability assessment of the motor skills (Paper 6) using the 'Get Skilled Get Active' skill measurement protocol, the hop had a particularly low reliability compared to the other five skills. This may indicate that some locomotor skills are hard to assess (at least with this instrument) which would have limited the ability to accurately confirm a certain standard of proficiency. If there was measurement error involved in the locomotor skill assessment this may have biased the study away from identifying a relationship between childhood locomotor ability and subsequent behaviour.

Since the interrater assessment in childhood as part of MIGI⁴⁹, did not calculate a separate reliability for each skill, it was uncertain whether low reliability of the hop was a possible limitation affecting the ability of the locomotor childhood skill scores to predict the outcome variables. To test this potential limitation in the context of this discussion, additional analysis (not specified in any of the papers) was performed. The side gallop and vertical

jump were summed to provide a childhood locomotor score (without the hop) and this new variable was used in separate general linear models to predict both main outcome variables: fitness and physical activity. Using an alpha of .05, and controlling for gender, school year group and possible interactions with each and the new locomotor child skill score, neither physical activity $F(1, 263) = .111$ $p = .740$) nor fitness $F(1, 234) = 3.031$, $p = .083$) was predicted in adolescence. This illustrates that the inability of the childhood locomotor skill score to predict the outcome variables was probably not due to any lack of reliability with the childhood hop assessment.

That fitness was predicted by object control proficiency, and that perceived sports competence acted as a mediator between object control skill proficiency and both physical activity and fitness, has not been identified by any other longitudinal studies. The finding that object control skill proficiency predicts subsequent physical activity differs to that of the only other longitudinal study assessing motor skill as a determinant for physical activity behaviour conducted in youth⁴². This study, by McKenzie et al examined early childhood (ages 4 - 6 years) motor skills (lateral jumping, catching a ball, and balancing on one foot) and early adolescent (12 years) physical activity participation, finding no relationship between these three motor tasks and subsequent physical activity⁴².

There may be a number of explanations for the discrepancy between these studies. While, in our research, object control skills were the determining factor in subsequent physical activity, McKenzie et al only measured one object control skill: catching a ball⁴². Also, in the PASS, skills were assessed at a later stage in childhood. By late primary school it may be expected that some children will have mastered their FMS whereas in early childhood children are only just beginning to develop these skills. Therefore, later childhood may be a better time to assess the predictive validity of motor skill performance for subsequent activity. The findings of the PASS are further supported by research that suggests that the strength of the relationship between motor skill proficiency and physical activity increases over time²⁰⁵. Lastly, our ability to construct composite scores may have allowed us to

discriminate in more detail between children's skill levels which may have helped predictive validity.

A secondary aim of the PASS was to assess the long-term impact of MIGI; a one year primary school-based intervention (1999-2000) that improved motor skill proficiency in students. This aim was addressed in Paper 4. Paper 4 illustrated that intervention students were still more proficient at one object control skill (catching) but being an intervention student did not result in higher adolescent physical activity participation. The hypothesis that intervention children would be more active than their control counterparts was therefore not supported. This was somewhat surprising, considering MIGI intervention children were more skilled directly following MIGI and the main PASS findings supported the hypothesis that object control skilled children were subsequently more active (Paper 1).

That intervention children were no more active than their control counterparts, may have been due to a number of factors. One possibility is that the difference between intervention and control students' object control skills may not have been great enough to influence physical activity after six years. The gains reported from MIGI were over and above those due to usual development as a child moves from one year to the next⁴³. But it is unclear what magnitude of gain is needed to make a future public health impact in terms of physical activity behaviour. Another possibility is that the motor skill instrument did not discriminate enough to detect intervention/control differences. The motor skill instrument was not developmental²⁰⁵, meaning that achievement of skill features was not aligned with developmental stages of motor skill development. Each skill has features that are considered introductory features, yet it is possible that near mastery may be reached by achieving a combination of skill features that does not include an introductory feature. It is also possible the APARQ lacked the resolution to be able to detect intervention/control differences. Finally, it may be that the sample size was inadequate to fully test this hypothesis, although even the observed trends were very limited.

There is little other evidence on the long-term impact of school-based motor skill interventions to compare these PASS findings with, as there are no motor skill interventions, and very few school-based physical activity interventions with long-term follow-ups. 'Switch-Play' found a significant improvement in fundamental skill z-scores for girls after a short-term follow-up (six and 12 months) and longer term effects reported on physical activity for intervention students¹⁶⁴. Of three physical activity interventions located with long-term follow-ups, all reported significant intervention effects on self-reported physical activity that declined over time⁴¹. More detailed discussion of these issues is provided in Paper 4.

Papers 1 and 2 also illustrate that the effects of childhood object control skill proficiency on fitness were stronger than the effects on physical activity (as shown in Paper 1 and Paper 3). This is consistent with the findings of cross-sectional research. The 1997 Australian NSW Schools Fitness and Physical Activity Survey found that proficiency in a battery of six motor skills explained 28% of the variance in fitness for Grade 10 girls and 18% for Grade 10 boys¹⁰⁸, compared with 8.7% of variance in children's physical activity using an objective physical activity measure³⁰, and 4.3% of organised activity variance in adolescents, using a self-report measure of physical activity²⁸. It is unclear why the variance explained for fitness may be greater than that explained for physical activity. It could be because some physical activities (e.g. walking, swimming, riding) are not dependent on object control skill proficiency whereas many 'fitness-promoting' organised sporting activities (all ball games/sports) require a certain level of object skill proficiency for participation. Yet conversely, many popular physical activities (jogging) which do not require object control proficiency, can and are performed to a degree that promotes fitness.

Another explanation of the stronger relationship between the constructs of motor skill proficiency and fitness may simply lie in the measures used. The fitness measure was an objective measure, while the physical activity was based on self-report. Likewise, perhaps if motor skill had been assessed using a product-oriented protocol, i.e. looking at skill execution such as time,

distance or number of successful attempts assessed³⁵, different patterns of relationship strength may have emerged.

It was anticipated that any effect on physical activity or fitness as a result of motor skill proficiency would differ according to gender. The PASS findings suggested males were more object control proficient (Paper 5) which is consistent with previous research^{21, 43, 45-47, 150}. Yet, when the work is viewed as a whole, even though males were more active (Paper 1), fitter (Paper 2), and had a higher perceived sports competence (Paper 3), the PASS suggests that gender did not moderate the relationships between childhood motor skill and these variables. Paper 1 and 2 both demonstrated that the cause and effect relationship between childhood object control skills and adolescent physical activity and fitness works in the same way for both genders.

Likewise, in Paper 3, gender did not moderate the relationship between childhood object control proficiency and adolescent perceived sports competence, physical activity and fitness. This is consistent with Crocker et al, who found in cross-sectional research, looking at the relationship of PSPP domains to self-reported physical activity amongst younger adolescents, that there was no moderating effect for gender³⁷. Paper 4 did not examine the effects of gender on long-term outcomes of intervention students, as the sample was already divided by control and intervention students and was not large enough to further partition by gender and expect to find meaningful results.

The hypothesis that gender would affect the relationships between variables was thus not supported. This implies that the nature of the relationship between these variables is the same for boys as girls. That is, motor skill proficiency is just as important and influential for both genders and influences the key behaviours and outcomes in the same manner. Of course, the PASS findings also show that object control skills were lower among girls (Paper 5), and that lower skills are likely to have negative health consequences in adolescence (in terms of physical activity participation and fitness levels). Thus, the findings also suggest that interventions in childhood to improve

skills may be particularly important for girls. In this regard it is interesting to note that the original MGI intervention was effective for both boys and girls

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6.2.1 Testing of hypothesis

These findings lead to the following conclusions about the research hypotheses.

(1) FMS proficiency during childhood predicts a) MVPA and vigorous physical activity participation in adolescence and b) participation in organised physical activity in adolescence.

PASS findings are consistent with this hypothesis. However it was the object control skills rather than the locomotor skills that predicted activity participation in all categories.

(2) FMS proficiency during childhood predicts adolescent cardiorespiratory fitness.

PASS findings are consistent with this hypothesis. However it was the object control skills rather than the locomotor skills that predicted cardiorespiratory fitness.

(3) Perceived sports competence mediates between FMS proficiency during childhood and adolescent physical activity.

PASS findings are consistent with this hypothesis. A mediation effect for perceived sports competence was found on the relationship between object control skills and physical activity.

(4) Perceived sports competence mediates between FMS proficiency during childhood and adolescent cardiorespiratory fitness.

PASS findings are consistent with this hypothesis. A mediation effect for perceived sports competence was found on the relationship between object control skills and cardiorespiratory fitness.

(5) Children who completed a FMS intervention during childhood perform FMS as an adolescent more proficiently than control group children.

PASS findings are generally not consistent with this hypothesis, as children who completed a FMS intervention during childhood performed the catch more proficiently as adolescents, than control students. However, children did not perform the kick, overhand throw, vertical jump, hop or side gallop more proficiently than control students as adolescents.

(6) Children who completed a FMS intervention during childhood would participate in more MVPA as an adolescent than control group children.

PASS findings are not consistent with this hypothesis as intervention children participated in no more MVPA than control children.

(7) Gender moderates relationships between childhood motor skill proficiency and adolescent physical activity, fitness, perceived sports competence and motor skill proficiency.

PASS findings are not consistent with this hypothesis as gender did not moderate the relationships between childhood object control proficiency and i) adolescent object control proficiency, ii) physical activity, iii) fitness and/or iv) perceived sports competence.

In summary, the major hypotheses tested in this study were supported in that childhood skill proficiency was a determinant for subsequent physical activity and fitness, and perceived sports competence did mediate within this relationship. However, it was object control skill proficiency not locomotor skill proficiency that was important. The secondary hypothesis was largely unsupported as intervention children only performed better than controls in one skill and were no more active at follow-up. The underlying hypothesis that gender would moderate the relationships between childhood object control proficiency and adolescent physical activity participation, fitness and perceived sports competence was not supported, although males were more motor skilled, physically active, fitter and had higher perceived sports competence.

6.2.2 Significance of Findings

The PASS is the only longitudinal study to follow children from primary to high school to assess the influence of childhood motor skill proficiency on subsequent physical activity and fitness. Increasing physical activity is a major national and international public health priority as there is vast evidence that physical activity participation¹⁻¹² and fitness¹³⁻¹⁶ is important for health. Therefore investigating potential adolescent physical activity and fitness determinants is of crucial importance. The main finding, that childhood object control proficiency is important to physical activity participation, fitness and perceived sports competence has widespread implications.

The results will be of importance to Health and Physical Education policy makers worldwide and may help shape our approaches to the design and delivery of physical activity interventions and school PE programs for youth. The place of FMS in the primary school PE curriculum has been based on cross-sectional research and critiqued for having no strong evidence base²⁰⁶. The findings from the PASS will therefore strengthen the rationale for the inclusion of FMS in PE programs.

Understanding the place of perceived sports competence as a potential mediating variable can inform the design of interventions to promote physical activity and fitness among youth by ensuring interventions include factors considered important to the development of perceived sports competence. Also, the planning and delivery of PE for children can be designed with perceived sports competence in mind. For instance, teachers should be encouraged to teach motor skills using a mastery learning environment where the child is able to succeed and is encouraged to personally improve which can lead to higher levels of enjoyment and greater levels of perceived competence²⁰⁷.

The PASS is also one of few international studies to conduct a long-term follow-up of a school physical activity intervention. Findings from the PASS suggest that improvement in motor skill proficiency gained through a childhood intervention can last beyond the intervention end point, at least in

one skill. Research into the reasons for stability of the catch may provide insights into how other skills might be taught or supported to improve their long term maintenance. However much more needs to be done in this area, in terms of research designs that can effectively track children from the start of an intervention to the follow-up point.

Furthermore, it is one of few international studies to look at how motor skill proficiency develops from childhood to adolescence and how this differs by gender. The finding that girls perform so poorly in object control skills, such as the overhand throw and kick, will help inform interventions to be tailored to the needs of each gender. The PASS findings are thus important and original and the recommendations will be beneficial for all those in the community interested in ensuring young people are healthy and physically active.

6.2.3 Limitations

Whilst the main strength of the PASS was its longitudinal design, there were a number of limitations in terms of follow-up, measurement instruments, analyses issues and control variables. There is potential for bias due to the follow-up rate of one third. This was unavoidable since the study was never designed for longitudinal assessment, the follow-up period was quite extended and many students had moved between regions or schools. Probably the biggest issue with locating students was the fact that many had left school by Grade 11 (students of this age in Australia can legally leave school).

Once students were located, several factors impacted on consent. The length of time of the follow-up period meant that students could not remember being a part of the original program. Also students and their parents or guardians were not asked originally if they could be followed up at a later date and thus were not expecting to be tracked down. Students and parents or guardians had to provide written consent for this study and students could withdraw at any time or not take part in any subset of the testing. Nevertheless, the consent rate in PASS was higher than at least one such similar study in this age group ²¹.

When we assessed the potential impact of loss to follow-up on the study findings, there was no difference in followed up students in terms of gender, although mean composite childhood skill score was greater in followed up students, suggesting followed up students may have been potentially more skilled. However, as the difference was only one point on a 30 point scale, loss to follow-up is unlikely to have biased the findings in any substantial way.

There were also limitations with the measurement instruments such as the use of a self-report partially validated measure for physical activity. The APARQ has been validated against the MFT and has moderate test-retest reliability¹⁷⁹. However, further validation would be beneficial. Nevertheless, the APARQ was chosen for this study as it identifies and quantifies most aspects of physical activity participation and is known to be acceptable to the target group, having been used in Australia previously in key school-based population studies^{21, 44}. Furthermore, due to the large sample tested in many different schools over a large geographical area, more objective measures of physical activity would have been problematic to monitor.

There were also possible limitations with the motor skill assessment. The process of the development of 'Get Skilled Get Active' appears thorough and meticulous however a limitation is that external validity has not been assessed, in terms of whether the specific skill features reflect a proficient skill performance. This can only be done by comparison to validated developmental motor sequences proposed by others to see if 'proficiency' with one instrument is also considered 'proficiency' with another. However, because of the different discrepancies in motor skill instruments in the way skill features are described and assessed, this is difficult to do. Details of the hop assessment as illustrative of this point are specified in Paper 5.

Furthermore, in the reliability assessment of skills assessed in adolescence (Paper 6), the hop had the lowest kappa of the skills tested. Because separate reliability of skills was not assessed in MIGI, it is possible the hop had lower reliability in childhood therefore potentially limiting the ability of the locomotor childhood score to be predictive. However, additional analysis

revealed that a composite childhood locomotor score, without the hop, still was not predictive of the key outcome variables, indicating that this potential limitation was unlikely to have affected the main findings of the study. Nevertheless, the low reliability of the hop in adolescence may have affected to what degree adolescent locomotor skill could be predicted by childhood locomotor skill. A point worth noting is that because the sample size was smaller for each skill than for the total number of skills combined, the confidence values were wider, thus reflecting the sampling error with the kappa statistic for each skill. When all the skills were combined, the kappa statistic was higher and also had less sampling error associated with it.

Another issue with the motor skill assessment was a potential ceiling effect operating as many students reached proficiency in their motor skills at follow-up, which may have masked potential differences between groups and variables of interest. Also, the motor skill instrument whilst process oriented was not developmental²⁰⁵. Each skill has features that are considered introductory features, yet it is possible that near mastery may be reached by achieving a combination of skill features that does not include an introductory feature.

A general analytical limitation (Papers 1 - 5) was not adjusting for school-level variation. It may be expected that there would be school variation in both primary and high school but because there were 18 primary schools and 28 high schools, a cross-classified model (which would have accounted for both primary school and high school variation) was not seen as viable. Only 11 of the 50 primary and high school combinations (excluding those with zero) had more than six students. To adjust by each school pair would therefore have meant that in most cases school variance would have been represented by six or less students which could not reasonably be said to be representative.

For some of the analyses (Paper 4), sample size was another potential limitation. It may be that our sample was not large enough to identify a relationship with being an intervention/control student and subsequent physical activity. Because we had no ability to identify students at MIGI

baseline (1999) by name, only at post-test (2000) and follow-up (2006/07), there was no way to track the followed up students back to baseline, meaning that a repeated trials analysis could not be conducted. When the original MIGI intervention was conducted the ethics institution concerned did not permit the storing of names with data, so the MIGI study was analysed as two cross-sectional studies. However, initials of the students were kept at MIGI post-test with class rolls enabling this data to be matched and then used as a baseline measure for the current follow-up study.

In addition, maturation¹¹¹ and weight status³² were not controlled for, both factors that may effect motor skill performance. Collecting information associated with these factors was seen as adding to participant burden with the potential to reduce consent rates.

6.3 Recommendations

With increasing youth obesity rates²⁰⁸, schools have been identified in a series of government reports as being a key setting for promoting public health goals, and in particular, achieving physical activity recommendations²⁰⁹. The concept of health-related PE²¹⁰ was developed nearly 20 years ago based on the premise that PE could be a medium to develop lifelong physical activity. Recent U.S. public health recommendations for schools include that: schools should ensure all children and youth participate in a minimum of 30 minutes of MVPA each day (including time spent being active in PE classes), evidence based PE programs are delivered which provide substantial amounts of MVPA (i.e. 50% of class time) and that motor and behavioural skills needed to engage in lifelong activity should be taught²¹¹.

In NSW, the current Board of Studies PDHPE syllabus document recommends that primary schools provide children with a significant contribution towards public health recommendations for physical activity²¹². The NSW PDHPE syllabus includes two key strands that are directly related to active lifestyles. 'Active Lifestyle' is identified as a key strand and is concerned with students developing activity patterns that will support their health. Another strand, 'Games and Sports', is concerned with developing

each student's motor skill competence and confidence in a broad range of games, sports and physical activities²¹². Thus, one of the major objectives of PDHPE today, is providing students with plenty of opportunity for physical activity, teaching basic motor skills and guiding children towards adopting an active lifestyle as adolescents and adults²¹³. As well as this, PDHPE has cognitive, social and emotional outcomes to achieve²⁰⁹.

Whilst these are all important outcomes, whether all are equally important, and whether PE has the capacity to achieve all these goals, is questionable. It has been demonstrated that physically active time during PE can be increased^{214, 215}. But, after the CATCH 2.5 year intervention, which aimed to increase physical activity in PE lessons, both types of teachers (specialists and classroom), decreased the lesson time spent conducting skill drills²¹⁴.

Recent Australian research has shown that motor skill development is lacking in many primary school PE programs^{216, 217}. At the same time, the emphasis on motor skill development in the learning outcomes listed in the National Association for Sport and Physical Education (U.S) 1995, has been criticised for being based on limited evidence associating motor skill proficiency with subsequent physical activity participation²⁰⁶.

While this critique was an accurate reflection of available evidence at that time²⁰⁶, PASS adds weight to these recommendations. It is worth noting that MIGI has been cited²⁰⁶ as an example of a program demonstrating there is no relationship between motor skills and physical activity since MIGI improved motor skills but not physical activity levels⁴⁹. Yet the MIGI program was not designed to determine the association between motor skills and physical activity. In MIGI, physical activity levels were measured within physical education lessons²¹⁸. It could be argued that how active a child is in a lesson is outside the control of the child and more dependent upon the teacher and nature of the activity than actual motor skill ability, and therefore not a suitable way to test the association between motor skill ability and physical activity.

The PASS findings that object control proficiency is a crucial determinant of subsequent physical activity, suggest it is important that providing an opportunity to be physically active should not become the sole priority of PE classes at the expense of motor skill development. Indeed, findings from the PASS suggest that motor skill development needs to be a key focus of physical education programs in primary schools. This does not have to be at the expense of physical activity goals for PE, but rather, can be structured in a way that allows motor skill development to be enhanced in a context of physical activity.

The Sports Play and Active Recreation for Kids (SPARK) six month intervention attempted to increase skill development in an active manner by structuring each PE lesson into two parts; health-fitness and skill-fitness ²¹⁹. This was achieved, with children in the two SPARK intervention groups (specialist PE teachers and classroom teachers with substantial training) more skilled and fitter than control children after the intervention ²¹⁹. Therefore the future challenge in PE is to focus on improving motor skill proficiency whilst helping children to achieve public health physical activity recommendations. But classroom teachers, as opposed to trained PE teachers, may not be able to incorporate public health demands in PE due to being unskilled and in many cases unwilling ²²⁰. As many classroom teachers do not feel confident or competent to teach motor skills ²²¹, staff should be provided with professional learning opportunities in the teaching of motor skills and should also be adequately trained in pre-service education. Teachers need to be able to detect and correct errors in performance and provide skill specific feedback so students can learn and improve.

All the skills assessed in the PASS are considered 'fundamental' ¹¹¹. Yet, 1 in 10 students had not mastered these skills by adolescence. In particular, girls were much less skilled in performing the overhand throw and kick; even by adolescence. So, girls may need to be provided with quality instruction and opportunities to practise these skills. Students may need to be separated (by gender or by high and low skill) and taught in an environment that is conducive to skill building. Activities on offer should appeal to girls' interests.

There may even need to be 'remedial' physical education in high school for those students that have not mastered fundamental skills.

Finally, the teaching of FMS should ensure children's self-esteem is enhanced and levels of perceived skill competence developed amongst all students. That is, students need to be taught skills in a non-competitive, non-threatening and supportive learning environment where all children have an opportunity to receive positive reinforcement, encouragement and success.

6.4 Future Research Directions

The PASS has explored motor skill proficiency as a potential determinant for physical activity behaviour and fitness levels. This relationship could also be viewed in the reverse direction. For example, participation in physical activities as a child could contribute to better object control skill development, and therefore the reason object control proficiency predicts subsequent physical activity is due to the more skilled children being more active children to start with. This could not be tested in the PASS because physical activity participation and fitness levels were not assessed in childhood. We are currently considering future research using the PASS dataset that would investigate this directional relationship by constructing a structural equation model that uses the adolescent physical activity participation and fitness level data to explain adolescent object control skill proficiency. Whilst this would be a cross-sectional model and not allow a cause and effect statement to be made, it would further help to explore the directional relationships between object control proficiency and physical activity.

It is likely that a circular relationship exists, in that object control proficient children are more physically active and that this in turn promotes more skill proficiency. This relationship also may work in this way for fitness. Figure 11 illustrates these relationships for both physical activity and fitness separately.

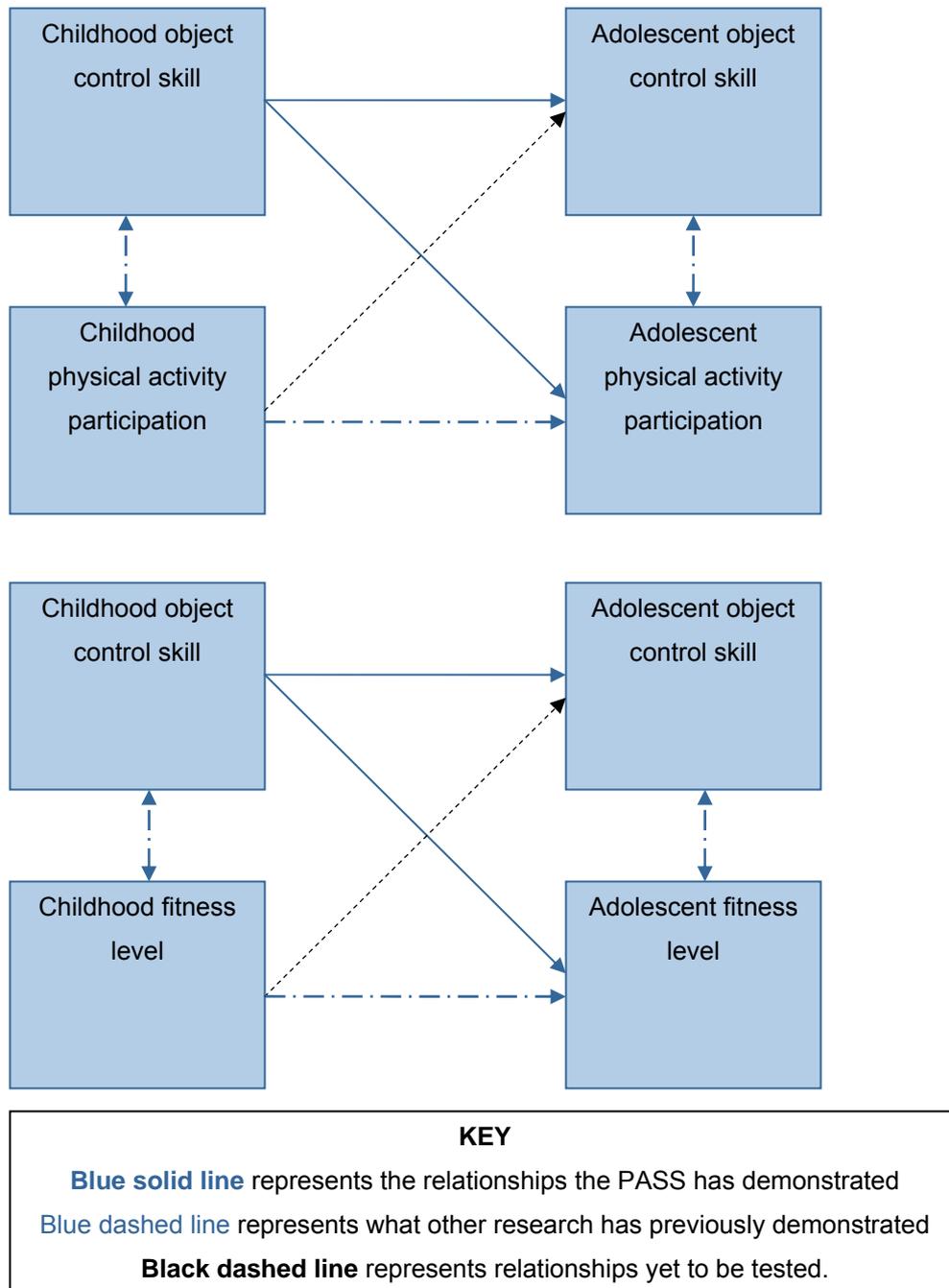


Figure 11: The potential bidirectional relationships between object control skill and physical activity and fitness, respectively

These relationships could also be viewed with the addition of perceived sports competence, with the cause and effect relationships between 1) childhood physical activity and adolescent object control proficiency and 2) between childhood perceived sports competence and adolescent physical activity participation and 3) between childhood perceived sports competence

and adolescent perceived competence and 4) between adolescent perceived sports competence and adolescent object control skill; yet to be tested. Figure 12 illustrates these potential relationships after the addition of perceived sports competence.

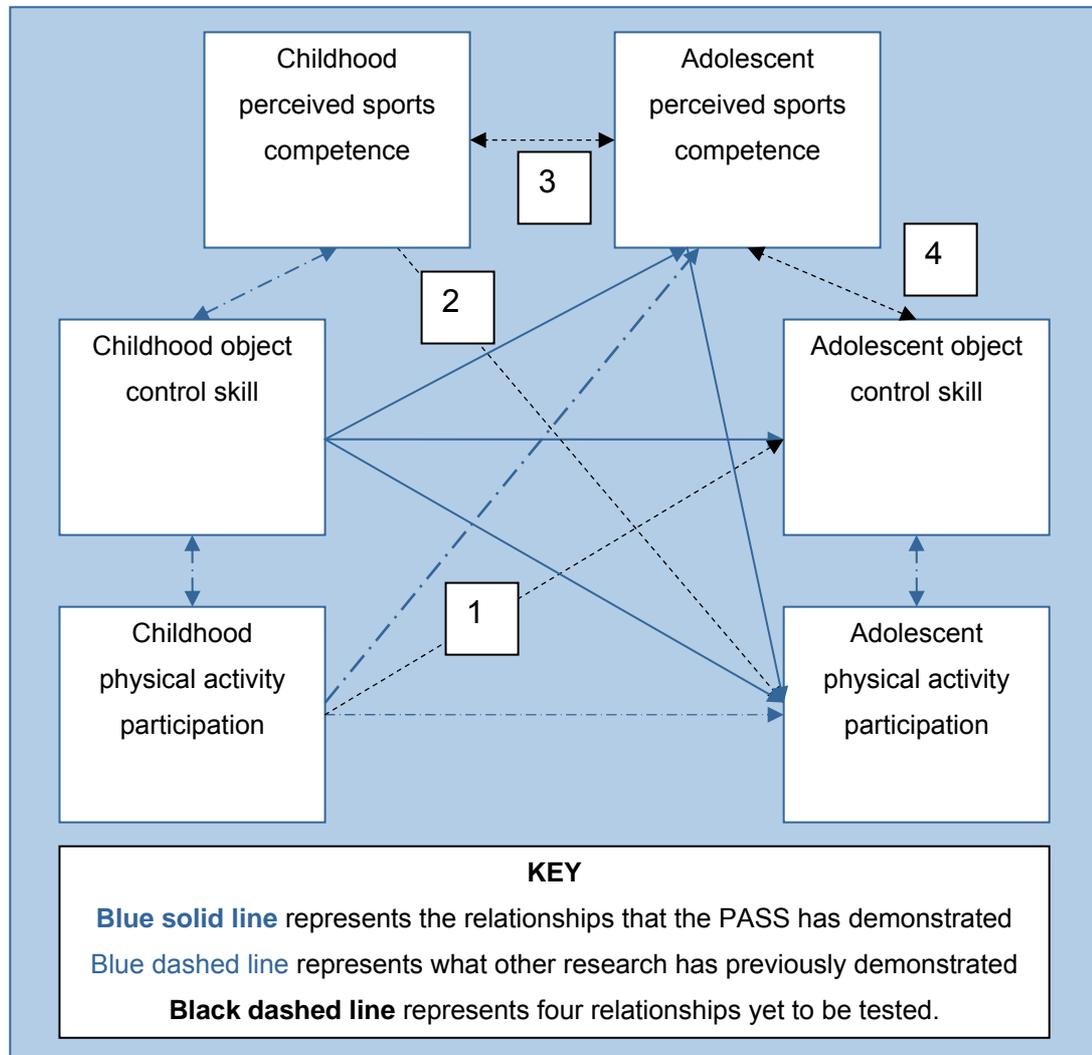


Figure 12: The potential relationship between childhood object control proficiency and adolescent object control proficiency and physical activity after the inclusion of adolescent perceived sports competence

A conceptual model has recently been proposed, from evidence drawn from cross-sectional studies, in which motor skill proficiency is seen to contribute to subsequent physical activity by way of perceived motor competence and fitness²⁰⁵. The model, described as unique²⁰⁵, is similar to that developed and tested in the PASS, but it also describes circular ‘reverse directional’

relationships between the constructs as discussed in Figures 9 and 10. There is seen to be a dynamic and reciprocal relationship between physical activity, motor skill competence, perceived motor competence and physical fitness which impacts on obesity²⁰⁵. Over time, a positive spiral of engagement is seen to produce higher motor skill, higher activity, higher perceived sports competence and higher fitness therefore promoting lower weight²⁰⁵. The longitudinal evidence from the PASS is consistent with this proposed model, with future research needing to confirm the reverse directional relationships.

More research is needed to further understand the role of object control versus locomotor proficiency in physical activity participation and fitness. More research is also needed with objective measures of physical activity, and other tests of fitness, to investigate the different strength of the relationship between motor skill proficiency and physical activity as compared to fitness. Because of the many different instruments and ways to assess all three main constructs assessed (physical activity, fitness and motor skills) it is hard to compare and understand findings.

In general terms, more longitudinal research is needed to simply understand more about which factors in childhood help to encourage physically active behaviour in adolescence. More research on mediating factors within longitudinal relationships would be useful. Also, more interventions based on current evidence are needed to help encourage children to develop motor skills and be physically active. Furthermore, the follow-up of these interventions needs to be at longer time intervals so it can be understood not just what worked at the time, but also, and importantly, what works for the long-term.

This study has provided important evidence of an important determinant of physical activity participation and fitness; object control proficiency, and a potential mediating variable; perceived sports competence. It has also suggested that some motor skill intervention effects can remain at long-term follow-up. Hopefully the PASS findings will encourage more research to assist our understanding of the role of object control skill proficiency. As

methods of assessment continue to improve in the physical activity arena it is hoped that future research will be able to refine and discover many of the answers to the questions posed for future research.

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