Evaluating a conceptual model of physical activity engagement across the transition from primary to secondary school

by

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and

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Úna Britton

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Abstract

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Introduction: Physical activity (PA) decreases with age, and the transition from primary to secondary school is noted for significant changes in PA behaviours. Given the negative health outcomes associated with low PA this is a worrying trend. A conceptual model developed by Stodden et al. (2008) hypothesises a reciprocal relationship between PA and motor competence (MC) that is mediated by perceived competence (PC) and health-related fitness (HRF). This model has guided research in the PA domain, but to date, no longitudinal study has evaluated it in its entirety. The purpose of this thesis is to evaluate the model across the school transition to identify key pathways for positive PA behaviour.

Method: Participants were measured at three timepoints (6th class primary: n = 261, 1st year: n = 299, and 2nd year: n = 108 secondary school. Baseline age = 12.22 ± 0.48 years). Measures at each timepoint included: PA (accelerometery), MC (five object-control skills, four locomotor skills, three balance skills), HRF (20m shuttle run test, horizontal jump, vertical jump, grip strength, push-ups, curl-ups, back-saver-sit-and-reach), and PC (perceived athletic competence, perceived physical appearance, global self-worth).

Results: HRF was a stronger mediator than PC, and the MC-PA relationship was dominant in the direction of MC predicting PA. HRF was the strongest predictor of PA across the school transition. Changes in PA, MC, HRF and PC during the school transition were influenced by proximity to the transition, and differed between males and females.

Conclusion: Findings partially support the pathways depicted in Stodden et al.'s (2008) model, particularly highlighting the importance of HRF as a mediator within the model, and as a predictor of future PA. Differences between males and females exist for some of the pathways, and for changes during the school transition.

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Abbreviations

ACSM	American College of Sports Medicine
BMI	Body mass index
BP	Blood pressure
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CI	Confidence interval
cIMT	Carotid artery intima-media thickness
CRE	Cardiorespiratory endurance
CSPPA	Children’s Sport Participation and Physical Activity
CVD	Cardiovascular disease
DCDQ-A	Developmental Coordination Disorder Questionnaire for Adults
FMS	Fundamental movement skills
GSGA	Get Skilled Get Active
GSHS	Global School-Based Student Health Survey
GSW	Global self-worth
HBSC	Health-Behaviour in School-Aged Children
HDL-C	High density lipoprotein cholesterol
HRF	Health-related fitness
ICC	Interclass correlation coefficient
KTK	Korperkoordinations Test fur Kinder
LDL-C	Low density lipoprotein cholesterol
MABC	Movement Assessment Battery for Children
MC	Motor competence
MCAR	Missing completely at random
ME	Muscular endurance
MET	Metabolic equivalent
MF	Muscular fitness
MS	Muscular strength
MVPA	Moderate-vigorous physical activity
NCD	Non-communicable disease
NFI	Normed fit index

NHANES	National Health and Nutrition Examination Survey
PA	Physical activity
PAC	Perceived athletic competence
PC	Perceived competence
PPA	Perceived physical appearance
PSPP	Physical Self-Perception Profile
RMSEA	Root mean square error of approximation
SDT	Self-determination theory
SPPA	Self-Perception Profile
SRMR	Standardised root mean square residual
TGMD	Test of Gross Motor Development
TLI	Tucker-Lewis index
VPA	Vigorous physical activity
WC	Waist circumference
WHO	World Health Organisation

CHAPTER 1

Introduction

Chapter 1 Introduction

1.1 Rationale for the thesis

Over half of annual deaths worldwide are attributed to non-communicable diseases (NCDs) such as obesity, cardiovascular disease (CVD) and diabetes (WHO 2017). Physical inactivity is one of the main risk factors for developing many of these NCDs, and is associated with other NCD risk factors including high blood pressure, high blood glucose, and obesity (WHO, 2009). Many of these risk factors manifest in youth causing serious health problems in later life (May et al., 2012; Raitakari et al., 2003). Being physically active in childhood offers both immediate and long-term health benefits (Hills et al., 2011; Warburton et al., 2006). The challenge lies however in encouraging youth to engage in PA. Globally, less than 20% of youth meet the PA guidelines for health (Hallal et al., 2012). It is recognised that there are multiple factors influencing engagement in PA among youth. A prominent conceptual model developed by Stodden and colleagues includes motor competence (MC), perceived competence (PC), and health-related fitness (HRF) as pertinent factors impacting on PA engagement in youth (Stodden et al., 2008). Compared to previous PA-promotion models (Welk, 1999) which focussed primarily on socio-environmental factors and perceived competence, Stodden et al.'s (2008) conceptual model places a stronger emphasis on actual competence. Since its publication many researchers in the field of PA-promotion and MC have used the conceptual model as a guide. While to date cross-sectional studies have lent support to many of the pathways depicted in the model, longitudinal research is needed to test the predictive ability of these factors on future behaviour, and to identify how pathways may change over time. If researchers are to continue focusing on MC, PC and HRF in youth PA promotion then it is necessary to understand how these variables interact over time to promote or negate health.

1.2 Physical Activity during the Transition from Primary to Secondary School

Globally there is a trend for decreasing PA with increasing age (Cooper et al., 2015; Corder et al., 2015). The transition from primary to secondary school is a particular period where significant changes in PA behaviour have been reported (Marks et al. 2015; Jago et al. 2012; De Meester et al. 2014). Evidence suggests that PA generally decreases across the school transition (Jago et al., 2012; Marks et al., 2015), although the decrease may be more pronounced directly post transition, and may reduce as adolescents settle into their new environment (Marks et al., 2015). In Ireland, the transition occurs at approximately 12 years of age, with children moving from 6th class (final year) of primary school into 1st year of secondary school. Research evidence indicates that, regardless of the physiological changes occurring at this time with the onset of puberty, the school transition itself is a significant factor in altering PA levels (Marks et al., 2015). Cross-sectionally, Irish secondary school students have been found to be significantly less active than their primary school counterparts (Gavin et al., 2014; Woods et al., 2010). There is however no longitudinal study in Irish youth that has tracked PA across this specific transition to determine if and when a decrease in PA occurs. Longitudinal measurement of PA and associated variables, along with analysis of the changing relationships between these variables across the school transition, is needed if PA promotion strategies targeting this critical period are to be successful.

1.3 The role of motor competence

Motor competence is an individual's proficiency in fundamental movement skills (FMS) (Stodden et al., 2008). Internationally, adolescents are not reaching the level of MC that they are generally expected to be capable of (Mitchell et al., 2013; Okely and Booth, 2004). This trend is reflected in Irish youth, with many adolescents showing poor execution of basic FMS (O' Brien et al., 2015a; O'Brien et al., 2018). It is generally accepted that without these basic FMS children are less likely to be sufficiently active for health (De Meester et al., 2018), and are more likely to become inactive adolescents and adults (Lloyd et al., 2014). The primary relationship identified in Stodden et al.'s (2008) conceptual model is between MC and PA. Stodden et al.(2008) hypothesised that the MC-PA relationship is reciprocal. This means that being proficient in FMS likely increases PA levels, but that the reverse is also true - being active provides the opportunity to further develop FMS (Stodden et al., 2008). Current research has followed along these lines, and evidence supports the idea that MC is an important determinant of future PA in childhood (Barnett et al. 2009; Green et al. 2011) and into adulthood (Lloyd et al., 2014). Given the health benefits associated with PA (Hills et al., 2011; Warburton et al., 2006), and the consistently identified positive association of MC with PA (Lopes et al. 2011; Barnett et al. 2009), it is clear that MC has some role to play in promoting PA. Evidence for this hypothesised reciprocal relationship is not conclusive however. In fact, contrary to expectations, some recent research has found that even in older adolescents, PA is driving the development of MC, rather than the reverse (Jaakkola et al., 2018). Thus, a longitudinal assessment of this relationship is warranted to determine its directionality and to ensure that current PA promotion strategies focus on factors that are proven to promote activity in adolescence.

1.4 The role of HRF and PC

While MC and PA are identified as the primary factors in Stodden et al.'s (2008) model, HRF and PC are hypothesised to contribute to positive PA behaviours, mediating the MC-PA relationship. Perceived competence is an individual's belief in their ability to effectively master a task (Feltz, 1988). Perceived competence tends to be higher in younger compared to older children (Piek et al., 2006) and to decrease with age (Shapka and Keating, 2005). In fact, the school transition period has been identified as a time when PC can be hit hardest, with significant decreases in PC reported (Arens et al., 2013). There is limited research within an Irish context on levels of PC in youth either cross-sectionally or longitudinally. In the context of PA, international research supports the idea of a positive association between PC and PA (Zhang et al., 2015; De Meester et al. 2016; Davison et al., 2010). In one of the few longitudinal studies examining the mediating effect of PC on the MC-PA relationship, findings from Barnett *et al.* (2008) supported this aspect of Stodden et al.'s (2008) model, with PC acting as a mediator between childhood MC and adolescent PA. What remains unclear is whether the mediating effect is influenced by age, or the school transition in the context of the current thesis, and whether methods of PA measurement may have some impact on the nature of the relationship between PC and PA. Tracking of this relationship over time can give further insight into the developmental nature of the mediation effects identified in the model.

Health-related fitness is also hypothesised to act as a mediator between MC and PA (Stodden et al., 2008). Health-related fitness is widely accepted as consisting of five components; cardiorespiratory endurance (CRE), muscular strength (MS) and muscular endurance (ME), flexibility, and body composition (Caspersen et al. 1985). That being said, studies which examine HRF in youth frequently choose just one or two tests to represent the overall HRF construct which can be problematic if a true understanding of the relationship between HRF and other variables is desired. Internationally HRF trends show a general increase in fitness with age (Ortega et al. 2011; Santos et al. 2014) and, generally speaking, higher fitness levels are associated with higher levels of both PA (Burgi et al. 2011; Bailey et al. 2012) and MC (Stodden, 2014). While there is strong evidence linking HRF to actual health (F Ortega et al., 2008; Ruiz et al., 2009), research on the role of HRF in the context of Stodden et al.'s (2008) model, and the longitudinal impact of HRF on developing positive PA behaviours, is not conclusive (Lai et al., 2014; Robinson et al., 2015). It appears that more research is needed to further understand the nature of the relationship of HRF with PA, MC, and PC.

1.5 Summary and justification for the research

To the best of this researchers' knowledge, no previous study has examined changes in the relationships between all four variables outlined in Stodden et al.'s (2008) model over a critical period such as the school transition. With the consistently documented low levels of PA in youth, and identification of the school transition period as a time when disengagement with PA can occur, this research provides a greater understanding of how PA changes across the transition, and how MC, PC and HRF interact with PA during this time. The longitudinal nature of this research allows for causal inference, where previously causality has been hypothesised. Given the popularity of Stodden et al.'s (2008) model as a framework for directing research within the field of youth PA promotion, it is imperative that a full test of the model is carried out to support or refute hypotheses made in the model.

1.6. Aims and Objectives

The primary aim of this research was to evaluate the conceptual model developed by Stodden and colleagues (2008) from a longitudinal perspective across the transition from primary to secondary school.

Objectives:

1. To investigate the underlying factor structure of HRF in youth and develop a composite score to be used for subsequent analysis of relationships between HRF and other variables (*Chapter 3).*

2. To evaluate the role of HRF and PC in mediating the MC-PA relationship across the transition from primary to secondary school (*Chapter 4).*

3. To explore the hypothesised reciprocal relationships between MC, PA, HRF and PC across the school transition (*Chapter 5).*

4. To identify causal pathways between MC, PA, HRF and PC in 6th class and these variables in 1st year (*Chapter 5).*

5. To measure longitudinal change in MC, PA, HRF and PC from 6th class of primary school through to 2nd year of secondary school (*Chapter 6).*

1.7 Research Questions

1. Is a five component HRF composite reflective of HRF in youth, and is HRF as a concept similar in primary and secondary school?

2. Do HRF and/or PC mediate the relationship between MC and PA during the school transition, and are the relationships the same for males and females?

3. Do reciprocal relationships exist between MC, PA, HRF and PC?

4. What is the dominant direction of causality in the MC-PA reciprocal relationship?

5. Does MC, PA, HRF and PC in 6th class significantly predict MC, PA, HRF or PC in 1st year, and are these pathways the same for males and females?

6. Do PA and PC decrease across the transition from primary to secondary school?

7. Do MC and HRF increase across the transition from primary to secondary school?

1.8 Thesis Structure

The thesis consists of eight chapters. Following this introduction to the thesis, Chapter 2 will critically review the current literature on youth PA, MC, HRF and PC. Chapter 3 outlines the overall research design and method. Chapter 4 presents research on the development of a composite HRF score which is used in each subsequent chapter when analysing relationships between HRF and PA, MC and PC. Chapters 5, 6 and 7 address the primary aim of this thesis consisting of studies assessing the mediating roles of HRF and PC within Stodden et al.'s (2008) model, the reciprocal nature of the relationships, and the direction of causality between variables across the transition. The final chapter provides a general discussion of the findings and conclusion.

Chapter 1 Introduction: Describes the rationale for this research and outlines the aims and objectives of the thesis.

Chapter 2 Literature Review: Provides an overview of current literature relating to youth PA, MC, HRF and PC and synthesises what is currently known and unknown regarding pathways hypothesised in Stodden et al.'s (2008) model.

Chapter 3 Methodology: Gives an overview of the research design including participant recruitment and details, test set-up, measures, data treatment, and statistical analyses.

Chapter 4 *What is Health-Related Fitness? Investigating the underlying factor structure of fitness in youth.* Contains the first study of this thesis. This study investigated the factor structure of HRF in youth and produced a statistically proofed HRF composite which was used in subsequent studies in this thesis.

Chapter 5 *The role of health-related fitness and perceived athletic competence in mediating the physical activity-motor competence relationship during the transition from primary to secondary school.* Evaluates the role of HRF and PC in mediating the MC-PA relationship across the transition from primary to secondary school.

Chapter 6 *Predicting physical activity, motor competence, health-related fitness, and perceived competence in adolescents after the transition from primary to secondary school.* Evaluates the reciprocal relationships among each of the variables within Stodden et al.'s (2008) model across the school transition, as well as determining 6th class predictors of 1st year PA, MC, HRF and PC.

Chapter 7 *Changes in PA, MC, HRF and PC across the school transition: a longitudinal study.* Reports on the longitudinal changes in PA, MC, HRF and PC from 6th class of primary school into 1st year, and then 2nd year, of secondary school.

Chapter 8 Discussion and Conclusions: Discusses the combined findings from the literature review and the thesis to identify implications within the field of youth PA promotion.

CHAPTER 2

Literature Review

Chapter 2 Literature Review

2.1 Physical Activity

2.1.1 Physical Activity: Introduction

Physical activity (PA) is defined by the World Health Organisation as "any bodily movement produced by skeletal muscles that requires energy expenditure" (WHO, 2018b). PA is not limited to organised or structured exercise but includes any movement that is carried out while playing, working, doing household jobs, travelling, or participating in recreational activities (WHO, 2018b). Activities are often classified into four different intensities – sedentary, light, moderate, or vigorous, in accordance with the energy expenditure associated with the activity (Ainsworth et al., 2000; Ridley et al., 2008). Energy expenditure is determined by metabolic equivalent (MET) values (Jetté et al., 1990). One MET is defined as the "the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml O_2 per kg body weight x min" and are used to express the energy cost of activities (Jetté et al., 1990). MET values range from as low as 0.9METs (sleeping) to 18METs (running at 10.9mph) (Ainsworth et al., 2000). Pate et al. (1995) have used MET values to classify PA into light, moderate and vigorous intensities (Table 2.1), while more user-friendly definitions of moderate and vigorous activity are provided by (Prochaska et al., 2001) (Table 2.1).

Table 2.1 Physical activity intensities

PA Intensity	**MET value** (Pate et al., 1995)	**User-friendly definition** (Prochaska et al., 2001)
Sedentary	1 MET	N/A
Light	< 3 METs	N/A
Moderate	3-6 METs	*"usually makes you breathe hard or feel tired some of the time"*
Vigorous	> 6 METs	*"usually makes you breathe hard or feel tired most of the time"*

2.1.2. Importance of PA in youth

Non-communicable diseases (NCDs) such as cardiovascular disease (CVD), cancers, respiratory diseases, diabetes, and obesity account for over half of deaths annually (59%) and contribute to just under half (45.9%) of the disease burden globally (WHO, 2013). The top five risk factors for mortality are high blood pressure (BP) (causing 13% of deaths worldwide), tobacco use (9%), high blood glucose (6%), physical inactivity (6%), and overweight/obesity (5%) (WHO, 2009). Physical inactivity in and of itself is a risk factor for mortality globally but is also associated with three of the remaining four highest risk factors (high BP and blood glucose, and overweight/obesity) (WHO, 2009).

Evidence is growing that risk factors for CVD, diabetes, stroke, and obesity manifest in youth (May et al. 2012; Raitakari et al. 2003). In a large-scale study of US adolescents (n = 3,383) aged from 12-19 years it was found that prevalence of pre-diabetes and diabetes is on the rise (9% in 1999-2000 compared to 23% in 2007-2008) (May et al., 2012). Other CVD risk factors were also identified in this population including high BP (14% of the adolescents studied), high low-density lipoprotein cholesterol (LDL-C) (22%), and low high-density lipoprotein cholesterol (HDL-C) (15%). Close to half (43%) of the participants had at least one CVD risk factor, and an overweight/obesity prevalence of 34% was found among this cohort (May et al., 2012). The prevalence of CVD risk factors increased with weight category, with 37%, 49%, and 61% of normal weight, overweight, and obese participants respectively having at least one CVD risk factor. Having any one of these cardiovascular risk factors in childhood is strongly associated with poorer cardiovascular health in adulthood (Raitakari et al., 2003). The Cardiovascular Risk in Young Finns Study (Raitakari et al., 2003), a population-based prospective cohort study, measured CVD risk factors in participants (n = 2229) at three time points: childhood (3 – 9 years), adolescence (12 – 18 years), and adulthood (24 – 33years). Results showed that the presence of CVD risk factors in adolescence was directly and significantly related to carotid artery intima-media thickness (cIMT) in adulthood ($\beta = .017 - .032$, $p < .001$), but that risk factors measured in childhood only weakly predicted cIMT in adulthood for males ($\beta = .016 - .020$. $p < .02$) and did not significantly predict cIMT in adulthood for females (Raitakari et al., 2003). The measurement of IMT, the two inner layers of an artery, is used to assess the extent of plaque build-up in the arteries, or atherosclerosis. Atherosclerosis is a precursor to CVD and can begin in youth (Dalla Pozza et al., 2015). While it is undoubtedly worrying that risk factors can occur in such a young population, and have a serious and negative effect on CVD health in adulthood, it is important to note that in this study CVD risk factors in childhood were only weakly related to cIMT in adulthood, compared to the much stronger relationship between CVD risk factors in adolescence and cIMT in adulthood (Raitakari et al., 2003). This indicates that while risk factors may develop early in youth, if children can reduce their risk of developing these prior to, or during, early adolescence the risk of developing atherosclerosis and subsequent CVD in adulthood may also be reduced. The prevalence of these risk factors can be largely reduced through lifestyle changes (WHO, 2018b). In both adults, and youth, promoting PA has been associated with improvements in health, with PA linked to reduced BP (Warburton et al. 2006; Ekelund et al. 2012; Bailey et al. 2012), improved blood glucose levels (Kriemler et al., 2010; Warburton et al., 2006), and more favourable weight status (Silva et al. 2014; Kriemler et al. 2010; Hills et al. 2011; Bailey et al. 2012; Ekelund et al. 2012). Disease prevention programmes that target physical inactivity, then, have the potential to greatly improve health because of the additional knock on reduction in incidences of other risk factors for premature mortality.

Encouragingly, intervention studies in children and adolescents have found that improving PA levels can reduce incidence of some CVD risk factors (Kriemler et al., 2010; Meyer et al., 2006; Nemet et al., 2005). In first grade (mean age 6.9 years) and fifth grade (mean age 11.2 years) children (n = 502), a physical education intervention which increased PA and fitness levels also led to a relative decrease in CVD risk score (-14%) which combined blood glucose, triglyceride, and HDL-C levels (Kriemler et al., 2010). In obese adolescents (n = 67; mean age 14.7 years) a six month activity intervention involving swimming, walking, and games reduced CVD risk factors significantly (IMT decreased by 6.3%; flow mediated dilation increased by 127%, $p < .05$) compared to a control group (Meyer et al., 2006). Nemet et al. (2005) found short and long-term benefits from a short three month PA and dietary intervention in obese children, with significant ($p < .05$) reductions in body mass index (BMI) (-1.7 $kg.m^{-2}$), weight (-2.8 kg), body fat (-3.3%), total cholesterol (-22.3 $mg.dL^{-1}$), and LDL-C (-16.6 $mg.dL^{-1}$) in the intervention (n = 24; mean age 10.9 years) compared to a control group (n = 22; mean age 11.3 years) immediately post intervention. A significant increase in habitual PA (+23.2units, p < .05) and cardiorespiratory endurance (CRE) (+161s in treadmill endurance time; $p < .05$) was also found post intervention in the intervention group compared to the control group (Nemet et al., 2005). Encouragingly, benefits sustained in the three-month intervention carried over to a one-year follow-up, where those who had been in the intervention group still displayed reduced presence of CVD risk factors compared to the control group. Importantly, there remained a significant increase (9.1 units, $p < .05$) in habitual PA in the intervention group compared to a non-significant decrease in habitual PA (7.3 units) in the control group (Nemet et al., 2005). Despite these positive findings, low numbers of young people are engaging in adequate PA for health (Borraccino et al., 2009), and encouraging youth to be physically active in their daily lives remains a significant challenge.

While there has been a focus on PA as a means for reducing CVD risk factors in youth, research has not conclusively stated whether it is PA per se, or improved HRF as a result of a sufficient level and intensity of PA, which elicits a reduction in CVD risk. The Muscatine Study which tracked children (n = 125; mean age at baseline 10.5 years) for five years found that changes in PA were not associated with CVD risk factors measured in this group (waist circumference, height/weight ratio, skinfold thickness, blood lipids and lipoproteins, and BP) (Janz et al., 2002). Instead, maintaining or improving HRF, specifically cardiorespiratory endurance (CRE) (r = -.21 to -.27) and muscular strength (MS) (r = -.21 to -.32) were more favourably associated with CVD risk factors at the end of the study (Janz et al., 2002). In saying that, the authors highlighted that while there was no association between PA and CVD risk factors, the subjective nature of the self-report measures used (interview and 3 Day Sweat Recall) may have led to a misclassification of participants regarding PA, compared to the classification of participants by HRF where objective measures (cycle ergometer VO_{2max} test and handgrip strength test) were used (Janz et al., 2002). It was also acknowledged that HRF test performances are the result of a combination of an individual's general activity levels, genetics, and lifestyle factors, whereas PA is a less complex variable (Janz et al. 2002). Therefore, it is more likely that a complex trait like HRF will have more of a bearing on cardiovascular health compared to a simple trait like PA (Janz et al., 2002). While PA may not be directly associated with improved cardiovascular health in this study, it may be that where PA is at a sufficient intensity to increase HRF, PA can lead to the maintenance, or improvement of CV health in young people.

2.1.3 PA guidelines

International guidelines for PA are in agreement that children and adolescents should engage in at least 60 minutes of moderate-vigorous PA (MVPA) per day, and should include muscle and bone strengthening exercises and flexibility exercises in their PA (Department of Health Physical Activity Health Improvement and Protection, 2011; U.S. Department of Health and Human Services, 2008; World Health Organization, 2010). The American Heart Association recognises the importance of sufficient PA for children to reduce the risk of atherosclerotic CVD which can begin in childhood, and recommends at least 60 minutes of MVPA on a daily basis for children and adolescents (Kavey et al., 2003). The Irish guidelines reflect the consensus internationally with current PA guidelines in Ireland recommending at least 60 minutes of MVPA per day for children and adolescents, with bone and muscle strengthening exercises and flexibility exercises included at least three times a week (Department of Health and Children: Health Service Executive, 2009).

2.1.4 Measurement of PA

PA can be measured by self-report using diaries, logs and recall questionnaires, or by objective measures using devices such as accelerometers and pedometers (Warren et al. 2010). Recall questionnaires are the most frequently used tool for assessing population PA levels (Helmerhorst et al., 2012). Numerous PA questionnaires are available to the researcher each varying in length and content. At one end of the spectrum, questionnaires are available that use just one or two items to report the number of days participants have met the PA guidelines in the preceding week (Milton et al., 2011; Prochaska et al., 2001), while at the other end, questionnaires can require the participant to give a detailed breakdown of the type, time, and intensity of their PA over 15-30minute time periods across a certain number of days (Plowman and Mahar, 2013; Weston et al., 1997). Self-report questionnaires are a relatively inexpensive and easy method of measuring PA in a large sample (Warren et al., 2010), and are widely used in large population-based studies in youth (Health Behaviour in School-Aged Children, HBSC 2017; Gavin et al. 2014; Woods et al. 2010). There are however recognised limitations when using self-report measures of PA including problems identifying frequency, duration and intensity of PA, as well as bias of respondents' answers, difficulty in correctly remembering PA, and difficulties in capturing all domains of PA (Sallis and Saelens, 2000). A recent review of self-report PA questionnaires in children and adolescents concluded that most widely used assessment tools lack conclusive reliability and/or validity ratings (Hidding et al., 2018). Objective measures of PA can address some of the problems associated with self-report PA assessment. Accelerometry is one such method which has widespread use in research among youth in the PA domain across a wide range of ages and in cross-sectional, intervention, and longitudinal studies (O' Brien et al. 2015; Barnett et al. 2015; Crane et al. 2015; Burgi et al. 2011; Jago et al. 2012; De Meester et al. 2011). Accelerometers are worn by participants and measure movement by monitoring acceleration of the body in one, two, or three planes of movement, depending on the accelerometer model (Chen and Bassett, 2005). Accelerometery is a more expensive method of measuring PA than self-report questionnaires, but can rule out some of the issues associated with subjective measurement (Warren et al., 2010). While accelerometery is an objective measure of PA, there are limitations. Capturing PA in predominantly upper body movement, or during activities like cycling, is often problematic (Warren et al., 2010) and many accelerometers cannot be worn in the water or during contact sports. In addition, subjective decisions need to be made regarding the selection of wear-time validation settings for including or excluding participants, as well as specific cut-points from which to define PA intensities (Toftager et al., 2013). Researchers often have to rely on a combination of both objective and self-report measures to capture as valid a picture as possible of participants' PA.

2.1.5 Current trends

It is estimated that 80.3% of 13 – 15 year olds globally do not meet the PA guidelines of 60 minutes MVPA per day (Hallal et al. 2012). Data from two of the most comprehensive international surveys of youth (HBSC and Global School-Based Student Health Survey (GSHS)) were used to document and graph current PA levels among 13-15 year olds across 122 countries (Fig. 2.1; Hallal et al. 2012). With regard to common patterns seen in PA participation worldwide, girls consistently report lower PA levels than boys (Borraccino et al., 2009; Cooper et al., 2015; Hallal et al., 2012). Research examining PA behaviours among youth, are in agreement with these global PA reports, with girls significantly less active than boys (Barnett et al. 2009; Green et al. 2011; Barnett et al. 2008; Cantell et al. 2008).

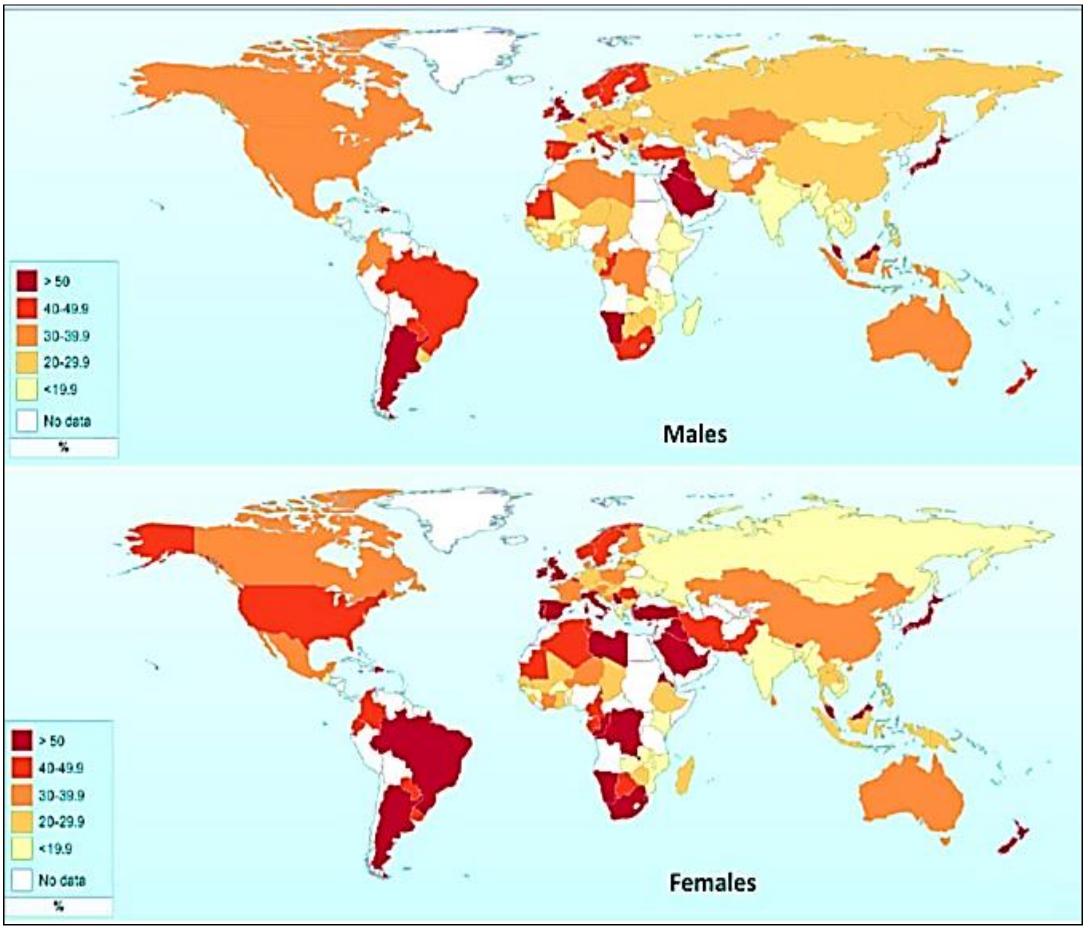


Figure 2.1 Percentage of 13-15-year olds not meeting PA guidelines (Hallal et al. 2012)

Globally, there is also a trend for decreasing PA with increasing age (Borraccino et al., 2009; Cooper et al., 2015; Corder et al., 2015; Nader et al., 2008). Accelerometer data from 27,637 participants (aged 2.8 – 18.4 years) showed that, cross-sectionally, for every year after the age of 5 years, there was a 4.2% decrease in PA (Cooper et al., 2015). Self-report PA data on the average number of days per week which youth reached the recommended guidelines, collected from 11, 13 and 15 year olds (n = 153,028) across 32 countries, found a consistent trend for lower MVPA in 15 year olds compared to 13 and 11 year olds (Borraccino et al., 2009). At each time point boys reported higher PA levels than girls (4.13 ±1.95 days vs 3.52 ± 1.88 days; $p < 0.001$) (Borraccino et al., 2009). In a sample of British children (n = 2,064; mean age at baseline 10.2 years) it was found that accelerometer-measured MVPA decreased (-10.3%) and was replaced by sedentary activity (+10.2%) as children entered adolescence (Corder et al., 2015). Similar to other studies girls were less active than boys at all time points (Corder et al., 2015). The decrease in MVPA was more dramatic in boys than girls however, probably due to the higher starting level of MVPA in boys (45.3 ± 12.0 versus 53.2 ±1 3.9 minutes) (Corder et al., 2015). Nader *et al.* (2008) monitored changes in accelerometer-measured MVPA in youth (n = 1,032) in the USA from nine years of age to fifteen years of age to determine trends in youth meeting the PA guidelines. They identified that MVPA decreased as children aged, with weekday daily MVPA decreasing by 38 minutes per year, and weekend day MVPA decreasing by 41 minutes per year (Nader et al., 2008). This study also estimated the age at which individuals dropped below the recommended level of PA. Girls fell below the recommended PA level at a younger age than boys (13.1 and 14.7 years respectively) (Nader et al., 2008). At nine years of age children were participating in approximately three hours a day of MVPA on both week days and weekends. By the time these participants reached fifteen years of age, they were participating in just 49 minutes and 35 minutes on weekdays and weekend days, respectively (Nader et al., 2008). There is a trend for decreasing PA with increasing age and many children and adolescents are not meeting PA guidelines. What have not been extensively explored in a longitudinal setting are the factors that lead to this substantial decrease in PA (Corder et al., 2015; Nader et al., 2008).

The school transition period, from primary to secondary school, has been identified as a specific period where substantial changes in PA behaviour often occur (De Meester et al., 2014; Inchley et al., 2008; Marks et al., 2015). This school transition occurs at approximately 12 years of age in many countries, including Ireland. In Australia, school children transition from primary to secondary education between the ages of 11 and 13 years. Some youth continue into secondary education in the same school as they completed primary education in, while others move to a new school environment (Marks et al., 2015). Significant reductions in accelerometer-measured MVPA (-4 minutes) and light PA (-23 minutes) along with a significant increase in sedentary time (+16 minutes), have been reported post school transition in Australian children (n = 249; Marks et al. 2015). Comparing PA changes at the time of the transition between children who moved school and those who continued into secondary in the same school environment, Marks et al. (2015) found that changing school environment independently and negatively impacted PA behaviours such as activity intensity at break times and cycling to school (Marks et al., 2015). This suggests that the school transition may be a period during which PA behaviours in youth change, independent of the significant physiological changes that occur about this time with the onset of puberty. Other studies measuring PA pre and post school transition have also reported significant changes in PA. Jago, Page and Cooper (2012) measured changes in accelerometer-measured PA in British youth (n = 932; mean age range at final year of primary school: 10 – 11 years) across the transition from primary to secondary school and found that mean after-school MVPA decreased in boys (-16%) and girls (-12%) after the transition. Contrary to the general trend for decreasing PA with increasing age however, it was found that weekend MVPA showed a mean increase in both boys and girls (+24% and +17% respectively) (Jago et al., 2012). Similar to the majority of research in this area, participants in this study were not achieving the recommended PA guidelines of 60mins MVPA per day pre- or post-school transition (Jago et al., 2012). De Meester et al. (2014) reported changes in PA behaviour of Belgian children (n = 420; mean age at baseline = 11.1 years; mean age at follow post school transition = 13.4 years) two years post-transition into secondary school. Again, contrary to the expected trend of decreasing PA with age, a significant increase in self-reported active transport was seen ($\beta = 5.84$, $p < .001$) in this sample (De Meester et al., 2014). Significant reductions in self-reported total PA ($\beta = -8.90$, $p < .01$) and extra-curricular PA ($\beta = -10.52$, $p < .001$) were also seen at follow-up (De Meester et al., 2014). Whether or not PA level decreased in participants was related to how active they were in primary school. Youth who were highly active and met the PA guidelines in primary school had a significant decrease in PA as they moved into secondary school, while youth who were low active in primary school showed little change in PA but remained relatively inactive. That is not to say that having high PA at a young age is a negative, rather those that engage in more PA at a young age are likely to see bigger decreases when the trend of decreasing PA occurs, compared to children who do very little PA.

In some countries, the transition period from one school to the next occurs earlier in childhood, or later into adolescence. A study on Iranian youth (n = 883; mean age baseline = 14.37 years, mean age follow-up = 16.42 years), where school transition occurs later in adolescence, found that self-reported PA decreased significantly in both males and females (53.75 versus 44.70 minutes in males; 31.82 versus 23.07 minutes in females) after the transition (Taymoori et al., 2011). In the USA, where the elementary- to middle-school transition takes place at a younger age, a significant decrease in PA was seen one and two years post-transition (n = 612; mean age at baseline = 10.6 ± 0.5 years), with the decline in PA greater immediately post-transition (Lau et al., 2017). Differences in the reported effects of the school transition on PA in youth may be related to the proximity of the follow-up measure to the transition. If the school transition has a significant impact on PA it may be more pronounced immediately post-transition, and may attenuate as adolescents adjust to a new environment (Marks et al., 2015). Thus, to gain a better understanding of how the school transition may affect PA throughout secondary school it is necessary to track PA across the transition, and then further into secondary school, rather than just immediately post-transition.

To the best of this researcher's knowledge, no Irish study has looked specifically at changes in PA across the primary to secondary school transition. That being said, research on Irish youth points to a similar trend in PA to that reported internationally, with older youth less active than younger, and a decrease in PA with increasing age. Cross-sectionally, the Children's Sport Participation and Physical Activity Study (CSPPA; Woods et al. 2010) reported that only 19% of Irish 10-12-year olds (n = 5,397) reported meeting the recommended PA guidelines. Even more worryingly, this percentage decreased to just 6% in 16-18-year olds (Woods et al. 2010). In keeping with global trends, fewer girls than boys reported meeting the PA guidelines at both primary (13% vs 27% respectively) and secondary (9% vs 15% respectively) school (Woods et al., 2010). Ireland's Report Card on PA in Children and Youth (Harrington et al., 2016) gave a score of D for PA, with grades indicating the proportion of children that are succeeding in a particular criteria; A = 81-100%, B = 61 – 80%, C = 41 – 60%, D = 21 – 40%, F = 0-20%) (Harrington et al., 2014, 2016). According to the HBSC, PA levels in Ireland decreased in both boys and girls (n = 13,611) between 11-15 years of age (Gavin et al., 2014), reflecting international trends (Borraccino et al., 2009; Corder et al., 2015). At age 11 years 31% of Irish girls and 45% of Irish boys reported taking part in at least 60 minutes of MVPA per day (Gavin et al., 2014). This dropped significantly to 9% and 25% for girls and boys respectively once they reached 15 years of age (Gavin et al., 2014). Evidently, both nationally and internationally there is a trend for decreasing PA with increasing age, which may be accentuated at specific periods in an individual's life, such as the school transition period. Studies have found that PA level in childhood is associated with PA level in adolescence, and that individuals who have high PA in childhood are more likely to maintain a higher level of PA into adolescence (Jaakkola and Washington, 2012; Lloyd et al., 2014). Therefore, it is important to understand the various factors that lead to a child being active or inactive, and how they change over time.

2.1.6 PA: Summary

In summary, PA is a fundamental element of health. Insufficient PA is linked with CVD risk factors in youth, and the development of both CVD and its risk factors in adulthood (Warburton et al. 2006; Ekelund et al. 2012; Bailey et al. 2012; Kriemler et al. 2010; Silva et al. 2014;Hills et al. 2011). Irish and international guidelines advise children and adolescents to participate in at least 60 minutes of MVPA per day for health (U.S. Department of Health and Human Services 2008; World Health Organization 2010; Department of Health Physical Activity Health Improvement and Protection 2011; Department of Health and Children: Health Service Executive 2009). As it stands, very few youth are meeting these guidelines in Ireland (Woods et al. 2010; Harrington et al. 2014), or around the world (Borraccino et al., 2009; Hallal et al., 2012), and the problem only worsens as children get older, with a global trend of decreasing PA with increasing age reported (Borraccino et al., 2009; Corder et al., 2015; Gavin et al., 2014).

2.2 Motor Competence

2.2.1 Motor Competence: Introduction

Motor competence (MC) is a concept that has gained attention recently because of its positive association with PA (D'Hondt et al., 2014; Saunders, Bremer, & Tremblay, 2014). The following section will give an overview of the current research on MC, its importance in youth, current national and international trends, expectations of MC levels in youth, and common measurement tools for assessing MC.

Motor competence (MC) is a global term generally used to describe goal-directed movement that requires coordination of the body (Cattuzzo et al., 2014). An important aspect of MC is proficiency in fundamental movement skills (FMS) (Stodden et al., 2008), with FMS seen as the basic building blocks required for future PA engagement (Clark and Metcalfe, 2002). Gallahue and Ozmun (2012) identified three categories of FMS that make up MC: locomotor, stability, and manipulative skills. Locomotor skills encompass skills such as running, jumping, hopping and skipping. Stability skills are those which require static or dynamic balance, such as standing on one foot, or zig-zag hopping. Manipulative skills are often referred to as object-control skills and include kicking, catching, throwing, and striking (Gallahue and Ozmun, 2012).

2.2.2 Importance of MC in youth

Developing MC to a sufficient proficiency at a young age has far-reaching consequences (D'Hondt et al. 2014; Lloyd et al. 2014). Being deficient in MC in childhood can negatively impact on PA in adolescence (Barnett et al. 2009; Green et al. 2011) and into adulthood (Lloyd et al., 2014), and as highlighted previously in this review, low levels of PA can in turn have serious negative health consequences for youth in the short and long-term

(Warburton et al. 2006; Ekelund et al. 2012; Bailey et al. 2012; Kriemler et al. 2010; Hills et al. 2011).

Individuals with lower competency in motor skills have been shown to be at risk of low levels of PA (Barnett et al., 2009; Lloyd et al., 2014; Lopes et al., 2011). In young children (n = 285; mean age at baseline = 6 years) MC at age 6 was a significant predictor of PA over the course of a five year longitudinal study (Lopes et al., 2011). Those in the lowest tertile of MC at age 6 had the greatest decline in PA during childhood (2.58 units/year), while children in the highest MC tertile at age 6 maintained a stable level of PA (Lopes et al., 2011), even in the face of the global trend of decreasing PA with increasing age (Borraccino et al., 2009; Corder et al., 2015; Nader et al., 2008). Interestingly, PA levels across three categories of MC (low, medium, and high competency) were not significantly different at age 6, yet by age 10 there were significant differences in PA between groups in favour of children who were more competent in motor skills at baseline (Lopes et al., 2011). This indicates that the negative consequences of low MC in childhood may not be apparent immediately, but may manifest later in childhood. Barnett *et al.* (2009) also found an association between childhood MC and adolescent PA, but only for object-control skills. Children (n = 276) who were more proficient in object-control skills at age 10 were 10-20% more likely to report participation in vigorous PA (VPA) at age 16 than their lower competent peers (Barnett et al. 2009). Lloyd et al. (2014) conducted a 20-year longitudinal study that followed participants from childhood (age 6) to adulthood (age 26) and measured MC and PA at four time-points. At age 6, MC was assessed using the Test of Gross Motor Development (TGMD)-II. Children (n = 100) were identified as being either low ($\leq 10^{th}$ percentile) or high ($\geq 84^{th}$ percentile) MC (Lloyd et al., 2014). A five-year follow-up with these participants (n = 60) found that children who had been identified as low MC at age 6 continued to score lower in MC (TGMD sum of raw scores; 36.50 ± 2.12 versus 40.75 ± 2.96, $p < .01$) and reported lower levels of PA than children who had been identified as high MC. Subsequent follow-up studies on these same participants found lower levels of PA in the low MC group at ages 16 (n = 43) and 26 (n = 17) (Lloyd et al. 2014). The 20-year follow-up study required participants (n = 17) to re-call their MC at age 16, and to report their current MC at age 26, using the Developmental Coordination Disorder Questionnaire for Adults (DCDQ-A; Cantell et al. 2008). The DCDQ is used to screen children for Developmental Coordination Disorder (Wilson et al., 2000), a medically recognised movement disorder which affects 5-6% of school-aged children (American Psychiatric Association, 2013). The DCDQ-A is an adult version of the questionnaire. The self-report and recall method of measuring MC at age 16 and 26 casts some uncertainty over the 10- and 20-year follow-up MC scores due to the questionable ability of individuals to correctly self-report for ten years prior, however, there are no available MC tests validated for use with adolescents and adults. Interestingly, from a long-term health and PA maintenance perspective, in results obtained from the adult part of this research, not only were adults who were identified as high MC in childhood reporting higher levels of MVPA in adulthood (62.73 ± 57.64minutes vs 31.67 ± 60.14minutes for low MC group) but those high in locomotor skill proficiency at age 6 also reported higher levels of active transport at age 26, and lower levels of time spent in a motor vehicle (Lloyd et al., 2014).

Increasing PA and decreasing sedentary time has numerous health benefits (Warburton et al. 2006; Ekelund et al. 2012; Bailey et al. 2012; Kriemler et al. 2010; Hills et al. 2011). The fact that MC at a young age may have such an effect on future PA behaviour (Lloyd et al., 2014) demonstrates the importance of developing MC in youth for the purpose of maintaining sufficient levels of PA for health (Lopes et al. 2011; Barnett et al. 2009; Lloyd et al. 2014; Green et al. 2011). For young girls in particular, who are consistently found to have lower levels of PA than boys (Hallal et al. 2012; Borraccino et al. 2009; Corder et al. 2015; Woods et al. 2010; Harrington et al. 2014; McKenzie et al. 2002; Barnett et al. 2009; Green et al. 2011), developing MC at a young age may promote engagement in PA and protect against the significant decrease in PA seen in adolescence (Woods et al. 2010; Kelly et al. 2015). In a cross-sectional study, Okely et al. (2001) found that improving MC in girls (n = 465) so that they entered the next highest quintile of MC than the one they currently inhabited, would result in a 50 minute per week increase in time spent in organised sport (Okely et al., 2001).

These longitudinal studies have highlighted the association between MC in childhood and PA in adolescence (Barnett et al. 2008) and adulthood (Lloyd et al. 2014), and have identified MC as factor that may, for young girls particularly, enhance the likelihood of PA participation over time. It is important to note however that, contrary to most of the research examining MC and its effect on PA, some longitudinal studies have not found childhood MC to predict later PA (McKenzie et al. 2002; Green et al. 2011). Green et al. (2011) found that childhood MC predicted later PA in boys, but not girls. McKenzie et al. (2002) did not find MC at age 4, 5, and 6 years to predict PA at age 12 years in either boys or girls (n = 207). The method of MC assessment may go some way to explaining why childhood MC did not predict PA at age 12 in this study, with only one skill for each component of MC included (balance on one foot (stability), jumping laterally (locomotor), catching a ball (object control). The authors also noted that MC assessment in childhood was carried out prior to entry into school and organised sport (McKenzie et al. 2002). According to Gallahue & Ozmun (2006), children have the developmental potential to proficiently execute the basic components of most FMS by the age of six; however, MC is not innate, but rather must be learned (Hardy et al., 2010). From the age of about six years children are more likely to be exposed to PA and organised sport through both school and sports club involvement, providing opportunities to enhance MC (Gallahue & Ozmun, 2006). Participants in McKenzie et al.'s (2002) study may not have had this opportunity due to their young age (age range 4 – 6 years). Results from this study indicate that just because a child may have low MC at a very young age, does not mean they cannot develop MC given the opportunity (i.e. in school/organised sport), and consequently avoid the reported negative effect of low childhood MC on later PA (McKenzie et al., 2002).

When considering the development of MC through childhood it is important to note that while low MC at a very young age may not have a detrimental effect on future PA (McKenzie et al., 2002), there likely is a stage by which competence in FMS needs to be achieved in order to avoid the negative consequences of low MC on later PA (Barnett et al., 2010). Haubenstricker and Seefeldt (1986) suggested a threshold of MC above which children have the skills to participate in a wide range of PA and are more likely to engage in PA. Children who are below this "proficiency threshold" may lack the skills required for many types of PA, resulting in low activity levels (Haubenstricker and Seefeldt, 1986). Recent research supports the existence of an MC proficiency barrier in children (De Meester et al., 2018). In a sample of US children (n = 361; mean age 9.50 ± 1.24 years) only 12% of children who were classified as low MC met the PA guidelines of 60mins MVPA per day (De Meester et al., 2018). To add to this problem, Barnett et al. (2010) found in their longitudinal study on MC development that, despite levels of MC increasing at a similar rate for all children through childhood, those who had low MC at age 10 never bridged the gap to their more proficient counterparts up to the age of 16. Therefore, there is evidence to suggest that there may be a need to develop MC to a high level by around 6-10 years old to promote health into adolescence and adulthood (Lopes et al. 2011; Barnett et al. 2009; Lloyd et al. 2014).

From the research, it appears that there is some association between childhood MC and later PA, and that a proficiency barrier may exist below which children are less likely to engage in adequate PA for health. What is not clear is whether the MC-PA association is age- (McKenzie et al., 2002) or sex- (Green et al., 2011) dependent, or whether the association only exists for particular components of MC (Barnett et al. 2009).

2.2.3 Expectations of MC levels in youth

Gallahue and Ozmun (2012) have identified four stages of motor development that individuals move through as they mature. These stages of motor development are age-related, although not age-determined, in that the rate at which an individual progresses through the stages will be influenced by environmental, biological and task factors (Gallahue and Ozmun, 2012). The four stages are; reflexive movement phase (4months – 1year), rudimentary movement phase (1-2years), fundamental movement phase (2-7years) and specialised movement phase (7+ years) (Gallahue and Ozmun, 2012). During the reflexive and rudimentary movement phases, a child's MC is determined by biological maturation (Barnett et al. 2016). As the child matures, improvements in MC are attributed to practice opportunities (Barnett et al. 2016). FMS are not innate and must be learned (Barnett et al., 2016; Hardy et al., 2010) but, according to Gallahue and Ozmun (2012), children have the developmental potential to proficiently execute the basic components of most FMS by the age of six or seven years. Research undertaken by the Department of Education, Victoria (1996) suggests that the basic components that make up all FMS can be mastered by the age of 9 years (Victoria Department of Education, 1996). There is a developmental expectation that MC will increase with age. In a review of correlates of MC in youth, age was the most consistent correlate reported, with increasing age associated with higher levels of MC (Barnett et al. 2016). In longitudinal studies MC tends to increase as children get older (Barnett et al. 2010; Vandorpe et al. 2012; D'Hondt et al. 2014; D'Hondt et al. 2013) and cross-sectional studies have consistently found that older children score higher in MC than their younger counterparts (Barnett et al., 2013; Saraiva et al., 2013; Spessato et al., 2013; Venetsanou and Kambas, 2011; Williams et al., 2008). That being said, recent studies examining MC in late childhood and adolescence have found that participants often do not achieve mastery/near mastery (Van Beurden et al., 2003) in many FMS at this development stage (Mitchell et al., 2013; O' Brien et al., 2015a; O'Brien et al., 2018; Okely and Booth, 2004). Therefore, while children and adolescents may have the developmental potential to proficiently execute the performance criteria of most FMS by early adolescence (Gallahue and Ozmun, 2012), numerous recent studies have documented that this is not a common occurrence.

2.2.4 Measurement of MC

Measurement of MC in youth can be either product-based or process-based. Product-based assessment is quantitative and focuses on the outcome of a movement e.g. speed, distance (Miller et al., 2007). Process-based assessment is qualitative and focuses on how the movement is performed compared to the most efficient form of the movement (Miller et al., 2007).

There are a wide array of both product- and process-based MC assessment tools to choose from when conducting research in youth (Griffiths et al., 2018). Examples of product-based assessment tools widely used in research are the Korperkoordinations Test fur Kinder (KTK: Kiphard and Schilling, 2007) and the Movement Assessment Battery for Children (MABC; Barnett, Henderson. and Sugden, 2007). The KTK (Kiphard and Schilling, 2007) has been validated for children aged 5 – 14 years (Cools et al., 2009; Vandorpe et al., 2011). It consists of four subtests (walking backwards, moving sideways, hopping for height and jumping sideways) and outcome measures are taken for each (Vandorpe et al., 2011). The KTK has been used in research to objectively assess MC in youth (D'Hondt et al., 2013; Vandendriessche et al., 2012; Vandorpe et al., 2012). Limitations of the KTK exist however, with only an overall gross MC score recorded, rather than breaking MC down into its three components (locomotor, object-control, stability). Another noted limitation of the KTK is the relatively old normative data (Cools et al., 2009). The MABC-2 (Barnett et al., 2007) is also product-based in its assessment of MC and is suitable for youth aged 3 to 16.9 years (Barnett et al., 2007). The MABC-2 has been used in research among youth across a range of ages (Fisher et al., 2005; Gísladóttir et al., 2014; Livesey et al., 2011; Vedul-Kjelsås et al., 2012a). It is used to identify impairments in MC across three skill categories – manual dexterity, aiming and catching, and balance (Barnett et al., 2007). Age-band norms are provided for each of the skill categories (3 – 6.9 years; 7 – 10.9 years; 11 – 16.9 years) (Brown and Lalor, 2009) and different tasks are included in each of the skill categories according to the participant's age (Barnett et al., 2007; Brown and Lalor, 2009). A traffic light system is used to identify individuals at risk of movement difficulties. Youth scoring at or below the 5th percentile are classified as having a significant movement difficulty. Those between the 6th and 15th percentiles are classified as at risk of movement impairment. Youth who score above the 16th percentile are regarded as unlikely to have a movement impairment (Brown and Lalor, 2009). Henderson, Sugden and Barnett (2007) have reported good test-retest reliability for the component scores (r = 0.73-0.84) and the total test scores (r = 0.80) across all age groups and good interrater reliability (ICC= 0.94-1.0). An advantage of the MABC-2 is that it assesses MC across three components, allowing for focusing on a single component of interest, without the need to complete the entire test battery. One drawback of the MABC-2, as with all product-based assessments, is that it does not identify if some components of a skill are correctly or incorrectly executed, but rather gives an overall outcome score. In addition to established product-based test batteries, some researchers have used outcome measures of skills included in process-oriented assessments as a means of objectively measuring MC (Rodrigues et al. 2016; Stodden et al. 2013; Stodden et al. 2009). In these studies, participants carried out a skill (e.g. standing long jump, throw, kick) whereby the distance jumped (standing long jump) or speed of the ball (throw and kick) was measured. This type of measurement can be useful to overcome the potential ceiling effect that can exist for older children when using some process-based assessments (Logan et al., 2016). That being said, differences between males and females, particularly in adolescence tend to be accentuated when using outcome measures such as speed or distance, due to physiological changes occurring around puberty (True et al., 2017).

Examples of process-based MC assessments used in youth research are the Test of Gross Motor Development (TGMD; Ulrich, 2016) and Get Skilled; Get Active (GSGA; NSW Department of Education and Training, 2000). The TGMD test battery is one of the most frequently used process-oriented assessments of MC in youth (Belton et al. 2014; O' Brien et al. 2013; O' Brien et al. 2015b; O' Brien et al. 2015a; Khodaverdi et al. 2015; Barnett et al. 2008). The TGMD-3 (Ulrich, 2016) is a revision of the second version of the TGMD (TGMD-2; Ulrich, 2000)), comprising 12 skills from the TGMD-2 plus one extra object-control skill, the one-hand strike (Ulrich, 2016). Thus, the TGMD-3 contains 6 locomotor skills and 7 object control skills (Ulrich, 2016). Each of the 13 skills is made up of specific movement components. MC is assessed in terms of the presence, or absence, of components that make up each skill. "Mastery" of a skill has previously been defined as the presence of all skill components in both trials, while "near mastery" is defined as the presence of all but one skill component in both trials (Belton et al., 2014; O' Brien et al., 2013, 2015a, 2015b; Van Beurden et al., 2003). The TGMD-2 has been validated in US youth aged 3 – 10 years (Ulrich, 2000). Recently, the use of the TGMD-2 among older children has been recommended with intraclass correlation coefficients of between 0.76-0.91 reported among adolescents (n = 844; mean age 12.03 ± 0.49 years) indicating good test-retest reliability (Issartel et al., 2017). Concurrent validity (total MC - r = .63; locomotor MC; r = .63;

object-control MC – *r* = .41; Ulrich, 2000) and test-retest reliability (*r* = .84 - .96; Ulrich 2000; Wong & Cheung 2010) of the TGMD-2 among children is also acceptable. A limitation noted for the TGMD test battery is a potential ceiling effect among older adolescents (Barnett *et al.*, 2016; Logan *et al.*, 2016) and the lack of skills to assess stability in the test battery (Ulrich, 2016). The GSGA comprises 12 skills (catch, overhand throw, kick, forehand strike, sprint run, leap, dodge, vertical jump, hop, side gallop, skip, and static balance), and uses a similar scoring process to the TGMD-3 , where each skill is broken down into its movement components (NSW Department of Education and Training, 2000). Participants are required to perform five trials for each skill and the presence or absence of each skill component is noted by the tester. If the participant displays a skill component in four of the five trials then this component is marked as present. The GSGA has been used in research assessing MC in youth (Barnett et al. 2008; Barnett et al. 2008; Foweather et al. 2008). Reliability coefficients were reported as greater than 0.70 for all skills included in the GSGA with the exception of the leap (*r* = .13) and the run (*r* = .17) (Okely and Booth, 2000). In comparison to the TGMD, the GSGA is useful in that it measures competence across each of the three MC components, namely stability, locomotor and object-control. While the GSGA is starting to be used more frequently outside of Australia, where it was developed, (Coker, 2018; Kelly et al., 2018) its use internationally is less frequent than other process-based assessments such as the TGMD.

In their review on correlates of MC, Barnett et al. (2016) highlighted the need for MC assessment tools that are age appropriate and have been validated in the study population. Many MC assessment methods, particularly process-measures, are designed for young children and as a result there may be a ceiling effect where age-related differences in MC in older children and adolescents are not identified (Barnett et al., 2016). While some process-based measures of MC may not be appropriate for adolescents due to the ceiling effect, product-based measures may favour size and strength as they focus on the outcome (how fast, how far etc.), rather than the process (Barnett et al., 2010, 2016). This could unfairly favour males, especially in adolescence, as post-pubertal males are stronger and faster than their female counterparts. In measuring MC, intra-individual comparisons over time, and comparisons among participants of the same sex, can be made between scores. Due to the physiological advantage pertaining to the male sex however, comparison between males and females on product-based motor competence assessments is not relevant. To address the limitations of solely product-oriented, or solely process-oriented measures, the use of both product and process measures has been recommended (Fisher et al., 2005).

2.2.5 Current trends

Lower than expected levels of MC have been reported in children and adolescents worldwide in recent years. In Australian children (n = 1,288; age range 6.2 – 8.2 years) prevalence of mastery across process-measured FMS did not exceed 35% across all ages, and prevalence of near-mastery did not exceed 50% across FMS, except balance, across all ages (Okely and Booth, 2004). Similarly, in a New-Zealand study, less than half of participants (n = 701; age range 5 – 13 years) showed competency in striking (40%), throwing (31%), or kicking (21%) at baseline (Mitchell et al., 2013).

Research has consistently reported that girls are significantly less competent in motor skills than boys (Barnett et al. 2009; Cantell et al. 2008; O' Brien et al. 2015a; Breslin et al. 2012; Lopes et al. 2011). When we consider the separate components that make up MC, girls consistently score lower in object-control skill proficiency compared to boys (Barnett et al. 2010; Breslin et al. 2012; Barnett et al. 2008). Differences between boys and girls have not been found to be as pronounced in locomotor skills. Researchers have found contrasting results when comparing boys and girls in this component of MC, with some studies finding no difference in locomotor skill proficiency level (Barnett et al., 2010), while others report girls as more proficient (Barnett et al., 2008). This is an important consideration when measuring MC among children and adolescents. As well as getting an overall score for MC, it is important to analyse each MC component (locomotor, object-control and stability) to determine differences. No difference between males and females may be reported if males score lower on locomotor and higher on object-control skills, as opposing differences may cancel each other out when looking at a composite MC score (Fisher et al., 2005).

The situation regarding MC in Irish youth mirrors that of results reported internationally. Research shows that the majority of Irish adolescents do not possess the expected level of MC, with only 11% of a sample of 12 – 13 year old adolescents (n = 242) reaching mastery, or near-mastery, across nine FMS (O' Brien et al., 2015a). Recently, similar findings in Irish adolescents (n = 219; mean age: 14.45 ± 0.96 years; O'Brien et al. 2018) have been reported, with a low proportion of youth achieving mastery or near-mastery across numerous locomotor and object-control skills (Figure 2.2). O'Keeffe et al. (2007) also reported low competence among Irish adolescents (n = 46; mean age 15.8 years) in the overhand throw. Evidently, many Irish adolescents are not proficient in FMS to the developmental level expected at this age.

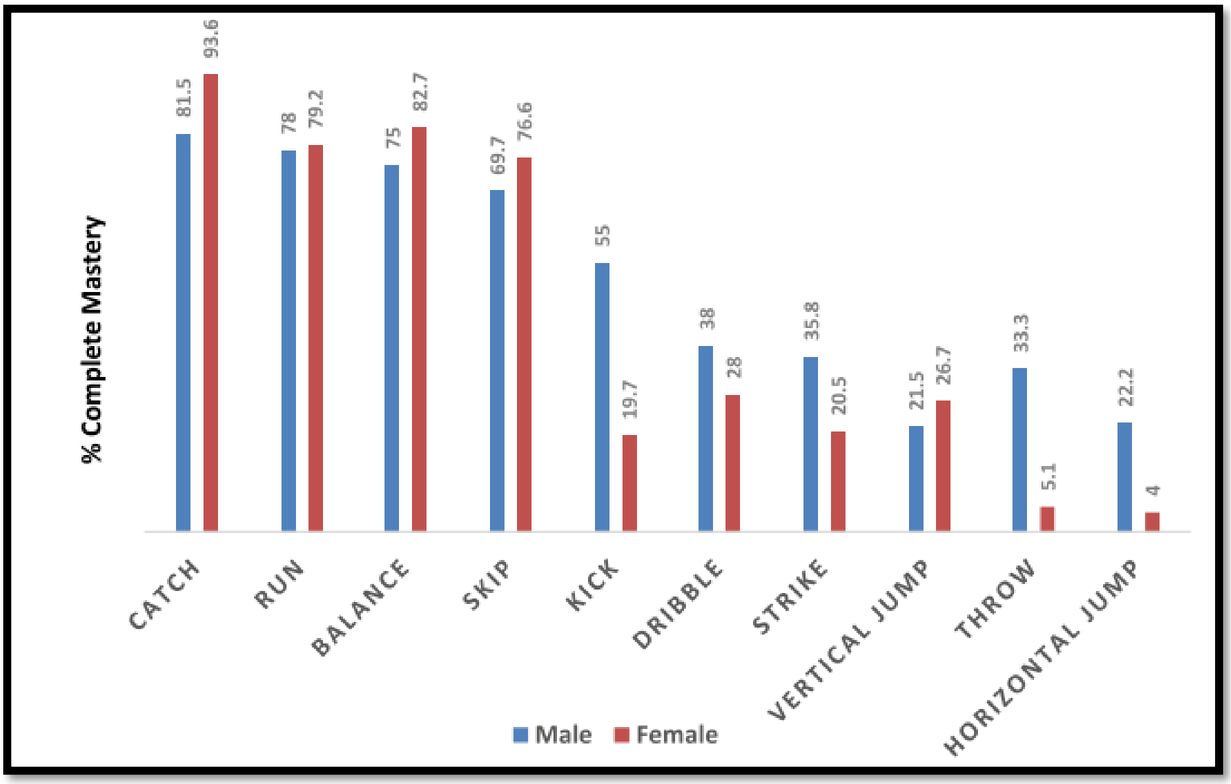


Figure 2.2 Percentage of Irish children achieving mastery in FMS (O'Brien et al., 2018)

In keeping with international trends, Irish adolescent females have significantly lower MC than adolescent males ($t(221) = 2.454$, $p < .05$; O' Brien et al. 2015a). This difference was only seen in object-control skills however ($t(221) = 3.382$, $p < .01$), with no significant differences between males and females in locomotor skill proficiency ($p > .05$; O' Brien et al. 2015a). Similar findings were reported by O'Brien et al. (2018) for a sample of Irish adolescents (n = 219; mean age = 14.45years) with males performing better than females on overall gross motor score ($p = .001$) and object-control skills ($p = .001$). Again, no significant differences between males and females were found for locomotor skills. This trend for differences in overall and object-control MC between males and females has also been documented in other countries (Barnett et al., 2010; Breslin et al., 2012). One potential explanation for such differences within an Irish context may be the type and amount of physical activities that males and females participate in. Organised sport provides individuals with opportunities to develop competency in numerous FMS. Object-control skills such as kicking, striking and catching form a large part of many of the most popular team sports in Ireland. Research in Irish youth has found that participation in both club and extra-curricular sport is higher in males compared to females (Hardie Murphy et al., 2017). In addition, across a span of five years, females were found to be significantly more likely to drop out of sports than males, and significantly less likely to take up a new sport (Hardie Murphy et al., 2017). Therefore, differences in organised sport participation between males and females may well result in a decrease in opportunities for females to develop aspects of MC, particularly object-control skills, during adolescence. To date however, no longitudinal study in Irish youth has tracked differences in MC development between males and females.

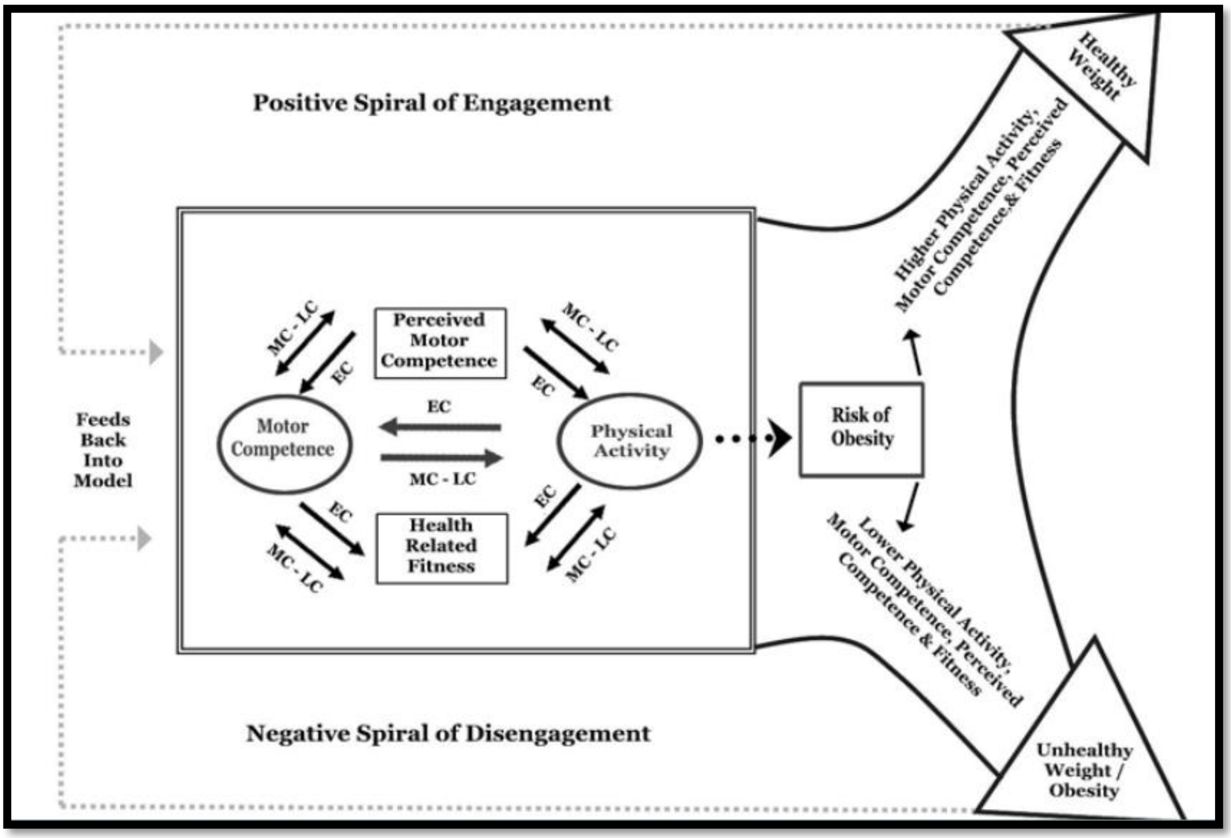
2.2.6 MC: Summary

MC refers to an individual's mastery of FMS in three categories of skill; locomotor, manipulative or object-control, and stability (Gallahue and Ozmun, 2012; Stodden et al., 2008). These FMS form the building blocks for movement and there is evidence to support the view that poor MC in childhood can lead to lower PA in later years (Barnett et al., 2009; Green et al., 2011; Lloyd et al., 2014), the consequence of which is an increased likelihood of developing risk factors for CVD and poor health (Bailey et al., 2012; Ekelund et al., 2012; Hills et al., 2011; Kriemler et al., 2010; Warburton et al., 2006). Children have the developmental potential to proficiently execute the basic movement criteria of all FMS by between 7 and 9 years of age (Gallahue and Ozmun, 2012; Victoria Department of Education, 1996). Statistics show, however, that currently a large proportion of youth are not reaching the expected level of MC on a global (Erwin and Castelli, 2008; Mitchell et al., 2013; Okely and Booth, 2004) and national (O' Brien et al., 2015a; O'Brien et al., 2018; O'Keeffe et al., 2007) stage. In a similar trend to that seen in PA, females consistently report lower levels of MC than their male counterparts (Barnett et al., 2009; Breslin et al., 2012; Cantell et al., 2008; Lopes et al., 2011; O' Brien et al., 2015a; O'Brien et al., 2018). There may be a skill category component to this trend however, with males generally scoring higher in object-control skills (Barnett et al. 2010; Breslin et al. 2012; Barnett et al. 2008; O'Brien et al. 2018) but no differences between males and females generally reported in locomotor skills (Barnett et al. 2008;O'Brien et al. 2018). What is still unclear regarding MC and its importance in relation to PA, is the extent of the influence of both age and sex/gender on how MC contributes to PA. While a large number of studies have found childhood MC to have a positive relationship with later PA (Barnett et al., 2009; Green et al., 2011; Lloyd et al., 2014; Lopes et al., 2011), in some cases, particularly among girls, and younger children, this relationship has not been demonstrated (Green et al., 2011; McKenzie et al., 2002).

2.3 Stodden et al.'s (2008) Conceptual Model

2.3.1 The MC-PA relationship

The relationship between MC and PA has been widely studied. Evidence suggests there is a reciprocal relationship between MC and PA that changes with age (Barnett et al., 2016; Jaakkola and Washington, 2012; Stodden et al., 2008). It is also recognised that the reciprocal relationship between MC and PA may be influenced by other variables. Stodden *et al.* (2008) have suggested that health-related fitness (HRF) and perceived competence (PC) play a role in mediating the MC-PA relationship, and accordingly have developed a theoretical conceptual model to depict these interacting relationships (Fig. 2.3).



EC = early childhood; MC = middle childhood; LC = late childhood

Figure 2.3 Stodden et al.'s (2008) conceptual model

This conceptual model depicts a spiral of engagement which can be either positive or negative. That is, individuals with higher actual and perceived MC are likely to be more positively inclined towards PA, and by engaging in PA may further enhance their actual and perceived MC. This positive spiral of engagement is hypothesised to promote health through the maintenance or development of a healthy weight status (Stodden et al., 2008). Stodden et al.'s (2008) conceptual model suggests that HRF and perceived MC mediate the relationship between actual MC and PA, with all of these variables combining to positively or negatively affect weight status.

One of the most frequently referenced models prior to the publication of Stodden and colleagues' (2008) model was the Youth Physical Activity Promotion (YPAP) model (Welk, 1999), which focuses specifically on children and adolescents. YPAP maintains that while factors such as actual MC and fitness may play a role in enabling PA, perceptions of competence are likely more important in promoting PA. In comparison, Stodden et al. (2008) have based their model on actual MC as a primary factor in facilitating PA engagement. Within this conceptual model the role of PC is not disregarded, rather it is included as a mediating factor, along with HRF. Recently, there is a growing focus on the role of MC in promoting PA in youth. Research examining interrelationships between variables in Stodden et al.'s (2008) model provides support for the inclusion of MC, HRF and PC within the context of youth PA promotion (Barnett *et al.*, 2008; Mitchell *et al.*, 2012; Babic *et al.*, 2014; Khodaverdi *et al.*, 2015; Robinson *et al.*, 2015). In developing their conceptual model, Stodden and colleagues (2008) aimed to integrate and link existing concepts within the field of PA promotion to facilitate an understanding of the pathways involved in youth PA engagement. Since its publication, Stodden et al.'s (2008) model has been one of the most widely used frameworks for guiding research on PA behaviours and health outcomes in youth (Robinson *et al.*, 2015; Rodrigues, Stodden and Lopes, 2016). However, to date no study has evaluated the model in its entirety. Considering its widespread use within the PA domain, it is essential to investigate the model as a whole, to support or refute the hypotheses presented by Stodden and colleagues.

The following section will provide an overview of the current literature regarding Stodden et al.'s (2008) conceptual model. Section 2.4.1. will give an overview of the MC-PA relationship, the primary relationship in Stodden et al.'s (2008) model. The developmental aspect of the relationship will first be discussed, followed by the reciprocal nature of the relationship. Current research on the stability of MC and PA over time will be presented, as well as differences between males and females in the relationship between MC and PA. Section 2.4.2 will give an overview of the proposed mediators, HRF and PC, developing the case for why they are important to adolescent health, how they have been measured to date, and current trends among youth. Current research on the direct pathways between HRF, PC, MC and PA will be presented, highlighting the existing gaps in the research relating to these pathways. Finally, current evidence for the mediating role of HRF and PC within Stodden et al.'s (2008) model will be discussed.

2.3.1.1 Developmental perspective of the MC-PA relationship

As previously outlined, MC is an individual's ability to master FMS, with FMS providing the building blocks for movement and engagement in future PA. There is evidence to suggest that childhood MC predicts adolescent (Barnett et al., 2009; Green et al., 2011) and adult (Lloyd et al., 2010) PA. So far in this review, the MC-PA relationship has been discussed focusing solely on the effect of MC on PA. Stodden et al. (2008) however have based their model on a reciprocal and developmental MC-PA relationship. That is, not only does MC influence PA, but PA also effects the development of MC, and the nature of these relationships is proposed to change with age.

This developmental perspective taken by Stodden et al. (2008) is a salient part of the conceptual model. Rather than assigning a fixed relationship between MC and PA to all ages, Stodden et al. (2008) address the way in which the relationship between MC and PA may change as children grow up, along with the potential influences of the key mediating variables (HRF and PC). This is significant because research has shown that many of the variables in the conceptual model are affected by a child's developmental stage (Gallahue et al., 2012; Harter 1978, cited in Horn 2008; Harter 1982). Stodden et al.'s (2008) conceptual model hypothesises that the MC-PA relationship will strengthen over time. That is, while the relationship between MC and PA may be only weak or moderate in early childhood, Stodden et al. (2008) proposed that this association would strengthen through later childhood and into adolescence. Evidence supports this concept to some extent in that weaker relationships have been reported between MC and PA in younger children compared to older children (Fisher et al., 2005; Logan et al., 2015; McKenzie et al., 2002; Williams et al., 2008). In pre-school children (n = 198; age range 3 – 4 years) a weak correlation was seen between MC and PA among 4-year-olds ($r = .33$; $p < .001$) (Williams et al., 2008). Among 3-year-olds there was no significant relationship between MC-PA ($r = .16$; $p > .05$) (Williams et al., 2008). In children of a similar age group (n = 394; mean age 4.2 years) weak relationships were again found between MC and PA (r = .10 (total PA), and .18 (% time in MVPA)) (Fisher et al., 2005). In McKenzie *et al.*'s (2002) longitudinal study there was no relationship found between MC measured between the ages of 4 and 6 years and PA at age 12 years.

A review of the MC-PA relationship among children and adolescents (Logan et al., 2015) partially supports the developmental model proposed by Stodden et al. (2008). For early (ages 3-5 years) and middle-late (ages 6-12 years) childhood, low to moderate relationships ($r = .16$ to $.48$) and low to high relationships ($r = .24$ to $.55$) respectively were found between MC and PA (Logan et al., 2015). In the only two adolescent studies (Barnett et al., 2011; Okely et al., 2001) included in Logan et al.'s (2015) review, only weak to moderate relationships ($r = .14$ to $.35$) between MC and PA were reported. Thus, the review findings do not support the proposed developmental relationship (Stodden et al. 2008) in its entirety (Logan et al., 2015). Despite the weaker MC-PA relationship in adolescents, aspects of MC significantly contributed to time in MVPA (Barnett et al., 2011; Okely et al., 2001). For example, Barnett et al. (2011) reported that object-control competency specifically contributed to 11% of the variance in MVPA among adolescents ($n = 215$). According to Okely et al. (2001), MC was a significant contributor to self-reported organised PA among adolescents ($n = 982$), but the proportion of time accounted for by MC in organised PA was only 3%. The low proportion of variance in MVPA accounted for by MC in this study indicates that while MC may be a significant factor in PA participation, there are other potentially more important factors that lead to adolescents engaging, or not, in PA (Okely et al., 2001). Research to date does not lend strong support to the hypothesis that the MC-PA relationship will strengthen with age, however, there is a lack of studies assessing this relationship longitudinally into adolescence. In addition, other factors, such as HRF and PC, may have an influence on the way in which the MC-PA relationship changes over time. This has yet to be thoroughly examined.

2.3.1.2 Understanding the reciprocal nature of the MC-PA relationship

Despite reciprocity of relationships being a central hypothesis in Stodden et al.'s (2008) model, there is limited research investigating this aspect of the model. The difficulty of collecting data longitudinally, which is needed if a true test of reciprocal relationships is to be conducted, may have played some role in the small number of studies on this aspect of the model. In one of the few longitudinal studies investigating the model, Burgi et al. (2011) examined the relationship between MC and PA in pre-school children ($n = 217$; aged 4 – 6 years). In these participants, the MC-PA relationship was dominated by the impact of PA on motor skills. PA was positively associated with MC at baseline ($\beta = .005$, $p < .01$) and nine months later ($\beta = .003$, $p < .01$), but baseline MC was not associated with improvements in PA ($p > .05$). This suggests that in early childhood, the more opportunities children have to be physically active, the more they will develop MC. On the other hand, at a very young age, a higher level of MC was not found to increase the likelihood of these children being more physically active than their lower MC peers (Burgi et al., 2011). These results highlight the more uni-directional relationship from PA to MC that is apparent in early childhood (Burgi et al., 2011; Stodden et al., 2008), compared to the more reciprocal relationship that is hypothesised to develop later in childhood and into adolescence, where increasing importance may be placed on MC for providing the necessary skills to continue PA (Fisher et al., 2005; Holfelder and Schott, 2014; Stodden et al., 2008; Williams et al., 2008). That being said, a recent study on adolescents (n = 336; mean age 12.0 ± 0.4 years; Jaakkola et al., 2018) reported stronger pathways in the direction of PA predicting MC, rather than the reverse, as would previously have been expected (Stodden et al., 2008). Barnett et al. (2011) did find evidence of a reciprocal relationship between PA and MC in adolescents (n = 215; mean age 16.4 years), but this reciprocal relationship only existed for object-control proficiency. In the current low active youth population, it is not clear if the hypothesised strengthening of the pathway from MC to PA in adolescence holds true. In addition, it is not fully clear from the available literature whether reciprocal relationships exist for all components of MC, or whether they are seen in specific components only.

2.3.1.3 Stability of MC and PA over time

Separately, PA and MC have been found to track, or remain stable, over time (Jaakkola and Washington, 2012; Lloyd et al., 2014). Tracking, or stability, refers to the tendency of an individual to remain in a particular rank position for a measured construct (PA or MC in this case) within a group, from one time point to the next (Malina, 2001). To say that PA and MC track over time is to say that childhood levels of PA and MC are indicative of adolescent levels of PA and MC.

PA in childhood has been found to track moderately into adolescence (Jaakkola and Washington, 2012; Janz et al., 2000). Janz et al. (2000) measured PA via self-report once every 3 months over a period of 5 years in youth (n = 126, aged 10.8 years (boys) and 10.3 years (girls) at baseline. Low to moderate stability ($r = .32 - .65$) was reported for vigorous activity in both boys and girls. That is, participants who were classified as sedentary, or active, were likely to remain in these PA categories throughout the study (Janz et al., 2000). Jaakkola & Washington (2012) found that self-reported PA at age 13 significantly predicted PA at age 15 ($n = 152$; $\beta = .45$, $p < .05$), indicating that PA habits developed in early adolescence are important for the subsequent maintenance of healthy PA behaviours throughout adolescence. In contrast, some studies have not found PA to be as stable across time (Dumith et al., 2012; McMurray et al., 2003). The highest correlation value for self-reported PA between baseline and seven year follow-up in youth (n = 1,064; age at baseline = 8 years) was r = .58 (McMurray et al., 2003), which is lower than the values reported by Janz et al. (2000). Dumith et al. (2012) assessed the stability of self-reported PA from age 11 to age 15 in Brazilian youth (n = 4,452) and found a weak relationship between childhood and adolescent PA (rho = .22). In all of these studies (Dumith et al., 2012; Jaakkola and Washington, 2012; Janz et al., 2000; McMurray et al., 2003), PA was measured using subjective recall measures. It was acknowledged by McMurray et al. (2003) that stability coefficients for self-report PA in younger children may not be reliable, given the difficulty in correctly recalling PA. This may have given rise to lower tracking of PA across time when children were younger at baseline (Janz et al., 2000; McMurray et al., 2003) compared to tracking in older children or adolescents (Jaakkola and Washington, 2012). One study that did use accelerometery and tracked PA over a two-year period in young children (n = 42; mean age at baseline = 3.8years) found moderate correlations between baseline and follow-up PA (r = .35 - .37) (Kelly et al., 2007). The research is inconclusive as to the strength of the tracking of youth PA over time. Studies using self-report PA data may be compromised by the ability of children to accurately report PA. Longitudinal studies using objective measures of PA are needed to further our understanding of PA changes with age.

Along with PA, MC has also been reported to track across time, with studies showing slightly stronger stability in MC over time compared with PA. Low motor competent children often become low motor competent adolescents and adults (Ahnert et al., 2009; Lloyd et al., 2014; Lubans et al., 2010; Vandorpe et al., 2012). Longitudinal studies have found MC to track over time in young children (Vandorpe et al., 2012) and from early childhood through to adulthood (Ahnert et al., 2009). In young children (n = 638; mean age at baseline = 8.3 years), MC tracked from baseline to follow-up (r = .66 for MC between age 6 and 8 years; r = .87 for MC between age 7 and 9 years) despite differing levels of exposure to organised sport participation (Vandorpe et al., 2012). As expected, all children, irrespective of organised sport participation level, showed increases in MC over time (Vandorpe et al., 2012). These findings are in keeping with observations made by Ahnert et al. (2009) in a 20-year longitudinal study on the development and intra-individual stability of MC over time, where stability coefficients for MC were found to be significant from pre-school onwards. Moderate to moderately high correlations (r = .30 - .54) were found between preschool MC and age 23 MC, with greater stability (r = .52 - .63) found between elementary school MC and age 23 MC (Ahnert et al., 2009). This suggests that MC level in middle to late childhood will have an important bearing on MC into adulthood and throughout the lifespan. At this stage the proposed MC "proficiency barrier" (Haubenstricker and Seefeldt, 1986) may come into effect, with individuals likely needing to possess the necessary competencies by this age to enable them to be physically active throughout the lifespan. It is worth noting however, that specific components of MC may track from childhood to adolescence more so than others. It has been shown that childhood object-control proficiency significantly predicts adolescent object-control proficiency for example, while childhood locomotor proficiency did not demonstrate this association with adolescent proficiency (Barnett et al., 2010).

While MC may be relatively stable over time (Ahnert et al., 2009; Vandorpe et al., 2012), the level of MC attained appears to be influenced by differences in PA participation, with research highlighting the need for practice opportunities for developing MC (Barnett et al., 2016; Hardy et al., 2010). For example, in the Vandorpe et al. (2012) study, despite increases in MC among all children with respect to increase in age, the children who reported constant participation in organised sport did score higher in MC than both the partial participation and no participation groups across the three-year study. In other words, MC increased across all sport participation groups, but children who participated in more organised sport scored higher in MC at the initial time-point and continued to score better as they got older. Therefore, PA or organised sport participation may not dictate whether a child improves their competency level from a young age to adolescence, but it does appear to influence the level of MC attained, with greater participation significantly associated with higher scores in the MC tests (Vandorpe et al., 2012).

2.3.1.4 Gender- and sex-related differences in MC and PA

Sex is defined as "a set of biological attributes" pertaining to physical and physiological factors such as chromosomes, hormones, and reproductive anatomy (Canadian Institutes of Health Research, 2018). It is predominantly referred to as a binary variable – male and female (Canadian Institutes of Health Research, 2018). Gender is a socially constructed concept and is defined as "*the roles, behaviours, expressions and identities of girls, women, boys, men, and gender diverse people"* (Canadian Institutes of Health Research, 2018). Similar to sex, gender is usually referred to as a binary variable – man/boy and woman/girl

(Canadian Institutes of Health Research, 2018). That being said, in comparison to biological sex which can be identified based on physical attributes, gender exists on a spectrum, with an array of ways to express gender identity (Heidari et al., 2016). Considering the definitions of sex and gender, when examining differences between groups, sex-based differences will pertain to physical or physiological differences, whereas gender-based differences will pertain to psychosocial or sociocultural differences (Canadian Institutes of Health Research, 2018). In saying that, sex and gender are integrally related and not mutually exclusive (Clayton and Tannenbaum, 2016). When considering pathways in Stodden et al.'s (2008) conceptual model, if differences exist between males/boys and females/girls it is likely due to a mix of both physiological (sex) and sociological (gender) factors.

As previously discussed, Stodden et al.'s (2008) conceptual model considers developmental age as an important factor influencing associations between variables. Based on research which has identified age-related differences in the variables included in the model, it is hypothesised that relationships between variables will change with developmental age (Stodden et al., 2008). A limitation of the model is the lack of consideration given to how gender/sex may impact the pathways in the model.

Research has highlighted the differences that exists in MC between boys and girls, with boys consistently reported to have higher levels of overall (Barnett et al., 2009; Breslin et al., 2012; Cantell et al., 2008; Lopes et al., 2011; O'Brien et al., 2018) and object-control (Barnett et al., 2008; Barnett et al., 2010; Breslin et al., 2012; O'Brien et al., 2018) MC compared to girls. Differences are also seen in PA with boys again consistently reported to have higher levels of PA than girls (Cantell, Crawford and (Tish) Doyle-Baker, 2008; Barnett et al., 2008; Barnett et al., 2009; Borraccino et al., 2009; Green et al., 2011; Hallal et al., 2012). When looking at the nature of the relationship between MC and PA in boys and girls however, such differences are not as definitive. While some studies have found differences in the MC-PA relationship (Green et al., 2011), other researchers propose that regardless of differences in level of PA and MC between boys and girls, the relationship between these variables is not dependent on sex/gender (Barnett et al. 2008; Crocker, Eklund and Kowalski, 2000). In other words, while boys may display higher object-control competency than girls, for example, the relationship between competency level and engagement in PA for boys is similar to the relationship between these two variables for girls. Most importantly in terms of addressing the pressing problem of physical inactivity and negative health trajectories, is the clear finding that girls, and low MC boys, are at higher risk of physical inactivity and concomitant health problems (Bailey et al., 2012; Ekelund et al., 2012; Hills et al., 2011; Kriemler et al., 2010; Warburton et al., 2006) than highly motor competent boys.

2.3.1.5 The MC-PA relationship: Summary

Stodden et al.'s (2008) conceptual model proposes a developmental and reciprocal MC-PA relationship that strengthens with age, and is influenced by other factors, namely HRF and PC. Research partially supports aspects of this model, with the proposed strengthening of the MC-PA relationship seen throughout childhood (Fisher et al., 2005; Logan et al., 2015; McKenzie et al., 2002; Williams et al., 2008) but not into adolescence (Barnett et al., 2011; Logan et al., 2015; Okely et al., 2001). The available literature is also not conclusive in whether a reciprocal MC-PA relationship exists for all MC components (locomotor, object-control, stability) (Barnett et al., 2011). It must be acknowledged that there is a distinct lack of research addressing the development of this MC-PA relationship in adolescents. In their review, Logan et al. (2015) highlighted the lack of longitudinal studies and called for studies that track the MC-PA relationship in youth, and that monitor other variables likely to influence this relationship. In addition, given the widely reported gender- and sex-related differences in PA and MC, as well as in the proposed mediating variables of HRF and PC, it is necessary to address whether, as with developmental age, there are sex/gender-based differences in the pathways hypothesised in the model. A full analysis of the interrelationships between all components of the model in a longitudinal manner is required to test Stodden et al.'s (2008) conceptual model in its entirety (Logan et al., 2015).

2.3.2 Mediators of the MC-PA relationship

Mediators are "intervening dependent variables" which can be affected by the independent variable and can consequently affect the dependent variable (Rubin & Babbie 2009, p.169). In the case of Stodden et al.'s (2008) proposed model, health-related fitness (HRF) and perceived competence (PC) are hypothesised to mediate the relationship between MC and PA (Fig. 2.3). That is, MC and/or PA may influence HRF and/or PC, which may subsequently determine an individual's spiral of engagement or disengagement in PA.

2.3.2.1 Health-Related Fitness: Introduction

Health-related fitness (HRF) is theoretically defined as a multidimensional construct containing the components cardiorespiratory endurance (CRE), muscular strength (MS), muscular endurance (ME), flexibility, and body composition (Caspersen et al. 1985; ACSM

2014, p.2. CRE is defined as "the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged strenuous exercise" (Ortega et al. 2008). MS and ME are often grouped together under the term muscular fitness (MF), where MF refers to the ability of the muscular system to produce force against a resistance, in one maximum effort (MS), or over a prolonged period (ME), dynamically or statically, and using large or small musculature (Ortega et al. 2008; Smith et al. 2014). Flexibility refers to the range of motion at a joint (Caspersen et al. 1985). Body composition is the make-up of the body, usually described in percentage of muscle, fat, bone and water within the body (Caspersen et al. 1985).

2.3.2.1.1 Importance of HRF in youth

HRF is considered a powerful indicator of health among children and adolescents, with higher fitness levels associated with positive outcomes for bone health, mental health, obesity and cardiovascular disease (CVD) risk (Ortega et al. 2008; Ruiz et al. 2009). In a review of the predictive validity of HRF in youth for health outcomes in later life, Ruiz et al. (2009) found substantial evidence supporting the contention that high levels of CRE in youth are associated with better cardiovascular health in adulthood (Ruiz et al. 2009). Another review of HRF studies and health outcomes in children and adolescents found that of the five HRF components, CRE levels in particular are related to adiposity, CVD risk factors, quality of life in cancer sufferers, and mental health (Ortega et al. 2008). MS and ME were also associated with CVD risk factors and quality of life, as well as bone health (Ortega et al. 2008). In a study examining the relationship between cardiometabolic disease risk factors, and CRE and PA in 10-14-year olds ($n = 100$), it was found that those classified as high in CRE had a significantly lower risk for cardiometabolic disease compared to those classified as low in CRE ($F = 9.79$, $p < .001$) (Bailey et al. 2012). Cardiometabolic disease risk was defined in this study as the sum of a number of risk factors including waist circumference (WC), blood pressure (BP), total triglycerides, total cholesterol to HDL-C ratio, and blood glucose (Bailey et al. 2012). Barker et al. (2018) found a similar negative relationship between CRE and clustered CVD risk ($\beta = -.388$; $p < .001$) in adolescents aged 12.5–17.5 years ($n = 534$). Interestingly, for participants in Bailey et al.'s (2012) study, where CRE was found to determine cardiometabolic risk, differences in objectively measured PA level had no significant effect on children's risk for cardiometabolic disease.

While CRE is the most widely studied component of HRF, there is growing evidence for the benefits of MF for health among children and adolescents. Superior MF has been favourably associated with a reduced risk of insulin insensitivity (Benson et al. 2006), a reduced likelihood of excess adiposity (Smith et al. 2014; Janz et al. 2002; Grøntved et al. 2015), and a reduced risk of CVD risk factors (Janz et al. 2002; Grøntved et al. 2015; Barker et al. 2018). Benson et al. (2006) found that in youth (n = 126; age range = 10 – 15 years) MS was a significantly associated with insulin resistance, a precursor to diabetes, independent of CRE, with groups achieving moderate and high strength levels (relative to all participants in the study) 98% less likely to have high insulin resistance levels when compared to the low strength group. In keeping with the large body of research on HRF and health, Benson et al. (2006) also found that high CRE was a significant protector against high insulin sensitivity. Importantly, both components of HRF (CRE and MF) measured by Benson et al. (2006) were independent of each other in terms of their protective effect on insulin resistance. Whereas high and moderate strength offered almost equal protection against high insulin insensitivity, only high CRE offered a protective effect against insulin resistance (Benson et al. 2006). A review by Smith et al. (2014) pooled the effect sizes of the individual studies it included and reported strong evidence for a negative association between MF and adiposity (r = -.25; 95% CI -.41 - -.08). Cross-sectionally, Barker et al. (2018) have also reported significant associations between MF and clustered CVD risk in youth (β = -.24, $p < .001$).

Longitudinal studies have identified the importance of developing MF at a young age for maintaining good health later in life (Ruiz et al. 2009; Janz et al. 2002; Grøntved et al. 2015). A review of longitudinal studies examining the relationship between childhood fitness and adult health found that increased MS from childhood to adulthood was negatively associated with adult adiposity (Ruiz et al. 2009). This same review could not draw any definitive conclusions about the relationship between MS and changes in other CVD risk factors (BP, blood lipids and lipoproteins) (Ruiz et al. 2009). In a five-year longitudinal study on HRF and health outcomes in youth (n = 125, mean age at baseline = 10.5years) Janz et al. (2002) found that MS predicted 8% of the variability in future adiposity. Their results also demonstrated that improvements in MS over the five years were favourably associated with systolic BP changes with changes in MS accounting for 4% of the variance in year five systolic BP (Janz et al. 2002). Similarly, Grøntved et al. (2015) found MS in adolescence (n = 332) to significantly predict waist circumference in early adulthood (β = -1.09, 95% CI = -2.10 - -.08, $p < .05$). Both Janz et al. (2002) and Grøntved et al. (2015) found MS to be a significant predictor for the development of numerous CVD risk factors, with participants who had higher baseline strength less likely to have any one of a number of CVD risk factors at follow-up. Again, as with Bailey et al. (2012), in the study by Janz et al. (2002) self-report

PA levels was assessed, and changes in self-report PA over time again were not associated with any of the health outcomes identified.

In comparison to both PA and MC, the association between most HRF components and health, both cross-sectionally and longitudinally, is clear. Higher levels of CRE and MF are associated with myriad health benefits and are predictive of better health into adolescence and adulthood. While development of HRF undoubtedly requires engagement in varied PA, positive health outcomes appear to be more associated with increases in HRF rather than increases in PA alone (Bailey et al., 2012; Janz et al., 2002). Comprehensive measurement of both HRF and PA over time is needed to untangle the interrelationships between these constructs and to further our understanding of how to elicit positive health outcomes in youth.

2.3.2.1.2 Measurement of HRF

HRF test batteries have been developed and used to test and compare fitness levels in different populations. FITNESSGRAM (The Cooper Institute, 2001) and EUROFIT (Council of Europe, 1983) are two field-based test batteries that have been used frequently and that share some of the same measures for components of HRF (Table 2.2). FITNESSGRAM was developed in the USA and provides testing procedures for all five components of fitness, with criterion-based and/or age-referenced norms which can be used to measure whether an individual is reaching the required fitness levels for health and their performance relative to others of a similar age (Welk et al., 2011). Using data from the countrywide NHANES study, the Cooper Institute developed age-specific thresholds, or healthy fitness zones (HFZ) below which a child or adolescent is at risk of poor health. All, or components, of the FITNESSGRAM have been used extensively in measuring HRF among adolescents worldwide (Khodaverdi et al., 2015; Ortega et al., 2011; Rodrigues et al., 2016; Stodden et al., 2014). EUROFIT is a European-developed field-based test battery similar to FITNESSGRAM. While EUROFIT does not provide age-referenced norms in their manual, a recent European-wide assessment of HRF in youth (n = 3,428) (Ortega et al., 2011) used many of the test protocols outlined in EUROFIT (Council of Europe, 1983), providing normative values for HRF in European youth (aged 13 – 17 years) and allowing for analysis and comparison of standards on HRF tests to a cohort norm. The EUROFIT test battery has been used extensively to measure HRF in adolescents (Baquet et al., 2006;

Bronikowski and Bronikowska, 2011; Carraro et al., 2010; Gísladóttir et al., 2014; Ortega et al., 2005; Vedul-Kjelsås et al., 2012a).

Table 2.2 Tests included in the FITNESSGRAM (The Cooper Institute 2001) and EUROFIT (Council of Europe, 1983) for each HRF component (overlap highlighted in green)

	FITNESSGRAM	EUROFIT	Test Reliability
	CRE		
1-mile run	*		% Agreement = .92 (Morrow et al., 2010)
20m PACER (shuttle run)	*	*	ICC: .78 - .99 (Artero et al., 2011) % Agreement = .82 (Morrow et al., 2010)
1mile walk	*		ICC = .91 (McSwegin et al. 1998)
PWC170(cycle ergometer)		*	ICC = .89^{b} (Nikolaïdis, 2011)
6min run test		*	ICC = .94^{c} (Li et al., 2005)
	ME		
Abdominal curl-up	*	*	% Agreement = .74 (Morrow et al., 2010)
90◦ push-up	*		% Agreement = .78 (Morrow et al., 2010)
Modified pull-up	*		ICC = .72 - .91 (Plowman and Mahar, 2013)
Pull-up	*	*	ICC = .91 - .96 (Plowman and Mahar, 2013)
Flexed arm hang	*	*	% Agreement = .82 (Morrow et al., 2010)
	MS		
Trunk extension/lift test	*	*	% Agreement = .86 (Morrow et al., 2010)
Standing broad jump		*	Non-significant (*p* > .05) intertrial difference in jump distance (cm) for males: -0.3 ± 12.9 and females: 0.3 ± 9.0

Vertical jump		*	Non-significant ($p > .05$) intertrial difference in jump height (cm) for males: 0.0 ± 3.4 and females: -0.4 ± 3.3 (F Ortega et al., 2008)
Flexibility			
Back-saver sit-and-reach	*		% Agreement = .89 (Morrow et al., 2010)
Sit-and-reach (double leg)		*	Cronbach's α = .99[a] (Morina et al., 2015)
Body Composition			
Skinfold thickness	*		ICC = .99 for males, .97 for females (Ihmels et al., 2004)
%BF via bioelectrical impedance	*		ICC ≥ .82 (Talma et al., 2013)
BMI	*		% Agreement = .97 (Morrow et al., 2010)

Notes: [a] male sample only. [b] female sample only [c]6-minute *walk* test

Many studies on youth have chosen tests from these batteries to measure HRF. For large groups of children or adolescents, the 20m shuttle run is one of the most common field-based tests of CRE (Ortega et al., 2005). Léger *et al.* (1988) developed this test and provided age-specific equations to calculate VO_{2max} from final score on the test. FITNESSGRAM (The Cooper Institute, 2001) provides criterion-based values for children and adolescents which identify age-relevant healthy ranges for CRE levels (Welk et al., 2011). Laboratory-based CRE tests which require analysis of expired air during exercise to exhaustion are the gold standard method for measuring VO_{2max} (Pate, Oria and Pillsbury, 2012). That being said, they are an expensive method of testing in terms of efficiency, expertise, and equipment (Grant et al., 1995). In addition, most laboratory-based tests of CRE can be conducted with only one participant at a time making them impractical for large groups of children. (Ramsbottom, Brewer and Williams (1988) found the 20metre shuttle run to be a valid tool for predicting VO_{2max}, as compared against the criterion incremental treadmill test ($r = 0.92$). Therefore, the 20m shuttle run is a valid alternative when expertise and expense limitations present, and when large groups are to be tested in a field-based setting.

For practical reasons, some of the tests of MF included in both the FITNESSGRAM and EUROFIT may be more applicable than others for field-based measuring of HRF in youth. Tests of core and upper body endurance such as curl-ups and sit-ups are easy to administer and require little equipment (The Cooper Institute, 2001). In comparison, tests such as pull-ups, or flexed arm hang, require gym equipment that may not be available in all field-based settings (Council of Europe, 1983; The Cooper Institute, 2001).

When assessing flexibility, the sit-and-reach, or back saver version, are commonly used (Minck *et al.*, 2000; Ortega *et al.*, 2011; Haugen, Ommundsen and Seiler, 2013; Rodrigues, Stodden and Lopes, 2016). The back saver sit-and-reach assesses flexibility one leg at a time and may reduce the risk of overstretching the back compared to the original test format (Ruiz et al., 2006). While the sit-and-reach tests measure hamstring flexibility, other tests such as the back-scratch test can be used to measure shoulder flexibility (Castro-Piñero et al., 2013; Plowman and Mahar, 2013). It has been recommended that flexibility be assessed at different locations considering that flexibility is unique to each specific joint (Castro-Piñero et al., 2013). In saying that, the vast majority of studies in youth which asses flexibility use the sit-and-reach test, or back-saver version. Therefore, for comparative purposes it is a useful measure of flexibility, albeit site-specific.

BMI is frequently used as a measure of body weight status (de Onis and Lobstein, 2010; Heinen et al., 2014; May et al., 2012; Ogden et al., 2015; Woods et al., 2010). Compared to other methods which measure the composition of an individual's mass in terms of fat, muscle, bone, and water, BMI measures an individual's body mass in relation to their height (de Onis and Lobstein, 2010) and is a relatively simple and inexpensive method of assessing body weight status (Gupta et al., 2011; Loenneke et al., 2013). Cut-off's for healthy and unhealthy BMI for children and adolescents have been developed by the World Health Organisation (de Onis et al., 2007). By 2010, 110 countries worldwide had adopted these cut-off's to identify levels of overweight and obesity in youth (de Onis and Lobstein, 2010). In comparison to BMI measurement in adults, BMI measurement in children and adolescents is age and sex specific. While BMI is the most frequently used method of assessing body weight status, there are some limitations. Compared to other measures, such as waist circumference (WC), it has been reported that BMI is less capable of predicting CVD risk in children (n = 1,987, mean age 11.0 ± 0.4years; (Savva et al., 2000), and it has been recommended for BMI to be used in conjunction with other body weight status measures when assessing youth (Mitchell et al., 2012). WC is a proxy measure for abdominal fat

(Després, 2012; Klein et al., 2007) and is strongly associated with cardiovascular and metabolic disease factors (Freedman et al., 1999; Savva et al., 2000; Shen et al., 2006). In children (n = 1,987; mean age 11 years) WC has been found to be a significantly stronger predictor of CVD risk factors compared to both BMI and waist-hip ratio (Savva et al., 2000). Cook, Auinger and Huang (2009) reported WC values above the 93rd (boys) or 86th (girls) percentile as the cut-off values for healthy WC in youth. It is important to note that WC may not be as strong a predictor in younger children compared to adolescents, as centralisation of body fat does not occur until puberty (Cameron et al., 2009). Other frequently used methods of measuring weight status include bioelectrical impedance analysis (BIA) and skinfold measurement. BIA can give a more accurate picture of total body composition (muscle, bone, fat content), while summing skinfolds taken at specific anatomical regions is used to measure %BF alone. Validity and reliability of BIA tools is difficult to establish between models (Gupta et al., 2011), and BIA requires the use of expensive equipment (www.tanita.com). Skinfold thickness measurement is a reliable measure of body fat percentage (Loenneke et al., 2013), however it requires some training to be proficient. In comparison, BMI and WC measurements are easier to perform and less invasive for the participant than skinfold thickness, and more economical than BIA.

In Stodden et al.'s (2008) conceptual model HRF is positioned as a mediator of the MC-PA relationship, but weight status is positioned as an outcome of that relationship, separate to HRF as a mediator. This is common in health promotion research (Lima, Pfeiffer, et al. 2017; Rodrigues et al. 2016; Casonatto et al. 2016; Bailey et al. 2012; Smith et al. 2014; Janz et al. 2002; Grøntved et al. 2015b). However, the inclusion of body weight status, or body composition, within the context of a HRF construct poses problems in analysing relationships between HRF and health when measures of body weight status such as BMI are used as indicators of health. Clearly, components cannot be both independent and dependent variables. In addition, studies which purport to measure HRF often only examine one or two components (Lima et al. 2017), with CRE chosen as the most relevant component in many studies (Barnett et al. 2008; Barnett et al. 2008; Kriemler et al. 2010; Woods et al. 2010). There is strong evidence for a positive association between CRE health in youth (Corbin et al. 2014; Pate et al. 2012; Ortega et al. 2008), which lends support to the frequency of its measurement in health promotion studies. That being said, a growing body of evidence indicates a positive association between MF and health exists in youth (Benson et al. 2006; Smith et al. 2014; Janz et al. 2002; Grøntved et al. 2015a). If only one component is measured under the HRF construct, then the important contribution of other components will be ignored. In the context of Stodden et al.'s (2008) conceptual model, where HRF is included as a composite, and pathways between HRF and MC, PA and PC are hypothesised to impact on weight status, it may be necessary to re-evaluate HRF as a construct to allow a full test of the model. As such, the following sections will discuss HRF trends, and the association of HRF with PA and MC, from the perspective of body weight status as an outcome of interactions between these health-related variables, rather than as a component of HRF.

2.3.2.1.3 Current trends

An extensive systematic review of HRF in European youth (2,779,165 EUROFIT test performances; age range 9-17 years) found that, across included studies, 78% of males (95% CI 72-85%) and 83% of females (95% CI 71-96%) were classified as having healthy CRE (Tomkinson et al., 2018). In a large cohort of European adolescents (n = 3,428; age range = 12.50 – 17.49 years) from 10 different European cities, 61% of boys and 58% of girls reported a healthy CRE level (Ortega et al., 2011). According to Santos *et al.* (2014), a similar proportion (61.1%) of Portuguese youth (n = 22,048; age range 10 – 18 years) were in the HFZ for CRE. In this sample of Portuguese youth, a significantly greater proportion ($p < .05$) of girls in the 10 – 14-year age brackets were in the HFZ for CRE compared to boys, but the opposite was then seen in 15 – 18 year olds ($p < .05$; Santos et al., 2014). In the same study, for ME (curl-up and push-up tests) and flexibility (modified-back-saver-sit-and-reach right leg, and left leg) the percentage of participants in the HFZ were 82.5%, 58.9%, 49.1% and 51.8%, respectively (Santos et al., 2014). For upper-body ME, more boys reached the healthy zone in the 10-, 11- and 13-year-old group than girls ($p < .05$). Again, an opposing trend was then seen from age 14 to 17, with more girls than boys in the HFZ ($p < .001$; Santos et al. 2014). In the US, data from NHANES (youth aged 12-15years), showed a lower percentage of individuals (42.3%, 95% CI 36.3 – 48.3%) reaching healthy levels of CRE compared to European youth (Beals et al., 2016). A similar sex divide was seen however, with a higher proportion of males (50.4%, 95% CI 42.7 - 58.2%) in the healthy zone for CRE compared to females (33.9%, 95% CI 27.5 - 40.2%) (Beals et al., 2016). In terms of the development of CRE, an earlier study also using NHANES data (Pate et al., 2006) found opposing trends in males and females for the progression of CRE with age. Males increased their CRE with increasing age, while for females CRE actually decreased with age (Pate et al., 2006). Research on changes in CRE has found that VO_{2max} tends to increase from childhood into adolescence (Janz et al., 2000; Kemper et al., 2013). This increase usually lasts into late adolescence for males, but for females a plateau in VO_{2max} is frequently reported much earlier in adolescence at about 13 or 14 years (Janz et al., 2000; Kemper et al., 2013). In their review, Tomkinson *et al.* (2018) found that the percentage of males and females achieving healthy CRE levels decreased by approximately 3% and 7%, respectively, every year from the age of 9 years. That being said, from childhood into adolescence generally speaking across all components there is a trend for individual increases in HRF with age (Ortega et al., 2011; Santos et al., 2014).

Sex differences have been reported for overall HRF scores in youth. Tomkinson et al.'s (2018) systematic review of HRF in European youth reported that, on average, males were significantly better than females in MS (large effect size), ME (moderate – large effect size) and CRE (large effect size). In contrast, females were generally found to perform significantly better in flexibility (moderate effect size; (Tomkinson et al., 2018). This trend has been reported in a number of studies in European youth (Ortega et al., 2011; Santos et al., 2014). Interestingly, when examining the development of HRF in youth, a trend for an increase in sex differences with age from about 12 years old was noted for CRE, MS and ME, with males improving at a faster rate than females (Tomkinson et al., 2018). This is reflective of physiological changes that occur around the onset of puberty whereby male levels of circulating testosterone increase substantially above female levels allowing for rapid increases in strength and endurance. For flexibility, male and female youth developed at a similar rate (Tomkinson et al., 2018).

In an Irish context, 77.6% of adolescents (n = 535; age 12.78 ± .42 years) were classified as having "Good" to "Superior" CRE (Belton, Issartel, et al., 2018). Similarly, data collected for CSPPA (Woods et al., 2010) found that the proportion of children (n = 5, 397) with healthy CRE levels was 77%, which is higher than the level reported among European (Ortega et al., 2011; Santos et al., 2014) and US youth (Beals et al., 2016). Similar to international trends, there is evidence of a sex difference in CRE levels in Irish adolescents (Irish Life Schools Fitness Challenge, 2016). Males in first year of secondary school were 32% fitter than females (Irish Life Schools Fitness Challenge, 2016). This sex-related difference increases with age, with a 42% difference in CRE level seen between adolescent males and females by fourth year of secondary school (Irish Life Schools Fitness Challenge, 2016). In contrast, Belton et al. (2018) found that, using the Cooper Institute standards (Heyward, 1998) the proportion of males reaching their optimal CRE score was lower than the proportion of females (45% vs 67%). Data on other components of fitness within the

Irish context are scarce, both cross-sectionally and longitudinally. Considering the strong evidence for a positive association between CRE, MS, and ME and health outcomes in youth it is important to assess fitness levels in youth across all components. In the context of the current research, and cognisant of the drop-off in PA frequently reported during adolescence, establishing the role of HRF at this stage of development is an important step in understanding how and why youth disengage from PA.

2.3.2.1.4 HRF, MC, PA: direct relationships

Direct relationships have been identified between HRF and both MC and PA. In general, the majority of studies in this area focus on CRE levels and body composition as markers of HRF, with fewer studies including measurement or reference to other HRF components (MS/ME/flexibility).

Cross-sectionally, CRE and PA have been found to be positively correlated among children, with higher levels of CRE associated with increased time in MVPA and VPA (Bailey et al., 2012; Burgi et al., 2011). Burgi et al. (2011) sought to identify the cross-sectional relationships between PA, CRE, MC, and percentage body fat (%BF) in children (n = 217; age 4 – 6 years). Cross-sectional results from this study showed that baseline CRE and PA were positively associated (Burgi et al., 2011). In 10 – 14 year olds (n = 100), time spent in MVPA ($r = .22$, $p < .05$) and VPA ($r = .39$, $p < .05$) was also positively associated with CRE (Bailey et al., 2012). LPA however was negatively associated with CRE ($r = -.35$, $p < .05$; Bailey *et al.*, 2012). One cross-sectional study on a large sample of adolescents (n = 1,839; mean age 15 years) examining among other variables, both PA and HRF, where all five HRF components were measured, found that higher PA was significantly associated with better HRF levels across all five components (MS: $r = .12$-$.25$, $p < .01$ (males), $r = .26 - .40$, $p < .01$ (females); CRE: $r = .24$, $p < .01$ (males), $r = .35$, $p < .01$ (females); flexibility: $r = .09$, $p < .05$ (males)) except flexibility for females, indicating that enhancements in HRF may be brought about by increases in PA (Haugen et al., 2013).

Another cross-sectional study examining the direct relationships among PA, MC, and HRF among adolescents (n = 1,585; mean age 14.06 years), found that low active adolescents had significantly lower CRE (p < .001) and upper body strength (p < .001) than their high active peers (Hands et al., 2009). Interestingly, low levels of PA appeared to favour performance in flexibility, with less active adolescents performing better on flexibility tests (Hands et al., 2009). Using multiple regression analysis, CRE was found to be the only component of

HRF that significantly predicted variance in PA among both males ($\beta = .17$; $p < .01$) and females ($\beta = .26$; $p < .01$) (Hands et al., 2009). In comparison, all HRF components significantly predicted variance in MC (Hands et al., 2009). From this study, the influence of HRF on MC in youth appeared to be stronger than the influence of HRF on PA. Utesch et al. (2019) noted that to adequately perform some FMS, a degree of MS or ME may be needed. This may result in a stronger relationship between these two variables, in comparison to the relationship between HRF and PA. In young adults (n = 188; mean age 20.4 years; (Stodden et al., 2009) and children (n = 267; age 4 - 13 years; (Stodden et al., 2014), performance on selected motor skills (kicking, throwing, jumping) was found to be positively associated with HRF ($r = .48–.74$ (Stodden et al., 2009); $r = .38-.65$ (Stodden et al., 2014)). Similar to the relationship between HRF and PA, all components of HRF except flexibility were positively associated with MC among young adults (Stodden et al., 2009). In children (n = 456) ranging in age from 4 – 13 years object-control MC (kicking and throwing) was found to be a predictor of HRF from age 6 years, and the strength of this association increased with age (Stodden et al., 2014). The association between locomotor MC (standing long-jump) and HRF however varied across developmental stage, with locomotor skill a predictor of HRF in 4 – 5, 8 - 9 and 10 - 11year olds, but not in 6 – 7 or 12 – 13 year olds (Stodden et al., 2014). These findings lend support to the authors' original conceptual model (Stodden et al., 2008), that favours a positive feedback loop where MC is necessary for participation in activities that will enhance HRF (Stodden et al., 2009, 2014).

A systematic review of the association between HRF and MC found strong evidence (60-100% of identified studies, which had a low risk of bias, reported significant correlations) for a positive relationship between CRE and MC, and between MF and MC (Cattuzzo et al., 2016). Cross-sectionally, Cantell, Crawford and Doyle-Baker (2008) measured differences in HRF between high and low MC groups of children, adolescents, and adults. Unlike the majority of HRF research, CRE was not included as a measure of HRF, with the authors focusing solely on MF. While no considerable differences based on MC level were seen in MF for either the child or adolescent groups, adults with lower MC had significantly ($p < .033$) lower scores on all MF indices (Cantell et al., 2008). Trends were noted between MC and MF for adolescents, as well as adults, with female adolescents who were identified as low MC occupying the "fair" category for fitness, compared to their high MC counterparts who occupied the "good" and "very good" categories for fitness. Similarly, a trend among adult males was found, with low MC males classified mainly as "good" for fitness level, compared to "excellent" for the high MC group (Cantell et al., 2008). In contrast to the research by Stodden et al., (2014) and Cantell, Crawford and Doyle-Baker (2008), Haga, Gisladottir and Sigmundsson (2015) found that the relationship between HRF and MC may be stronger among younger participants, rather than older. In a sample of children and adolescents (n = 194), the MC-HRF relationship was stronger in 4–6 year olds (r = .56; p < .001) and 11–12 year olds (r = .44; p < .001) compared to 15–16 year olds (r = .20; p > .05) (Haga et al., 2015). Other research has found that MC may not be necessary for adolescents to maintain fitness levels, with only a weak correlation (r = .25) found between MC and fitness indices in 15-16year olds (n = 94; Gísladóttir, Haga and Sigmundsson, 2014). Thus, results from both Haga et al. (2015) and Gisladottir et al. (2014) bring into question the proposed strengthening nature of relationships with age between variables in Stodden et al.'s (2008) conceptual model and point to the need for longitudinal research designs which can fully untangle the complex and dynamic relationships proposed in the model.

Some longitudinal studies have found relationships between HRF and both PA and MC, with CRE again the most commonly studied component of HRF across age groups (Burgi et al., 2011; Larsen et al., 2015). Larsen et al. (2014) included measures of CRE and MS in their longitudinal study of children (n = 673) aged between 6 and 12 years when examining the relationship between HRF and PA. Childhood CRE was identified as the strongest HRF determinant of adolescent MVPA in this study (Males: β = .87, 95% CI = .48 – 1.26; Females: β = .27, 95% CI = .01-.54; Larsen et al., 2015). An increase of one standard deviation in CRE level resulted in an increase of 54 minutes per week of MVPA for boys and 16 minutes per week for girls (Larsen et al., 2015). As well as examining cross-sectional relationships between HRF, PA and MC, Burgi et al. (2011) also measured these same participants longitudinally. While CRE and PA were associated at baseline in Burgi et al.'s (2011) study, baseline CRE was not found to predict changes in PA. That being said, higher levels of vigorous PA at baseline were positively associated with changes in CRE (β = .003, 95% CI = .001 - .007; Burgi et al. (2011).

It is important to acknowledge the link between the level and intensity of PA, and HRF. It may not simply be any type of PA that is positively associated with HRF, but PA at the right intensity. One longitudinal study following children (n = 158) from 11 to 16 years of age found that maintaining a high level of PA (> 60minutes MVPA per day) across the years was most strongly associated with HRF rather than simply increasing PA (Baquet et al., 2006). Children who increased their PA time during the study, but who did not reach the standard of more than 60 minutes MVPA per day, did not improve HRF (Baquet et al., 2006). This is not unexpected, given that the recommended PA guidelines for youth were determined to ensure individuals engaged in an amount and intensity of PA that is sufficient to protect them from adverse health outcomes resulting from insufficient PA. Longitudinal studies such as these (Baquet et al., 2006; Burgi et al., 2011; Larsen et al., 2015) that examine the relationship between childhood and adolescent MC, PA and HRF are few and far between. A systematic review of MC and HRF in youth found only 18% of the studies were longitudinal (Cattuzzo et al., 2014), highlighting the need for studies which examine the developmental relationships outlined in Stodden et al.'s (2008) conceptual model, where a particular focus on the role of HRF within the model is needed (Robinson et al., 2015).

2.3.2.2 Perceived Competence: Introduction

PC is the other proposed mediator within Stodden et al.'s (2008) conceptual model (Fig 2.3). Feltz (1988) defined PC as an individual's belief in their capacity to effectively master a task. PC is a construct that falls into the often confusing area of psychological definitions for "self-concept" – the wide term that encompasses emotions, beliefs, and cognitions an individual has about their capacity to perform some task or behaviour, or the confidence they have in their abilities in a particular domain (Shavelson et al., 1976). According to Shavelson et al. (1976) an individual's self-concept refers to an understanding of one's own strengths and limitations.

2.3.2.2.1 PC: Theoretical Background

Concepts of a similar nature to self-concept, such as self-efficacy, self-esteem, and self-confidence often appear in the PA literature. According to Horn (2004), self-concept is a relatively stable *descriptive* component of the self, while self-worth/self-esteem, is a relatively stable *evaluative* component of the self. Our understanding of self-concept is that it can be domain specific e.g. academic and non-academic self-concept. Non-academic self-concept can be further divided into social, emotional, and physical self-concept (Shavelson et al., 1976). Going forward, this literature review will focus on the physical self-concept domain. For the purpose of this literature review, perceived competence (PC) will refer specifically to the construct as described in Harter's Competence Motivation Theory, where PC is an individual's perception of their abilities to be successful within specific domains (Harter, 1982a, 2012). PC will be used as a global term for all types of perceived competence in the physical domain as described by Harter, when PC in the physical domain is not further broken down into sub-components. Specific terms such as perceived athletic competence (PAC) or perceived physical appearance (PPA) will be used when the research clearly distinguishes between sub-components of physical PC. The broad term "physical self-concept" will be used where it is necessary to include a broad range of self-descriptive concepts related to the physical domain such as self-efficacy and self-confidence, rather than PC alone.

2.3.2.2.2 PC and Harter's Competence Motivation Theory

Stodden et al.'s (2008) conceptual model refers to perceptions of competence in the physical domain. PC is a concept found in Self-Determination Theory (SDT; Deci and Ryan, 2000). SDT contains the fundamental precept that for an individual to engage in a behaviour they must first believe that they have the capacity to do so. SDT also purports that PC influences goal attainment, and that information for both comes from past experiences (Rodgers et al., 2014). SDT posits that individuals are motivated once three basic psychological needs are met, namely the need for autonomy, relatedness, and competency (Deci and Ryan, 2000). Individuals have a desire to display competency, or to demonstrate that they can have an effect on their environment (White, 1959). As a result, competence, in addition to referring to an individual's capabilities, also relates to the degree of importance that the individual places on the task involved (Rodgers et al., 2014). In other words, PC refers to an individual's psychological need to master tasks which are viewed as challenging and important (Rodgers et al., 2014).

Harter's competence motivation theory (Harter, 1982a, 2012) has similarities with SDT, where the importance placed on a task or behaviour is associated with PC as a construct (Deci and Ryan, 2000). Competence motivation theory provides a theoretical framework that is developmental in nature and explains how PC influences motivation and behaviour in various domains throughout the developmental period from childhood to adolescence. In the original theory four measurable domains were included: cognitive, social, physical, and global self-worth (Harter, 1982a). Within the physical sub-domain are two further sub-domains; perceived athletic competence (PAC) and perceived physical appearance (PPA) (Harter, 1978). PAC refers to an individual's belief in their ability to perform sports and PA-related skills, while PPA refers to how happy a person is about the way they look (Harter, 2012). Harter (1982) highlighted how individuals distinguish between achievement domains, and that perceptions of competence in one area may not necessarily equate to PC in another. According to competence motivation theory, individuals who have high PC, take responsibility for their own performances and are intrinsically motivated, and are likely to persist in their behaviour. Conversely, individuals with low PC who are extrinsically motivated, and who do not believe they are responsible for their performances are unlikely to persist (Feltz, 1988; Harter, 1978). These predictions of behaviour are similar to those formed in SDT, where high PC and perceived internal control increase motivation (Deci and Ryan, 2000). Competence motivation theory acknowledges the important influence of socialising agents (parents, teachers, coaches, peers, etc.) on youth self-perceptions, affective responses, and motivation (Harter, 1978). It also highlights that motivation will only be facilitated when the task is at an optimally challenging level (Harter, 1978).

While other theories relating to PC did not provide for empirical measurement of the construct in question, Harter developed a self-perception profile for children (SPP-C) (Harter, 1982a) and later for adolescents (SPP-A) (Harter, 2012).

2.3.2.2.3 Importance of PC

PC has been found to be positively associated with current and future PA behaviours (Baker and Davison, 2011; Crocker et al., 2000; Davison et al., 2010; De Meester, Maes, et al., 2016; Raudsepp et al., 2002; Zhang et al., 2015). Given the health benefits associated with PA (Bailey et al., 2012; Ekelund et al., 2012; Hills et al., 2011; Kriemler et al., 2010; Warburton et al., 2006), any increase in PA, be it through PC, MC, or HRF, is a positive. In children and adolescents (n = 466; mean age 11.7 years), PC explained 27-29% of the variance in PA, with more positive perceptions associated with greater self-reported PA (Crocker et al., 2000). In a similar age group (n = 288; 10-12 years), PC was found to be a significant positive predictor of self-report PA among both boys ($\beta = .19$; $p < .05$) and girls ($\beta = .36$; $p < .01$) (Zhang et al., 2015). In both male and female adolescents (n = 153; age range = 11 – 14 years), dimensions of PC (athletic competence, physical self-worth, perceived strength competence) were significantly and positively correlated with self-report MVPA ($r = .17$ - $.37$; $p < .05$) (Raudsepp et al., 2002). De Meester et al. (2016) found that, in adolescents (n = 215; mean age = 13.64 ± .58 years) PC was significantly related to self-report weekly PA ($\beta = 163.38$, $p < .001$) whereas actual competence was not ($p > .05$). In addition, adolescents with low actual MC but high PC reported partaking in significantly more PA than adolescents who had both low actual and perceived competence (De Meester, Maes, et al., 2016). In their study on children (n = 90; mean age 7.5 ± 1.2 years), Masci et al. (2017) also found that participants who overestimated their physical competence also reported partaking in significantly more ($p < .05$) after-school sport than children who accurately assessed, or underestimated, their ability. Interestingly, each of the above studies which reported positive associations between PC and PA relied on self-report measurement of PA. The link between perceptions of competence in the physical domain, and perceptions of PA may accentuate this association given that both are reliant on individual interpretation. Some studies using accelerometer-measured PA have not reported a significant association between PC and PA (Crane et al., 2015). In young children (n = 116; mean age 5 years 7 months) PC did not significantly predict objectively-measured MVPA (Crane et al., 2015; Kavanaugh et al., 2015). Likewise, in older children (n = 232; mean age 12.3 years) measures of physical self-concept were not significantly correlated with objectively measured PA, but were found to correlate with subjectively measured PA (Kavanaugh et al., 2015). Measuring PA objectively could shed some more light on the nature of this relationship.

Some longitudinal studies have found positive associations between PC and PA even when using objective methods of PA measurement. PAC in childhood (Baker and Davison, 2011; Davison et al., 2006), and relative change in PAC from childhood to adolescence (Baker and Davison, 2011), were significant positive predictors of both self-report (Davison et al., 2006) and accelerometer-measured (Baker and Davison, 2011) PA in adolescent girls. Davison et al. (2006) found that girls (n = 174; age range 9 – 11 years) with higher PC at age 9 self-reported higher PA at age 11. Baker and Davison (2011) found that a one unit increase in PAC at age 11 resulted in a 4.4-minute increase in MVPA at age 13. Another study among adolescent girls (n = 151; mean age at baseline = 13 years) reported that PC was strongly correlated with an inclination to be physically active (Davison et al., 2010). Girls who reported a lack of PC as a reason for non-participation in PA were significantly less likely to achieve sufficient PA levels, measured via accelerometry across the early adolescent years (Davison et al., 2010). For each one unit decrease in PC there was a 30% lower chance of maintaining PA levels (Davison et al., 2010). It was highlighted by Davison et al. (2006) that other factors may influence the nature of the PC-PA relationship, such as family and parental support. In their study, girls with higher PC at age 9 and who displayed higher PA at age 11 were also more likely to elicit greater parental support at age 11, thus establishing the importance of social support for PA, but also identifying that children higher in PC are more likely to receive a beneficial level of social support from parents. While the adolescent female population appears a popular cohort for research on PC and PA, and evidence points to an association between these variables when PA is measured either subjectively (self-report) or objectively (accelerometry), it is less clear as to the relationship between PC and PA in adolescent males. One study measuring predictors of PA in adolescents (n = 333; mean age at baseline = 12.41 ± .27 years) found that PC significantly predicted both moderate ($\beta = .18$, $p < .05$) and vigorous ($\beta = .29$, $p < .01$) PA in both males and females 6 years later (Timo et al., 2016), but again, PA in this study was measured via self-report. Thus it is still unclear whether the relationship between PC and PA is influenced by measurement method, or by gender.

2.3.2.2.4 Measurement of PC

PC is assessed using questionnaires. The SPP (Harter, 1982b, 2012), and the Physical Self-Perception Profile (PSPP) (Fox and Corbin, 1990) are examples of questionnaires that have been used to assess PC among youth. Harter (1982b, 2012) developed the SPP to measure domain specific PC using a question format that reduces the likelihood of socially desirable responses (Feltz, 1988; Harter, 1982b) and taps into an individual's perceptions of competence across separate domains; athletic competence (PAC), physical appearance (PPA), scholastic competence, social competence, job competence, romantic appeal, behavioural conduct, close friendship (Harter, 2012). The structure of the SPP allows for the assessment of selected dimensions within the questionnaire if desired (such as PAC and PPA) (Harter, 2012). An overall measure of competence, called global self-worth (GSW) is also included in an adolescent version of the questionnaire (SPP-A) (Harter, 2012). The use of Harter's SPP is widespread in research that focuses on youth and PA or health. Both the child (SPP-C) (Cairney et al., 2012; Fu et al., 2013; Mitchell et al., 2012; Vedul-Kjelsås et al., 2012b) and adolescent (SPP-A) (Baker and Davison, 2011; Haugen et al., 2013; Neumark-Sztainer et al., 2003) versions of the questionnaire have been used in cross-sectional, longitudinal and intervention studies. In younger children, the ability to evaluate self-worth is not present, therefore the GSW subscale of the SPP is not included in measurements of PC with children younger than 8 years of age (Harter and Pike, 1984). When assessing PC in young children there are also questions as to the accuracy of younger children's self-judgements (Harter and Pike, 1984). Younger children are often not as capable of making accurate judgements about themselves and may confuse their desire to be competent with the reality of their competence level (Harter and Pike, 1984). That being said, while it is generally believed that perceptions of competence align more with actual competence as children enter into adolescence and become more cognitively developed, recent studies on Irish children and adolescents have highlighted a mismatch between perceived and actual competence within the physical domain even in adolescence (Farmer et al., 2017; O'Brien et al., 2018). Among adolescents, the SPP-A has been used across a wide age range of participants from age 11 to age 15.4 years (Baker and Davison, 2011; Haugen et al., 2013; Neumark-Sztainer et al., 2003).

The PSPP developed by Fox & Corbin (1990) is based on Harter's (1985) competence motivation theory but only pertains to competence in the physical domain. Within this domain are five sub-domains: attractive body, sports competence, physical strength, physical condition, physical self-worth. The PSPP was originally developed on university students (mean age 19.7 years) (Fox and Corbin, 1990) but was later validated among a younger population aged 12 – 14 years (Whitehead, 1995). As with the SPP, the PSPP has been used across a range of ages to measure PC in the physical domain in youth in cross-sectional, intervention, and longitudinal studies (Barnett et al., 2008; Crocker et al., 2000; McIntyre et al., 2014; Raudsepp et al., 2002).

2.3.2.2.5 Current trends

Harter's competence motivation theory (Harter, 1982b) supports Stodden et al.'s (2008) developmental approach, proposing that the importance of PC changes as children develop and improve their capacity for more accurate perceptions of competency. Piek, Baynam and Barrett (2006) found an inverse association between PAC and age, with younger participants (n = 164; mean age 9.10 ± 0.81 years) having significantly higher PAC ($\beta = -.064$, $p < .001$) than older (n = 101; mean age = 13.84 ± 1.12 years). In comparison, PAC was found to increase over the course of two years in a sample of slightly younger children (n = 2,150; mean age at baseline = 9.6 years) (Cairney et al., 2012). Shapka and Keating (2005) found no significant differences in PAC, PPA, or GSW by age in their longitudinal study on adolescents (n = 518; aged 14 – 18years). Differences in results found for change in PC with age (Cairney et al., 2012; Piek et al., 2006; Shapka and Keating, 2005) may be due to the difficulty attributed to measuring PC in young children resulting from their inability to accurately evaluate competency levels (Harter and Pike, 1984; Harter 2006). At a young age, PC may be higher, but when individuals begin to more accurately link PC to actual competence, or compare themselves to others, their PC may decrease (Harter 2006). Alternatively, PC may remain stable over time due to initial overestimation of competency (Harter and Pike, 1984), which is followed by an increase in actual competency (Barnett et al., 2010; D'Hondt et al., 2013, 2014; Vandorpe et al., 2012), as well as more accurate self-perceptions (Harter and Pike, 1984).

Significant life transitions can impact self-perceptions longitudinally. The impact of school transition on numerous psychological constructs has been extensively researched, but it remains unclear whether the transition has a positive or negative effect (Evans et al., 2018;

Symonds and Galton, 2014). Considering the school transition often coincides with the onset of puberty it can be difficult to separate the impact of the transition on PC from the impact of puberty. One study in Germany where the school transition occurs before puberty (after Grade 4; age approx. 10years) found that PC did decrease after the transition, providing an argument for the independent impact of school transition on PC beyond that of puberty (Arens et al., 2013).

Males often report higher PC in the physical domain than females (Lisa Barnett et al., 2008; Crocker et al., 2000; De Meester, Maes, et al., 2016; Masci et al., 2017; Piek et al., 2006; Shapka and Keating, 2005). De Meester et al. (2016) reported a significant difference between male and female adolescents for PC (β = -.16, $p < .05$) despite no significant differences in actual competence. In a longitudinal study tracking adolescents during two years of high school (n = 517; age range at baseline = 14 – 15 years) girls reported significantly lower PAC ($p < .001$) and PPA ($p < .001$) than boys, but no significant differences were reported for GSW (Shapka and Keating, 2005). In children gender differences for PAC ($p < .01$) were seen by Crocker et al. (2000) in Canadian school children with boys reporting significantly higher levels of PC in the physical domain (Crocker et al., 2000). Masci *et al.* (2017) also found that a significantly higher proportion of females underestimated their competence levels, at just 7 years of age. There are relatively few studies examining trends in PC in the physical domain among Irish youth. In one study examining perceived motor competence among Irish adolescents (n = 395; mean age 13.78 years) a gender difference was reported for PC, with boys scoring significantly higher ($p < .001$) in physical self-confidence measured across 15 selected motor skills, compared to girls (McGrane et al., 2016). In Northern Irish adolescents (n = 546; age range 11 – 15 years) significant gender differences were reported for PPA ($p < .001$) and PAC ($p < .05$) (McClenahan et al., 2003). In keeping with international trends, boys reported higher levels of PC in both domains compared to girls (McClenahan et al., 2003). Similarly, in a longitudinal study of Northern Irish children (n = 110) studied at age 8 years and again at age 11 years, higher levels of PAC ($p < .001$) were reported among boys at both time points (Muldoon, 2000). For PPA, significant gender differences ($p < .001$) in favour of boys were only seen at age 11. Similar to Shapka & Keating (2005), no significant changes in PC with age were noted among this sample as a whole with both PPA and PAC at age 8 significantly correlated with age 11 PPA and PAC (r = .359 and r = .422; p < .001) (Muldoon, 2000). When analysing trends in PPA by gender however, girls' PPA decreased significantly over time (Muldoon, 2000).

PC is identified as a mediator within Stodden et al.'s (2008) conceptual model, yet the role of PC in promoting PA engagement is questionable when PA is objectively measured (Crane et al., 2015; Kavanaugh et al., 2015). Considering the significant level of attention given in the research field to PC, particularly regarding its role within Stodden et al.'s (2008) conceptual model (Robinson et al., 2015), it is imperative to fully understand how PC develops, particularly during key phases such as the school transition, and the role of PC in promoting PA engagement over time.

2.3.2.2.6 PC, MC, PA: direct relationships

Reviews in the PA domain have highlighted PC as a positive correlate for PA in youth (Babic et al., 2014; Robinson et al., 2015). In their review of physical self-concept Babic et al. (2014) found that PC was the construct most strongly associated with PA. However, it should be noted that the majority of studies included in this review used self-report measures of PA which may have had an impact on how variables were associated with PA (Kavanaugh et al., 2015). From the studies included in their review it was found that there was a positive relationship between PA and PC (r = .33), which was influenced by age (r = .08 for children; r = .35 for early adolescents; r = .31 for late adolescents; (Babic et al., 2014). Weak relationships found between PC and PA in childhood are consistent with Stodden et al. (2008), who suggest that PC is not strongly correlated with PA in early childhood, but rather the relationship between the two strengthens as children develop into adolescents and develop more accurate perceptions of their physical abilities. Research supports this view point that the effect of PC on PA is age-dependent (Cohen et al., 2015).

PC has also been consistently associated with MC (Lubans et al., 2010). In their review of health-benefits associated with MC in youth, Lubans et al. (2010) found that PC and at least one aspect of MC were associated in each of the studies included in the review. Vedul-Kjelsås *et al.* (2012a) found that PC was positively associated with both HRF ($r = 0.56$, $p < .01$) and MC ($r = -.35$, $p < .01$) in children (n = 67; mean age 11.47 years). High performers in MC had higher overall self-perceptions (Vedul-Kjelsås et al., 2012a). PC was most strongly related to MC in girls, while it was more strongly associated with HRF in boys (Vedul-Kjelsås et al., 2012a). In a two year longitudinal study of changes in MC, PC and intelligence, in which participants (n = 65; age at baseline = 15 years) were categorised as DCD, intermediate (DCD at baseline but no longer DCD at follow-up), or controls, level of

MC was found to influence PC (specifically PAC, and perceived scholastic competence) (Cantell et al., 2003). Participants in the DCD group reported lower levels of PAC, and perceived scholastic competence than both the intermediate and control groups (Cantell et al., 2003).

A review by Robinson et al. (2015) also highlighted evidence that pointed to a positive relationship between PC and MC. It was noted however, that when assessing the validity of Stodden et al.'s (2008) conceptual model, many studies were limited in that an overall measure of PC was taken, rather than a measure of perceived MC (PMC) specifically. Therefore, it was suggested that measures which focus specifically on PMC may be important when evaluating the relationship between PC and MC as outlined in Stodden et al.'s (2008) model. Interestingly, in a cross-sectional study examining associations among most of Stodden et al.'s (2008) variables (except HRF), (Haerens et al., 2016) did not find a significant association between PC and objectively-measured PA in children (n = 361; mean age 9.5 years) when they grouped children into clusters based on their levels of both PC and actual MC. Children who had high perceived and actual MC were significantly ($p < .001$) more active than children who had low perceived and actual MC. The interesting finding from this study however, which questions the role of PC in promoting PA, was that children who had low actual but high perceived competence were not significantly more active than those who displayed low levels of both actual and perceived MC (De Meester, Stodden, et al., 2016). PC was not highlighted as being redundant or unimportant however. When MC/PC clusters were compared with respect to BMI, it was found that the children who had high actual and perceived MC had significantly lower BMI scores than children in the low perceived and actual MC cluster (De Meester, Stodden, et al., 2016). Nevertheless, those who were clustered in the low actual but high perceived MC were not significantly different with regards to BMI to either the high or low clusters (De Meester, Stodden, et al., 2016). This indicates that while only actual MC is associated with PA level among the participants in this study, a combination of both actual and perceived MC may influence BMI. Results from this study are in contrast with those of De Meester, Maes, et al. (2016). While there are differences in the ages of the participants (9.5 years versus 13.6 years) another notable difference is the method of PA measurement used in each study. Researchers should be cognisant of the impact of PA measurement method used when evaluating conclusions made about relationships between PA and other health-related variables (Kavanaugh et al., 2015).

2.3.2.3 Mediators: Relationship between HRF and PC

Existing research regarding the direct relationships of both HRF and PC with MC and PA has been outlined above. While both HRF and PC have independently been studied with regard to MC and/or PA, direct relationships between these two proposed mediating variables in Stodden et al.'s (2008) model have also been identified. HRF has been found to be positively associated with PC, global self-worth (GSW), and MC (Smith et al. 2014). In their review of the health benefits of MF in youth, Smith et al. (2014) found that overall the included studies showed a moderate positive association (r = 42, 95% CI = .36 - .47) between MF and PC in youth. Cross-sectionally, Carraro, Scarpa and Ventura (2010) examined the correlations between PC and HRF in adolescents (n = 103; mean age = 13.2 years). Significant correlations were found between PC and HRF (r = .33 - .45, $p < .05$), with higher PC in the physical domain generally associated with higher HRF scores. Dunton *et al.* (2006) also examined the relationship between HRF and physical self-perceptions and included PA as an additional variable of interest. Their study looked specifically at adolescent girls (n = 103; age range = 14 – 17 years), and measured CRE and body composition as components of HRF. Results showed that PC was positively associated with CRE (r = .41 - .72, $p < .001$) and negatively associated with %BF (r = -.35 - -.60, $p < .005$) (Dunton et al., 2006). In another study, it was found that improving HRF (CRE and MS were targeted) through a 13-week exercise intervention lead to a concomitant increase in PC in adolescents with low MC (McIntyre et al., 2014). Significant improvements ($p < .04$) in PC were only seen among males in this study, possibly due to the smaller sample size of females (n = 25 males and n = 10 females). This study did not assess or discuss actual changes in HRF, but rather focused on changes in self-perceptions. Neither did it measure if significant improvements in self-perceptions led to any changes in PA behaviour. It would be interesting to examine the effects of enhanced PC through HRF on PA to determine if by improving HRF there is an improvement in PA caused by enhanced PC, independent of HRF improvement.

As a component of HRF, CRE has been identified as a mediator in the relationship between PC and weight status in children (n = 104; mean age 10.7 years) (Mitchell et al., 2012). Children with a high BMI combined with high CRE were more likely to have high PAC than children who had a high BMI but were low in CRE. A significant negative relationship between BMI and PPA was also found for the low CRE participants only (β = -.311, $p < .05$) (Mitchell et al., 2012). In this case, high CRE appears to be a protective factor against developing low PC, irrespective of BMI. Or, to put it another way, having higher CRE may negate the detrimental impact of being overweight on levels of PC. CRE has also been identified as a predictor of PAC across sexes among adolescents (Haugen et al., 2013). Research is equivocal when determining whether it is HRF or indeed PA which has a greater influence on PC. In adolescent girls (n = 103; age range 14 – 17 years), actual physical fitness may have a more positive bearing on self-perceptions than PA (Dunton et al., 2006). Dunton et al. (2006) suggest that interventions aiming to increase PA, but that do not contain sufficient stimulus to increase HRF, may not have any effect on self-perceptions in the physical domain

2.3.3 HRF and PC: mediating effects on the MC-PA relationship

So far the direct relationships between each of the variables outlined in Stodden et al.'s (2008) conceptual model have been discussed. This section will focus on the mediating effect of both HRF and PC on the MC-PA relationship as proposed in the model (Stodden et al., 2008).

2.3.3.1 HRF as a mediator

HRF is one of two proposed mediators of the MC-PA relationship (Stodden et al., 2008), but research that looks specifically at the mediating aspect of HRF on the developmental MC-PA relationship as suggested in Stodden et al.'s (2008) model is limited (Robinson et al., 2015). Cross-sectionally, Khodaverdi *et al.* (2015) looked to specifically examine the mediating effects of both variables identified by Stodden et al. (2008) (HRF and PC) on the MC-PA relationship in 8 – 9 year old girls (n = 352). Measurement of HRF in this study included tests for four of the five components of HRF, namely body weight status (BMI), ME (maximum number of pull-ups and sit-ups), flexibility (sit and reach test) and CRE (600yard run/walk). CRE was the only HRF component identified as a mediator for the MC-PA relationship in this study, with CRE mediating specifically the relationship between locomotor proficiency and PA (B = .28; CI = .21, .39) (Khodaverdi et al., 2015). Activities which focus solely on locomotor skill may require, and enhance, CRE, while activities which require object-control skills may benefit from fitness in all aspects of HRF (Khodaverdi et al., 2015). This may partly explain why CRE mediated the locomotor skills to PA relationship, but did not influence the object-control to PA relationship (Khodaverdi et al., 2015). In addition, an age-related effect has been found for the relationships between HRF and MC (Stodden, 2014). Therefore, the age of the participants in Khodaverdi et al.'s (2015) study may also have influenced the associations found. The MC-HRF relationship has been found to be stronger in later childhood and early adolescence compared to early childhood, and, it appears that age may have a bearing on which MC components are associated with HRF (Stodden, 2014). In younger children, associations between HRF and MC were found for locomotor skills, compared to older children and adolescents where the association is stronger between object-control skills and HRF (Stodden et al., 2014). It is possible that in older children, having better object-control skills, which are required for a multitude of competitive sports, enables individuals to engage in a range of sports and PA which require and develop fitness across multiple HRF components. In turn, having the fitness to engage in these types of activities will facilitate further development of object-control skills. Overall, in the older child and adolescent population there is a lack of research assessing the mediating effect of HRF, as a composite, on the MC-PA relationship. If Stodden et al.'s (2008) conceptual model is to be used to guide research, then this gap in the literature needs to be addressed in order to either support or dismiss Stodden et al.'s (2008) hypothesis.

2.3.3.2 PC as a mediator

Compared to the paucity of research on HRF as a mediator for the MC-PA relationship, a greater amount of studies have examined the potential mediating effect of PC on the MC-PA relationship, although Robinson et al. (2015) have highlighted this as an area which is also in need of more research, particularly in terms of longitudinal studies. In one of the few longitudinal studies in this area which did look at the mediating effect of PC, it was found that childhood MC influenced adolescent PA through the mediating effect of PC (Barnett et al., 2008). Being competent in specifically object control skills in childhood had a significant and positive effect on PC in adolescence, which in turn had a significant and positive effect on adolescent PA ($\beta = .28$; 95% CI = [.16, .39]) and CRE ($\beta = .39$; 95% CI = [.28, .49]) (Barnett et al., 2008). In keeping with Stodden et al.'s (2008) conceptual framework, research studies have found that the mediating effect of PC on the MC-PA relationship appears to be influenced by an individual's stage of development. PC was not found to be a significant mediator ($B = –0.194$; $p = .837$) of the relationship between MC and PA in younger children ($n = 116$; mean age 5.6 years) (Crane et al., 2015), but has been found to act as a mediator ($B = .16$; 95% CI =[.12, .32]) in older children ($n = 352$; mean age = 8.7 years (Khodaverdi et al., 2015) and adolescents ($\beta = .33$; 90% CI = [.33, .58]; $n = 215$; mean age = 16.4 years) (Barnett et al., 2011).

2.3.3.3 Mediators of the MC-PA relationship: Summary

HRF and PC have been proposed by Stodden et al. (2008) as mediators in the developmental MC-PA relationship. The model hypothesises that the associations among variables in the model will strengthen over time. The evidence is not clear-cut however, when examining the relationship between HRF and MC in particular. Some studies have found the association between HRF and MC to strengthen with age (Marja Cantell et al., 2008; Stodden et al., 2014), while others have found the reverse to be true (Gísladóttir et al., 2014; Haga et al., 2015). In one of the only studies to analyse the entirety of Stodden et al.'s (2008) model, it was found that, in a small sample of Finnish youth (n = 42, mean age = 11.26 ± 0.31 years), when both HRF and PC were included as mediators, reciprocal relationships for all of the pathways in Stodden et al.'s (2008) model existed, except for PC-MVPA in males (Jaakkola et al., 2019). While addressing the questions of mediation, and reciprocal relationships in Stodden et al.'s (2008) model, Jaakkola et al. (2019) assessed the model from a cross-sectional perspective. There is an evident need for longitudinal studies to fully understand the predictive nature of the pathways outlined in the model. Cattuzzo *et al.* (2016) highlighted in their systematic review of MC and HRF that only 18% of the studies included were longitudinal in design. Longitudinal studies can help in identifying developmental trends and can aid in addressing the knowledge gaps that currently exist. Another observation from reviewing the HRF literature is that, generally speaking, there are few studies that measure all five components of HRF when examining relationships between some/all of the variables in Stodden et al.'s (2008) model. A study design that encompasses all five components for a true reflection of HRF is needed. The most obvious gap in the literature when looking at the proposed conceptual model by Stodden et al. (2008) is the paucity of research looking at the mediating effect of both HRF and PC on the MC-PA relationship (Robinson et al., 2015). Again, to fully test Stodden et al.'s (2008) model, researchers need to establish whether HRF and PC do act as mediators in the model, and if so, what the nature of these mediating relationships is.

2.4 General Ph.D Overview

Current trends show that a large proportion of youth are not reaching the guideline 60 minutes of MVPA per day recommended for health, and that girls consistently report lower PA levels than boys (Borraccino et al., 2009; Hallal et al., 2012). A significant decrease in PA is seen as children transition from childhood to adolescence (Borraccino et al., 2009; Corder et al., 2015; Nader et al., 2008). This decrease in PA often coincides with a transition from primary to secondary school (De Meester et al., 2014; Jago et al., 2012; Marks et al., 2015). These trends are seen on both an international (Corder et al., 2015; De Meester et al., 2014; Jago et al., 2012; Marks et al., 2015; Nader et al., 2008) and national scale (Gavin et al., 2014; Harrington et al., 2016; Woods et al., 2010). PA is an important factor in promoting good health among youth, with a reduced prevalence of CVD risk factors found in youth who have higher levels of PA (Bailey et al., 2012; Ekelund et al., 2012; Hills et al., 2011; Janz et al., 2002; Kriemler et al., 2010; Nemet et al., 2005; Silva et al., 2014; Warburton et al., 2006). Physical inactivity is itself one of the top five risk factors for premature mortality globally and is also a leading contributor to three of the remaining four risk factors (WHO, 2009). Increasing PA therefore and decreasing inactivity will have massive health benefits in youth. Despite the promotion of PA for the reduction of CVD risk factors in youth, research has not conclusively stated whether it is PA, or improved HRF as a result of a sufficient level and intensity of PA, which brings about a reduced CVD risk (Janz et al., 2002).

MC may be an important factor in developing healthy PA habits, with research evidence promoting the necessity of MC for engagement in PA throughout childhood and adolescence (Barnett et al., 2009; Green et al., 2011; Lloyd et al., 2014). Recently, MC in adolescence has been found to be poor, with a large proportion of adolescents not reaching the expected standard of MC both internationally (Erwin and Castelli, 2008; Mitchell et al., 2013; Okely and Booth, 2004) and nationally (O’Brien et al., 2018; O’Keeffe et al., 2007). Similar to the gender differences seen in PA behaviours, girls consistently report poorer levels of overall MC (Barnett et al., 2009; Breslin et al., 2012; Marja Cantell et al., 2008; Lopes et al., 2011; O’Brien et al., 2018) and specifically poorer object-control skill competency (Barnett et al., 2010; Lisa Barnett et al., 2008; Breslin et al., 2012). Given that girls are already at risk of lower than healthy PA levels, this concomitant inadequacy in MC may add even greater disadvantage to adolescent girls. Findings from the research are inconclusive however, when explaining how both gender and age impact on the importance of MC for promoting PA. In a number of cases, childhood MC has been found to be positively associated with adolescent PA (Barnett et al., 2009; Green et al., 2011; Lloyd et al., 2014; Lopes et al., 2011), but in other cases, especially where girls and younger children are concerned, this relationship has not been found (Green et al., 2011; McKenzie et al., 2002).

Stodden et al. (2008) have proposed and developed a conceptual model that looks at this relationship between MC and PA. The proposed model includes HRF and PC as mediators in the MC-PA relationship (Stodden et al., 2008). Key to the model is the idea that the relationship between MC and PA is reciprocal and developmental. It is hypothesised that MC will promote PA, but that PA will also provide the opportunity for advancing MC. It is also hypothesised that the nature of the relationships between variables in the model will strengthen as children develop (Stodden et al., 2008). There is partial support for aspects of the model, with research showing a strengthening of the MC-PA relationship overtime from early to middle childhood (Fisher et al., 2005; Logan et al., 2015; McKenzie et al., 2002; Williams et al., 2008). Stodden et al. (2008) propose a continuation of this developmental trend into adolescence that has yet to be proven in the research (Barnett et al., 2011; Logan et al., 2015; Okely et al., 2001). The reciprocal relationship element of the model has also not been tested conclusively, particularly with regard to whether this relationship exists for all components that make up the MC composite (Barnett et al., 2011).

In terms of HRF and PC as mediators of the MC-PA relationship, to date there is a lack of research examining this area (Robinson et al., 2015). Where research does examine relationships among Stodden et al.'s (2008) variables, the findings are not conclusive as to the developmental nature of these relationships (Marja Cantell et al., 2008; Gísladóttir et al., 2014; Haga et al., 2015; Stodden et al., 2014). HRF and MC are composite terms that encompass numerous components. The traditional definition of HRF contains the components MS, ME, CVE, flexibility, and body composition (Caspersen et al. 1985; ACSM, 2014), while MC contains three components, namely locomotor, object-control, and stability skills (Gallahue and Ozmun, 2012). Where research has looked at relationships between some of the variables in Stodden et al.'s (2008) model, oftentimes only some of the components of either HRF or MC are examined. To gain a full understanding of the influence of these variables it is important to measure all components, rather than focusing on one or two aspects within each composite. Overall, there is a need for longitudinal studies that can allow for examination of how the MC-PA relationship develops over time, looking at all components of MC, and taking into account the mediating influence of both HRF and PC (Cattuzzo et al., 2014; Logan et al., 2015).

The conceptual model depicts a spiral of engagement between MC and PA (and mediated by HRF and PC) which can be either positive or negative, with a positive spiral of engagement hypothesised to promote health through the maintenance or development of a healthy weight status (Stodden et al., 2008). The importance of weight status as an outcome of the model is clear – weight status is a significant marker of health and disease (Benson et al., 2006; Després, 2012; Freedman et al., 1999; Melo et al., 2014; Raitakari et al., 2003; Shen et al., 2006; WHO, 2018a). Currently the prevalence of overweight and obesity among youth is alarming (Keane et al., 2014; Ng et al., 2014; Ogden et al., 2015; Woods et al., 2010). High prevalence of overweight/obesity coupled with low levels of PA are creating health problems for youth that will negatively affect their lifestyles both now and into adulthood. While all the variables included in Stodden et al.'s (2008) model are independently important, the end goal of health-related research is to improve and promote health. Therefore, Stodden et al.'s (2008) proposed model, if fully tested and validated, may hold the key to potential methods for improving health (weight status) through its four main variables (MC, PA, HRF, PC).

2.5 Purpose of the Current Study

The purpose of the current study is to test the proposed relationships depicted in Stodden et al.'s (2008) conceptual model, with a view to gaining a better understanding of how MC, PA, HRF and PC interact to promote or negate health in youth. Considering the problems posed by the current theoretical definition of HRF, an analysis of the composition of HRF will be conducted to allow for a full examination of the pathways depicted in Stodden et al.'s (2008) model. The transition from childhood to adolescence, often coinciding with the move from primary to secondary school, has been identified as a key period where there is substantial drop-off in PA levels. Recent reviews (Cattuzzo et al., 2014; Logan et al., 2015; Robinson et al., 2015) have highlighted the need for longitudinal studies that monitor changes in the variables identified by Stodden et al. (2008) to develop a clearer picture of what leads youth to withdraw from PA participation as they get older. Given the negative short- and long-term health consequences of physical inactivity in youth, it is essential that we gain a full understanding of the factors leading to declining PA with age. The current study aims to test Stodden et al.'s (2008) conceptual model by measuring PA, MC, PC, and HRF, longitudinally over three years as children transition from primary to secondary school.

CHAPTER 3

Methodology

Chapter 3 Methodology

3.1 Study Design

This study was concerned with tracking changes in PA, MC, HRF, and PC over the transition from primary to secondary school. In a longitudinal study design, measures were taken at three timepoints; final year (6th class) of primary school, 1st year of secondary school, and 2nd year of secondary school. Schools were convenience sampled, using the procedures detailed below, to maximise the availability of participants for longitudinal testing from primary school through the school transition into secondary school.

3.2 Participant Details and Recruitment

Recruitment began with contacting, via email and phone, five specific secondary schools where the majority of 1st year students were known to transfer from three or less feeder primary schools. Two of the secondary schools that were contacted expressed interest in participating, and met the criteria relating to feeder primary schools. Both schools were mixed-gender schools located in the Greater Dublin Area and were comparable in terms of school-level socio-economic status. Approval from participating secondary schools was granted by each school principal, whereupon the relevant feeder primary schools were then contacted. Both secondary schools had three main feeder primary schools. The principal of each of these primary schools was contacted via email and/or phone. All six primary schools expressed interest in participating in the study and were subsequently provided with a plain language statement detailing what the study entailed. All six primary school principals and boards of management gave consent to participate in the study.

Participant demographics for each of the three timepoints are detailed in Table 3.1. Participants were students who began 6th class of primary school in September 2016, and who met the following inclusion criteria: a) attended one of six primary schools which acted as main feeder schools for two selected secondary schools located in the Greater Dublin Area, b) returned informed consent signed by parent/guardian, and c) returned a Physical Activity Readiness Questionnaire (PAR-Q) signed by parent/guardian. Student assent was also provided prior to participation in the study. Ethical approval was granted by DCU Research Ethics Committee (DCUREC2016_109).

In 6th class (time point 1), 261 students met the inclusion criteria. Of the participants involved in 6th class, 37 did not transfer into the designated secondary schools and were therefore not tested in 1st year (time point 2). Participants in 1st year included an additional 75 students who had not attended the initial feeder primary schools giving a total sample of 299 participants at time point 2. In 2nd year (time point 3), students in one secondary school were unavailable to participate due to administrative issues within the school, therefore 108 adolescents were available for participation in 2nd year from one secondary school. There were no significant differences for age or sex between students who attended either secondary school . The total number of participants with data for at least one timepoint was 336. Of the total sample, 224 participants had data for the first two timepoints, and 85 participants were tested at all three time points.

Table 3.1 Participant details

		Primary School	**Secondary School**	
		T1 6th Class	**T2 1st Year**	**T3 2nd Year**
Participants (n)		261	299	108
Age (years)		12.25 ± .37	13.21 ± .39	14.18 ± .50
Sex (%)	**Male**	49	52	48
	Female	51	48	52

No significant difference in demographics between participants who attended one secondary school or the other (p > .05).

3.3 Measures

At each timepoint, the research team was led by the lead researcher/author and included a number of undergraduate and postgraduate students as research assistants. Before each phase of data collection, the research team was trained by the lead researcher in the procedures for the tests used. Each research team member was assigned a station consisting of one to two tests and provided with a testing manual and recording sheet for those tests. Detailed maps of the testing set-up for each of the three testing sessions can be seen in Figures 3.1 – 3.3. Before the first phase of data collection (time point 1) a pilot study to gauge the feasibility of the testing protocols selected was carried out in one primary school that was not part of the study.

Participants were longitudinally assessed on PA, MC, HRF and PC. The first phase of data collection (time point 1: 6th class primary) was completed in February/March 2017 with the second and third phases (timepoint 2: 1st year secondary, timepoint 3: 2nd year secondary) taking place one and two years later, respectively. Each participant was given an ID code which was used for that participant each year. Details of all measures taken are given below.

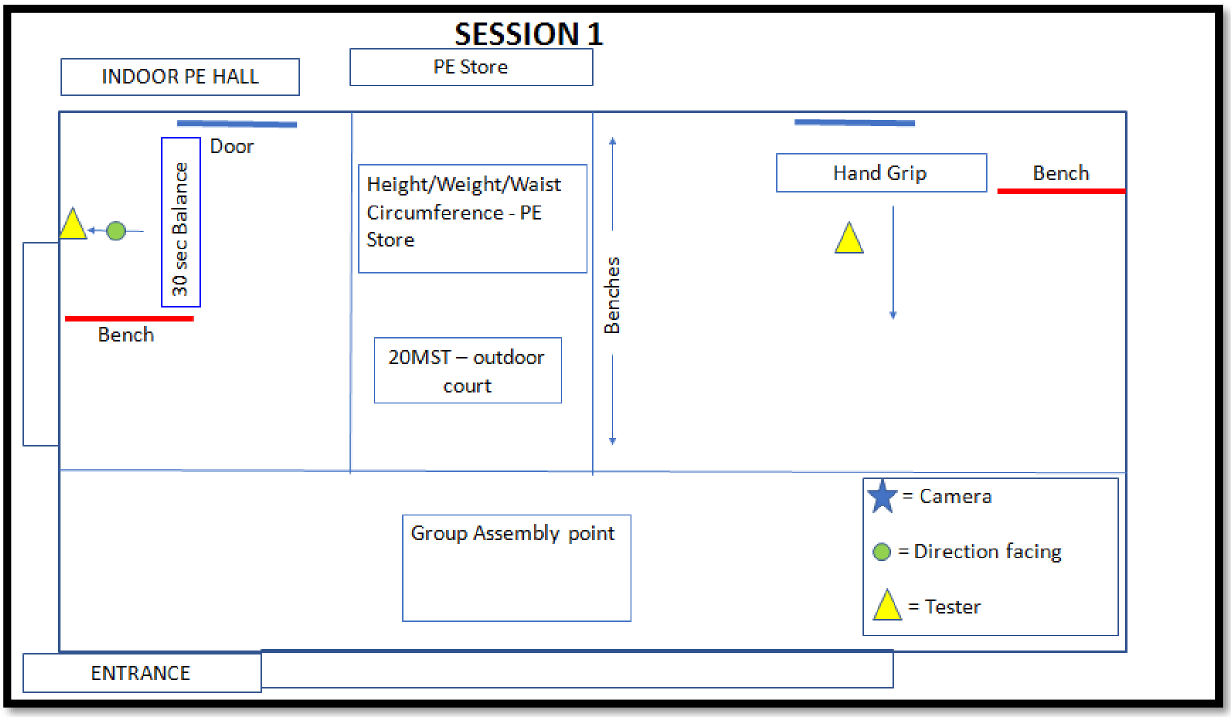


Figure 3.1. Testing set-up – Session 1

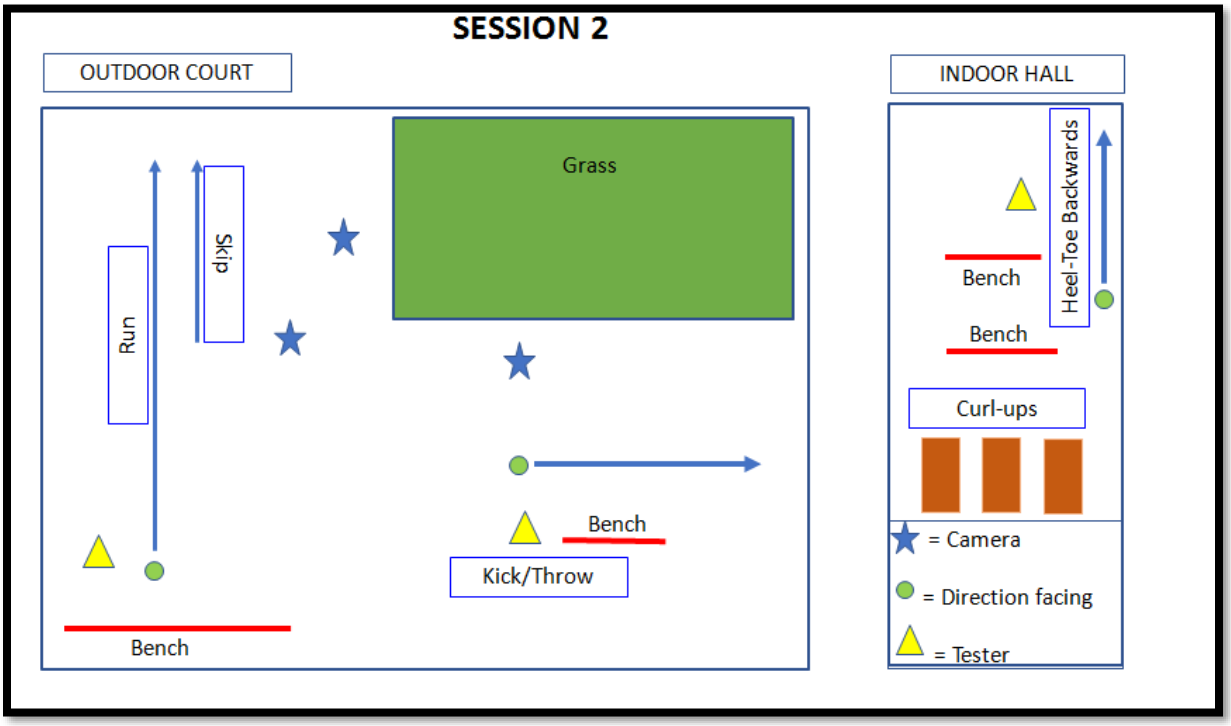


Figure 3.2. Testing set-up – Session 2

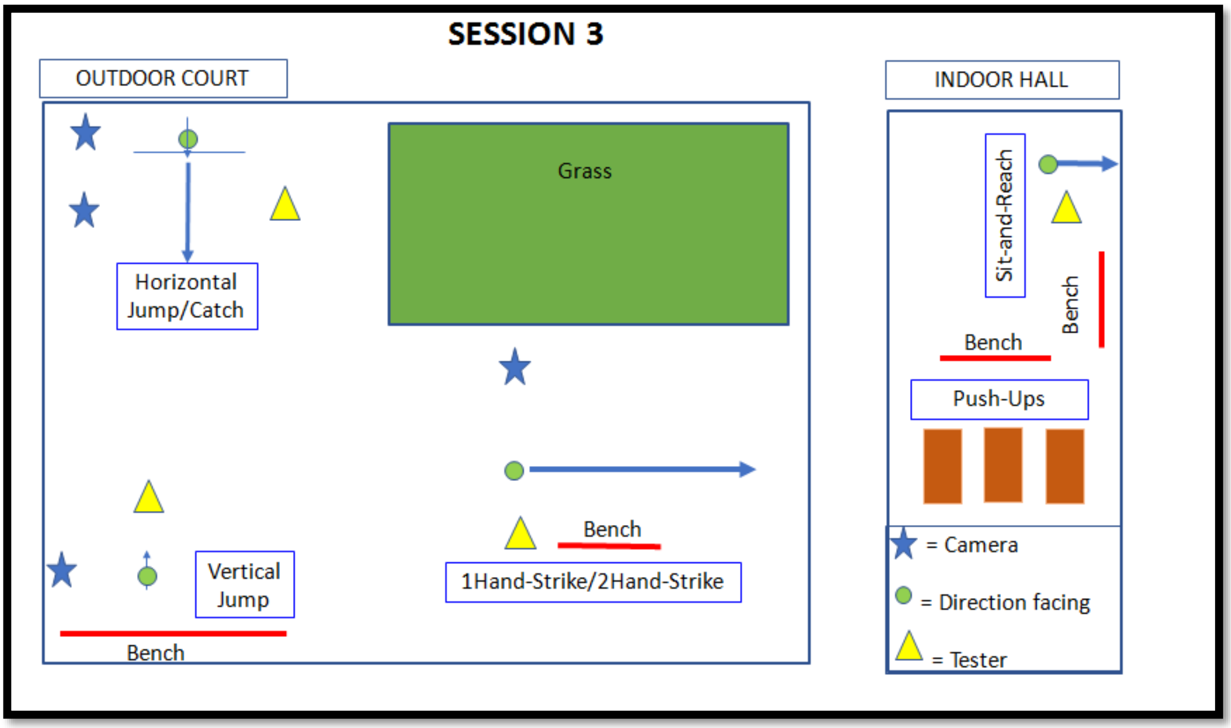


Figure 3.3. Testing set-up – Session 3

3.3.1 Physical Activity

PA was measured objectively using accelerometery (Actigraph models: GT1M, GT3X, GT3X+, wGT3X-BT). Accelerometer validation studies have found the four Actigraph models to be comparable when recording data in the y-axis (Grydeland et al., 2014; Kaminsky and Ozemek, 2012; Powell et al., 2016).

At each time point, prior to testing, accelerometers were charged, initialised for a 9-day period (allowing for exclusion of the first and last days of wear to account for participant reactivity, and incomplete day recording) and labelled with participant ID codes. A record sheet was created with each accelerometer code matched to a participant ID code. Mobile phone numbers were also recorded, when participants elected to provide it, to allow for sending of SMS reminders to wear the accelerometer, a strategy which has been shown to aid compliance (Belton et al., 2013). On the first day of testing at each time point accelerometers were distributed to each class. The testing team demonstrated and verbally explained how to wear the accelerometer. Participants were instructed to wear the accelerometer on their right hip, with the belt adjusted so that the accelerometer was snug against the hip and not bouncing on movement. Participants were advised they could wear the accelerometer under or over their clothes depending on personal preference. Participants were asked to wear the accelerometer for nine consecutive days during waking hours.

Participants were instructed to remove the accelerometer when sleeping and showering/bathing, as well as for water-based activities and contact sports. In addition, each participant received a small plastic bag containing an instruction sheet detailing when and how to wear the accelerometer. Participants were advised to return their own accelerometer into this bag at times when they needed to remove it i.e. for water-based or contact sports. The accelerometers were set to record in 10 second epochs to capture the sporadic and intermittent behaviour of youth (Esliger et al., 2005). Accelerometers were collected at the end of the 9-day period. Data were downloaded and analysed using Actilife version 6.13.3.

3.3.2 Motor Competence

MC was assessed across 12 FMS: kick, catch, overhand throw, one-hand strike, and two-hand strike (object control skills); run, skip, horizontal jump, and vertical jump (locomotor skills); two-board balance, zig-zag hop, and walking toe-heel backwards (stability skills). All object-control and locomotor skills, with the exception of the vertical jump, were assessed according to the performance criteria set out in the Test of Gross Motor Development III (TGMD-III; Ulrich 2016). The vertical jump was assessed in accordance with the criteria set out in the Victoria Department of Education training manual (Victoria Department of Education, 1996). For both manuals, each locomotor and object control skill is made up of specific movement components, with presence or absence of a component scored as 1 or 0 respectively. All stability skills were assessed according to the criteria set out in the Movement Assessment Battery for Children-2 (MABC-2; Barnett et al. 2007) Prior to participants performing each skill, one trained field staff member gave an accurate demonstration of the skill. Each participant had one practice attempt for familiarisation followed by two recorded trials. To ensure consistency, no verbal feedback was given to the participants during the trials. Participants were videoed performing each of the object-control and locomotor skills using Canon type Legria FS21 cameras (Canon Inc., Tokyo, Japan). Cameras were positioned to ensure the entire body was captured throughout the movement. Scoring of these skills was done at a later date by trained members of the research team and the lead researcher. Additional measures, as detailed in Table 3.2 below, were also recorded during testing for seven of the skills to allow for some estimation of outcome along with the process measures described above.

Table 3.2 Additional outcome measures for MC tests

FMS	Outcome Measure	Instrument
Horizontal Jump	cm (to the nearest 0.1cm)	Measuring tape
Vertical Jump	cm (to the nearest 0.1cm)	Jump belt
Run	Speed (m.s)	Speed gates (Brower Timing System)
One-Hand Strike	Speed (km.hr)	Speed gun (Stalker Pro II Sports Radar Gun)
Two-Hand Strike	Speed (km.hr)	Speed gun (Stalker Pro II Sports Radar Gun)
Kick	Speed (km.hr)	Speed gun (Stalker Pro II Sports Radar Gun)
Overhand Throw	Speed (km.hr)	Speed gun (Stalker Pro II Sports Radar Gun)

3.3.3 Health-Related Fitness

Five components of HRF were assessed using protocols from EUROFIT (Council Of Europe, 1983), FITNESSGRAM (Plowman and Mahar, 2013), and the HELENA Study (Ortega et al., 2011). Tests and protocols used to measure the various components of HRF are given in Table 3.3 below.

Table 3.3 Tests and protocols for HRF

HRF Component	Test	Protocol
CRE	20 MST	EUROFIT (Council of Europe 1983, 1988) and FITNESSGRAM (Plowman & Mahar 2013)
MS	Horizontal jump	EUROFIT (Council of Europe 1983, 1988)and HELENA Study (Ortega et al., 2011)
	Vertical jump	HELENA Study (Ortega et al., 2011)
	Hand grip strength	EUROFIT (Council of Europe 1983, 1988) and HELENA Study (Ortega et al., 2011)
ME	Curl-ups	FITNESSGRAM (Plowman and Mahar, 2013)
	Push-ups	FITNESSGRAM (Plowman and Mahar, 2013)
Flexibility	Backsaver sit-and-reach	FITNESSGRAM (Plowman and Mahar, 2013)
Body Weight Status	BMI	EUROFIT (Council of Europe 1983, 1988) and FITNESSGRAM (Plowman and Mahar, 2013)

Trained field staff followed the standardised testing protocols when administering all HRF tests. Some overlap between MC and HRF tests occurred (horizontal and vertical jumps). In these cases, the test was carried out once, with each participant given one practice and two recorded trials and both MC and HRF results were recorded. To ensure consistency with MC tests no feedback was given during the trials. Prior to each HRF test participants were given clear instructions from a trained research team member, along with a demonstration.

For the CRE test (20m shuttle run) participants received clear instructions prior to commencement. Verbal encouragement from the research team was given to motivate participants to reach maximum effort during the 20MST. When testing handgrip strength (MS) each participant was given three recorded trials on each hand. For the ME tests (sit-ups and curl-ups) participants were given one practice attempt of 1-3 repetitions, followed by one recorded trial. Technical feedback was given during the practice attempt only. Flexibility was measured using the back-saver sit and reach, with each participant having four attempts on each leg, and measurement taken on the fourth attempt only. During all HRF tests no performance feedback was given to participants, and participants were not informed of their scores on any of the tests.

Height and weight were measured for each participant. Height was measured to the nearest 0.1cm using a SECA Leicester Portable Height Measure. Weight was measured to the nearest 0.1kg using a Seca 761 dual platform weighing scales. In accordance with standard measurement protocol for height and weight (Health Service Executive, 2012), participants removed their shoes and any heavy clothing before being measured. WC was measured to the nearest 0.1cm.

3.3.4 Perceived Competence

PC was assessed using three subscales of the Self-Perception Profile for Adolescents (SPP-A; Harter 2012) namely; perceived athletic competence (PAC), perceived physical appearance (PPA), and global self-worth (GSW). Each subscale of the SPP-A contains five items (Harter 2012). The answering format requires participants to first decide which teenager they identify with the most, the teenager described in the first part of the sentence, or the teenager described in the second part of the sentence (e.g. "Some teenagers are *not* happy with the way they look, but, other teenagers *are* happy with the way they look"). After making this initial decision, participants must then decide whether the description of the teenager that they decided is most like them is "really true" or "sort of true" for them. Each item is scored from 1 (low PC) to 4 (high PC). Assessment of PC was conducted in a classroom setting (with a maximum of 30 participants) with the primary researcher and/or a trained research team member, and the class teacher present throughout. Prior to answering the questionnaire participants received clear instructions from the researcher. One example question was verbally completed by the researcher to demonstrate the correct answering format. Participants were then instructed to answer the sample question at the top of the questionnaire (SPP-A). The researcher checked that all students had followed the correct answering format before participants continued answering the questions.

3.4 Data Analysis Preparation

3.4.1 Physical Activity

PA data was processed using Actilife software version 6.13.3. The first and last days of the wear period were omitted from analysis to account for subject reactivity (Dossegger et al., 2014). In line with other studies assessing PA across a transition period, a valid day was deemed as having wear-time of greater than or equal to 8 hours (Jago et al., 2012; Marks et al., 2015) . Specific wear-time details for separate studies are given in each chapter. Greater than 20 minutes of zero-counts were identified as non-wear time and activity count values of <0 and ≥15,000 counts per minute were excluded as these count values are deemed biologically impossible (Esliger et al., 2005). Minutes of MVPA per day were calculated by applying the Evenson et al. (2008) cut-points which equate counts per minute to a particular intensity of PA (i.e. sedentary, light, moderate, vigoous). Evenson et al. (2008) cut-points have been validated for use in youth (Trost et al., 2011) and used in studies with similar samples to the participants in this study (Jago et al., 2012; Marks et al., 2015; O' Brien et al., 2015b).

3.4.2 Motor Competence

MC data scoring for the nine skills taken from the TGMD-III (Ulrich 2016) and Victoria Department of Education (1996) manuals was carried out post test day by analysing the recorded video footage of each participant. A minimum inter-observer agreement between trained field staff of 95% was required for scoring each of the nine skills (kick, catch, throw, one-hand strike, two-hand strike, run, skip, horizontal jump, and vertical jump). Each skill is made up of specific movement components. The presence of a component was marked with a score of 1, while the absence of a component was marked with a score of 0. Previous studies have defined "Mastery" as the presence of all skill components in both trials, while "Near Mastery" is defined as the presence of all but one skill component in both trials (Van Beurden et al. 2003). For each of the nine skills taken from the TGMD-III (Ulrich, 2016) and Victoria Department of Education (1996) manual the number of components present over two trials was summed for each participant, giving a score for each skill. The three stability skills (two-board balance, zig-zag hop, walking toe-heel backwards) were scored using the MABC-2 manual (Barnett et al. 2007). Each of the three skills was scored on the testing day, producing a raw score indicating time in seconds (two-board balance), number of consecutive hops (zig-zag hop), and number of steps (walking toe-heel backwards) (Barnett et al. 2007). Using the participant's age in years and months each raw score was converted to a standard score and then the three standard scores for the balance skills were summed to produce a balance composite score. The MABC-2 manual allows for comparison of scores for components (e.g. balance) to standard and percentile scores (Barnett et al. 2007).

3.4.3 Health Related Fitness

Maximum running speed on the 20MST, taken as the speed in km/hr of the participant's last completed shuttle, was used to calculate VO_{2max} (Léger et al. 1988). Maximum height (VJ) and distance (HJ) jumped was calculated. Maximum grip strength on each hand was calculated. These two scores were averaged to give a mean total grip strength score. The total number of curl-ups and push-ups achieved, as well as the distance reached in the back-saver sit-and-reach test was calculated. Scores on FITNESSGRAM HRF tests were compared to FITNESSGRAM norms to assign participants to healthy fitness zones or not. World Health Organisation Child Growth Standards for BMI (de Onis et al., 2007) were used to categorise participants into severe thin, thin, normal weight, overweight, and obese categories.

3.4.4 Perceived Competence

The scores for the 5 items of each subscale of the SPP-A (PAC, PPA, and GSW) were averaged to give a mean PC score of between 1 and 4 for each specific subscale (Harter 2012).

3.5 Data Treatment

3.5.1 Data Storage

Hard copies of record sheets and questionnaires from each time point were stored in a locked filing cabinet in the office of the lead researcher in the School of Health & Human Performance at Dublin City University. For questionnaires, the front page, which contained the participant name, was removed and destroyed once the participant ID number on the first page was cross-checked with the name. Video files were transferred from camera SD cards to a password-protected external harddrive and then deleted from the cameras.

3.5.2 Data Entry

Participant details and corresponding ID codes were entered into an SPSS spreadsheet. At each timepoint this spreadsheet was updated to include additional participants. A separate SPSS spreadheet was created to enter all test data along with participant ID codes. At each time point, the lead researcher created blank Excel templates for each of the tests. The research team were trained by the lead researcher in how to enter the data into these master

Excel sheets. Excel spreadsheets were then converted to SPSS files, and merged by the lead researcher to create a single file for each timepoint. The output SPSS file was inspected to ensure correct matching of participant ID codes across time points. Finally, the SPSS spreadsheets for each time point were merged on completion of data entry at time point 3, to create one SPSS file containing data across the three years.

3.5.3 Data Cleaning

Basic descriptive statistics (means, standard deviations, frequencies, maximums, minimums) were conducted to check the data. Where minimum or maximum values were found to be below or above the range defined (i.e. below 0 or above 1 for criteria in the TGMD skills) the value was cross-checked with the relevant hardcopy and corrected accordingly.

3.5.4 Statistical Analysis

Details of the specific analysis carried out for each study can be found in Chapter 4 – 7. Statistical analysis included descriptive statistics, independent samples t-tests, confirmatory factor analysis, repeated-measures ANOVA, path analysis, and cross-lagged regressions. Confirmatory factor analysis, path analysis, and cross-lagged regressions were conducted using AMOS version 23. All other statistical analysis was conducted using SPSS version 23.

CHAPTER 4

What is Health-Related Fitness? Investigating the underlying factor structure of fitness in youth.

Chapter 4 Study 1

4.1 Purpose of the chapter

4.1.1 Rationale

There is a scarcity of research on the role of HRF within Stodden et al.'s (2008) conceptual model. This is in part due to difficulties in analysing relationships between HRF and other health-related variables while accounting for the multicomponent nature of HRF. The purpose of this study was to test the underlying factor structure of HRF in youth to create a composite score that could be used in subsequent analyses within this thesis of the pathways hypothesised in Stodden et al.'s (2008) conceptual model.

4.1.2 Contribution to the field

This study adds to the field by providing a statistically and theoretically proofed HRF composite that is representative of the HRF construct in youth. Where previously researchers were inclined to choose just one component of HRF when analysing relationships between HRF and other variables, or combined HRF test scores into an equally weighted composite, this study provides a HRF composite that accounts for the relative importance of each component of HRF, providing the means to analyse relationships between HRF, as a composite, and other health-related variables.

4.1.3 Peer review status

The study in this chapter was presented as a poster presentation at the 2018 European College of Sport Science conference. It is currently under review in the European Physical Education Review under the title; *What is Health-Related Fitness? Investigating the underlying factor structure of fitness in youth.*

4.2 Abstract

Health-related fitness (HRF) is theoretically defined as a multidimensional construct containing the components cardiorespiratory endurance, muscular strength, muscular endurance, flexibility and body composition. Given the range of field-based HRF tests available, health practitioners face a difficult task in selecting tests that best reflect the HRF construct as defined in the literature. This study aimed to investigate the underlying factor structure of the theoretical HRF construct with a view to identifying field-based tests representative of HRF in youth. Participants were 261 children (53% female, 47% males; mean age 12.22 ± 0.48 years). Indicators of four fitness components (20m shuttle run, curl-ups, push-ups, horizontal jump, vertical jump, grip strength, and modified-back-saver-sit-and-reach) were measured. Confirmatory factor analysis of the four-component model revealed a low contribution of flexibility (.10) to the overall model, leading to its removal. The subsequent three-component model showed better fit across all fit statistics (NFI, TLI, CFI, RMSEA, SRMR). Analysis of indicator loadings led to the removal of grip strength (.37), further improving model fit. The reduced three-component model was re-specified as a first-order model containing five indicators, and showed the best fit (NFI, CFI, SRMR). These findings suggest that a fitness construct in youth is adequately represented by three HRF components included in the theoretical definition (cardiorespiratory endurance, muscular strength, muscular endurance). These components load onto the same construct and can be tested using five (20m shuttle run, curl-ups, push-ups, horizontal jump, vertical jump) tests suitable for field-based research.

4.3 Introduction

Physical fitness is a powerful indicator of health among youth (Ortega et al., 2008; Ruiz et al., 2009). In children and adolescents higher fitness levels are associated with positive outcomes for bone health, mental health, obesity, and cardiovascular disease (CVD) (Ortega et al., 2008; Ruiz et al., 2009). It is important to note however that physical fitness is a hypothetical construct (Marsh, 1993). In the past, studies assessing physical fitness have included a range of variables, from blood pressure, lung function, and body girth, to cardiorespiratory endurance (CRE), strength, coordination, and flexibility (Fleishman, 1964; Marsh, 1993). A definition of health-related fitness (HRF) was proposed by Caspersen and colleagues (1985), who suggested that HRF is a multidimensional construct comprised of five components (Caspersen et al., 1985). Specifically, these five components are CRE, muscular strength (MS), muscular endurance (ME), flexibility, and body composition. CRE refers to the capacity of the respiratory and cardiovascular systems to carry out continuous strenuous exercise (Ortega et al. 2008). MS is the ability of the muscular system to produce force against a resistance in one maximal effort (Smith et al., 2014). Many researchers in the health field choose tests of explosive (e.g. horizontal and vertical jumps) strength or power to represent MS as a component of fitness (Ortega et al., 2011; Tomkinson et al., 2018). ME is the ability of the muscular system to produce force over a prolonged period (Ortega et al. 2008; Smith et al. 2014). ME and MS together contribute to muscular fitness (MF), a term that refers to the ability to do work against a resistance either maximally, explosively, or repeatedly (Ortega et al. 2008; Smith et al. 2014). Flexibility is the range of motion at a joint (Pate, Oria and Pillsbury, 2012). Body composition is the physical make-up of the body, often described as the percentage of muscle, fat, bone and water within the body (Caspersen et al. 1985). This definition of HRF, as a multidimensional construct consisting of five components, is predominantly accepted and utilised within health-promotion research (ACSM, 2014; Payne and Isaacs, 2016). According to Pate (1988) these five components were included in the HRF construct because they are affected by physical training and are associated with important health outcomes.

Recent research provides evidence for associations between health and CRE, MS and ME (Ortega et al. 2008; Smith et al. 2014), but there is limited evidence to suggest an association between health and flexibility (Pate, Oria and Pillsbury, 2012). The relationship between CRE and health is well-established (Corbin et al. 2014; Pate et al. 2012; Ortega et al. 2008). In their review, Ortega and colleagues (2008) found strong evidence for associations between CRE and adiposity, CVD risk, quality of life, and mental health. Associations between MF and health have been reported, but are less well established (Corbin et al. 2014; Ortega et al. 2008). Despite this there is growing evidence for the benefits of MF for health among youth. Specifically, superior MS and ME have been favourably associated with a reduced risk of insulin insensitivity (Benson et al., 2006), a reduced likelihood of excess adiposity (Grøntved et al., 2015b; Janz et al., 2002; Smith et al., 2014), and a reduced risk of CVD (Grøntved et al., 2015b; Janz et al., 2002). Longitudinal studies have also identified the importance of developing MF at a young age for maintaining good health later in life (Grøntved et al., 2015a; Janz et al., 2002; Ruiz et al., 2009). There is limited research on the relationship between flexibility and health in youth (Pate, Oria and Pillsbury, 2012). Studies that have measured flexibility and health outcomes have not found significant associations (Casonatto et al., 2016; Stodden et al., 2015). It is worth questioning, then, the inclusion of flexibility as a component of HRF, given the lack of research evidence supporting its link to important health outcomes.

Another problem arising from a five-component HRF construct occurs when body composition is positioned as an outcome of relationships between HRF and other variables. This is common in health promotion research (Lima, Pfeiffer, et al. 2017; Rodrigues et al. 2016; Casonatto et al. 2016; Bailey et al. 2012; Smith et al. 2014; Janz et al. 2002; Grøntved et al. 2015b). A current conceptual model developed by Stodden et al. (2008) highlights physical activity, motor competence, HRF, and perceived competence as central to health in youth. This model proposes HRF as a mediator in the reciprocal relationship between motor competence and physical activity, while "weight status" is presented as the outcome of these relationships. From a methodological perspective, indicators (e.g. body composition) cannot be both independent and dependent variables. Therefore, where measures of body composition are outcomes of the research question, HRF can only be treated as a four-component construct (should flexibility remain as a component of the construct). In addition, assessment of body composition involves passive tests such as measuring height, weight and body circumferences, compared to the four remaining components of HRF which are measured using active tests that require the participant to perform some action or skill (e.g. running to measure CRE; jumping to measure MS). This further highlights the difference in nature between body composition and the other components of HRF included in the traditional definition (Caspersen et al., 1985) lending support to the argument for removing body composition as a component, thus reducing HRF to a four-component construct.

Another issue of note is that within the field of health promotion research, all components of HRF are not always measured when associations between HRF and other variables are being examined. Often, individual tests from popular fitness test batteries are chosen, with selected tests used to measure specific components of HRF. For example, FITNESSGRAM (Plowman and Mahar, 2013) suggests push-ups, curl-ups and trunk extension as methods to assess MF while EUROFIT (Council of Europe, 1983), dividing MF into MS and ME, offers a bent-arm hang in addition to curl-ups to assess ME, and an arm-pull and standing broad jump to assess MS. If HRF is a multidimensional five component construct, then important information may be lost by measuring just one component and using this as a representation of the overall construct. For example, in recent studies testing Stodden et al.'s (2008) conceptual model, just one component of HRF (CRE) was measured (Lima, Pfeiffer, et al., 2017). CRE is evidently an important HRF component (Ortega et al., 2008; Ruiz et al., 2009), but considering the reported contribution of both MS and ME to health in youth (Benson et al., 2006; Grøntved et al., 2015a; Janz et al., 2002; Ortega et al., 2008; Smith et al., 2014) the exclusion of these components may be problematic.

Numerous valid and reliable HRF tests are available to the researcher for use in field-based settings (Artero et al., 2011; Morrow et al., 2010; Ortega et al., 2008). In addition to a requirement for valid and reliable measures, time and equipment/facilities are extremely important considerations for researchers and health practitioners. As such, some of the available fitness tests are more applicable than others in certain settings. For example, tests of ME such as curl-ups and push-ups are easy to administer and require little equipment (Plowman and Mahar, 2013). In comparison, tests such as pull-ups, or flexed arm hang, require gym equipment that may not be available in some field settings (Council of Europe, 1983; Plowman and Mahar, 2013). Given the wide range of options available to field-based researchers, the decisions around a testing protocol which includes tests of HRF that reflect the overall construct can be problematic.

Despite numerous studies assessing components of HRF, to the author's knowledge no study has assessed the factor structure of this theoretical construct among youth. Given that various individual components of HRF are often used as indicators of the overall construct, it is important to understand the underlying structure of HRF so that discussions of HRF are talking about a general and comparable concept. In addition, although sex differences in absolute scores for HRF are widely reported, with males consistently scoring higher than females across all HRF components except flexibility (Ortega et al., 2011; Santos et al., 2014), it is generally accepted that the overall HRF construct is the same for males and females. To the author's knowledge, no study has tested this assumed sex invariance for HRF.

This research aims to test, using factor analysis, a four-component HRF construct based primarily on the theoretical definition of HRF (Caspersen et al., 1985) but excluding the component of body composition (due to the previously outlined problems posed by its inclusion as an independent variable), to determine the underlying structure of HRF within a youth population and to test its invariance across sex. In addition, this research aims to provide support for the selection of specific field-based tests which can adequately represent the HRF construct within a youth population.

4.4 Methods

4.4.1 Participants and settings

Data for this cross-sectional study were collected as part of the first phase of a longitudinal study which aims to track changes in health-related variables in children as they transition from primary to secondary school. Principals from six mixed gender primary schools were contacted via email to invite their 6th class students to participate in this study. These schools were specifically chosen as they were identified as the main feeder primary schools for two second level schools which were invited to, and confirmed participation in, phase two of the longitudinal aspect of this study. Informed consent was granted by all six primary school principals, and individual consent was obtained from parents/guardians. Ethical approval was obtained from the authors' institutional ethics committee. Prior to testing, a physical activity readiness questionnaire was also completed for each participant by their parent/guardian. The consenting sample consisted of 261 children (53% female and 47% males; mean age 12.22 ± 0.48 years).

4.4.2 Measures

Seven tests were used to measure four components (MS, ME, CRE and flexibility) of HRF (Table 4.1). Tests were selected following a review of methodologies in recent large-scale studies of HRF in youth (Ortega et al., 2011; Ruiz, Castro-Piñero, et al., 2011; Santos et al., 2014), with specific consideration paid to the applicability of tests within a school-based setting, test reliability, and the ability of the tests to measure each of the four specified components of the proposed HRF construct. Protocols for each HRF test can be found in the FITNESSGRAM manual (Plowman and Mahar, 2013), the EUROFIT manual (Council of Europe, 1983), and the HELENA study (Ortega et al. 2008; Ortega et al. 2011) (Table 4.1).

Table 4.1. Measurement of HRF

HRF Component	Test	Source	Reliability
CRE	20MST	FITNESSGRAM; EUROFIT	0.78 - 0.99 (Artero et al. 2011)
MS	Grip strength	EUROFIT; HELENA Study	0.96 - 0.98 (Artero et al. 2011)
	HJ	EUROFIT; HELENA Study	p > .05 test-retest differences (Ortega et al. 2008)
	VJ*	HELENA Study	p > .05 test-retest differences (Ortega et al. 2008)
ME	Pushups	FITNESSGRAM	0.77 (Morrow et al. 2010)
	Curlups	FITNESSGRAM	0.87 (Morrow et al. 2010)
Flex	BS S&R	FITNESSGRAM	0.89 (Morrow et al. 2010)

20MST=20metre shuttle run test; HJ=horizontal jump; VJ=vertical jump; BS S&R=backsaver sit-and-reach; EUROFIT (Council of Europe 1983). FITNESSGRAM (Meredith & Welk 2010). The HELENA Study (Ortega et al. 2008). *VJ was assessed using the Abalakov jump test protocol outlined in the HELENA study (Ortega et al. 2008) and using a jump mat and belt (Coulson & Archer 2009) in place of an infrared jump platform.

A minimum of four trained field staff conducted the testing sessions. Each class group was tested separately, with approximately 25 students in each class group. Testing was performed over the course of three separate physical education classes. 20MST, and grip strength were tested on the first day, curlups on the second day, and HJ_{max}, VJ_{max}, pushups, and BS S&R on the third day. On each day participants were put into groups of 5-6 students and each group rotated through the tests in a circuit fashion. One trained field staff member provided every 5-6 participants with a demonstration and verbal instructions of the test, the exception being the 20MST where groups of 10-12 participants were given a demonstration and instructions prior to beginning the test. Trained field staff followed the standardised testing protocols (Council of Europe, 1983; Ortega et al., 2011; Plowman and Mahar, 2013) when administering all tests. For the 20MST verbal encouragement from field staff was given to motivate participants to reach maximum effort. Speed reached on the last completed shuttle in the 20MST was used to calculate VO_{2max} (Léger et al., 1988). No performance feedback was given to participants during testing, and participants were not informed of their scores on any of the tests.

4.4.3 Data Analysis

Data were analysed using SPSS version 23 and AMOS version 23 for Windows. Raw scores for each HRF test were entered into SPSS and descriptive statistics for each HRF test were calculated. A one-way between-groups multivariate analysis of variance (MANOVA) was conducted to identify sex differences for HRF tests. A Bonferroni adjusted alpha level of < .017 was used to calculate significance. Effect sizes were calculated to identify the magnitude of any differences.

To analyse the underlying structure of HRF, a confirmatory factor analysis (CFA) using maximum likelihood estimation methods was conducted in AMOS version 23 (Arbuckle, 2014). CFA is widely used to test whether a hypothesised model fits the data (Fox, 2010). The initial model tested a four component HRF construct (Model 1; Fig. 4.1) based primarily on the theoretical definitions of HRF (Caspersen et al., 1985;ACSM, 2014; Pate, 1988; Payne and Isaacs, 2016) while taking into account the argument for excluding body composition as the fifth component. Within CFA, the presence of single-indicator latent variables (such as CRE in Fig 4.1) can cause identification issues (Kelloway, 1998; Kline, 2015). To address this identification issue in the current study, and enable the testing of the theoretically defined HRF construct, the error variance for CRE was set to 0 and the loading to 1 as recommended in Lämmle et al. (2010). To account for missing data, the nature of missing data was tested using Little's "missing completely at random" MCAR test (χ^2 = 2016.83; $p = 0.971$). A statistically non-significant result for Little's MCAR test allows for MCAR to be inferred (Tabachnick and Fidell, 2007). Where data is MCAR and there is a low percentage of data missing, most procedures to deal with this issue can be used successfully (Tabachnick and Fidell, 2007). In this data set all measured variables had low levels of missing data (< 7%). Group mean substitution was therefore selected to estimate missing values (Tabachnick and Fidell, 2007).

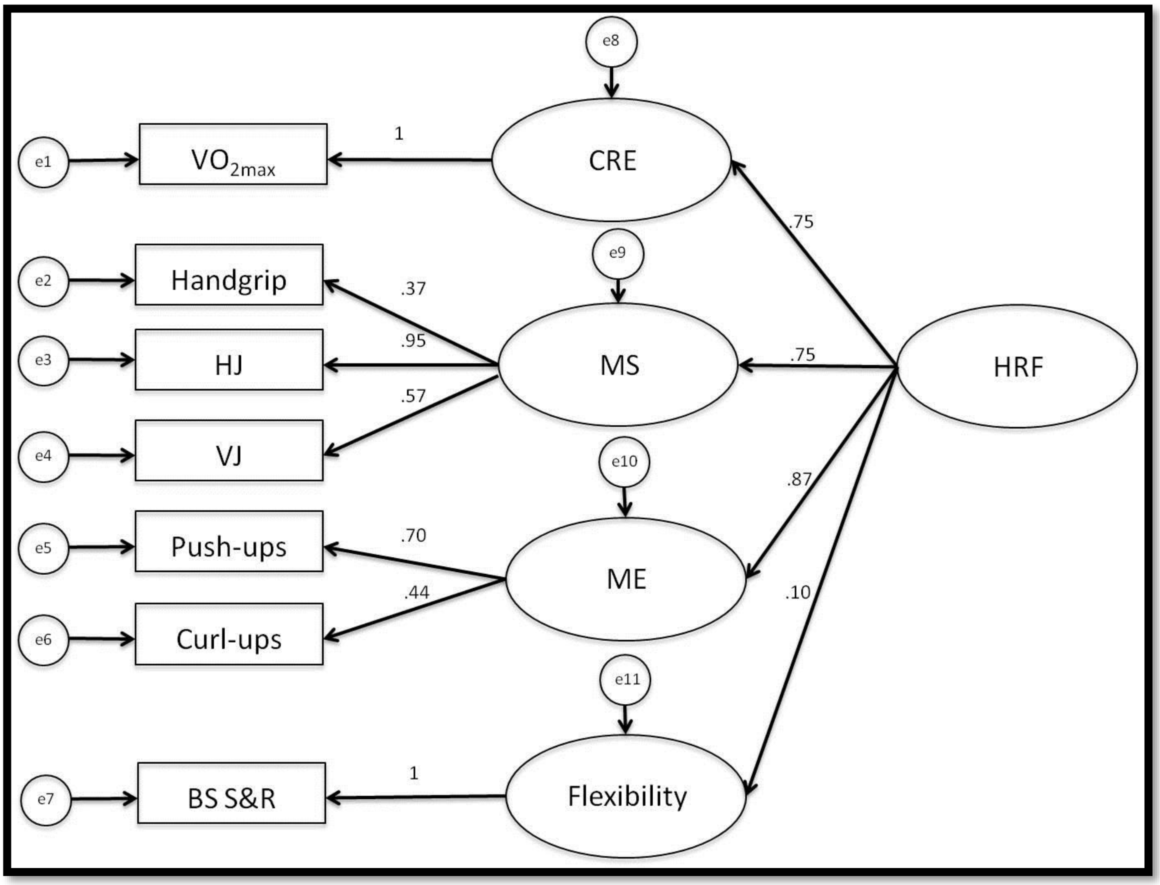


Figure 4.1. Model 1 – Four component HRF model

To begin with, χ^2 was used to assess goodness of fit between the observed and fitted covariance matrices. A statistically insignificant χ^2 indicates a good fitting model, even though a poor χ^2 does not necessarily imply a poor model fit, since χ^2 can give erroneous results with large samples (Byrne, 2010). In addition, model fit was further assessed based on the Normed-Fit Index (NFI), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardised Root Mean Square Residual (SRMR). NFI, TLI and CFI values of >0.9 signify acceptable model fit (Byrne, 2010; Schumacker and Lomax, 1996), with values of >0.95 for TLI and CFI considered to signify superior fit (Hu and Bentler, 1999). For RMSEA and SRMR, values of <0.06 and <0.08 respectively indicate a good fitting model (Hu and Bentler, 1999). The strength of each factor loading was inspected to determine its contribution to the model. Factor loadings approaching 0.30 are generally deemed to indicate poor contribution of that factor to the model (Brown, 2006). Decisions on the removal or retention of factors were made based both on evaluation of factor loadings and theory. Based on analysis of the factor loadings for the four-component HRF construct (Fig. 4.1 Model 1), additional models were subsequently tested, and a multiple-group analysis was used test invariance in the HRF construct across sex.

4.5 Results

Performances on each HRF test are shown in Table 4.2. One-way MANOVA revealed significant sex differences for VO_{2max}, HJmax, push-ups, and flexibility (Table 4.2). The importance of the differences can be seen by examining the effect sizes in Table 4.2. According to Cohen (1992) effect sizes of .20 - .49 are small, .50 - .79 are medium, and ≥.80 are large. Males had significantly higher scores for VO_{2max}, HJmax and push-ups. Females had significantly higher scores for flexibility. VO_{2max}, push-ups, curl-ups and BS S&R tests were all tested in accordance with FITNESSGRAM (Plowman and Mahar, 2013) protocols. When these HRF test-scores were assigned age and sex-specific values in accordance with FITNESSGRAM norms (Ortega et al., 2011; Plowman and Mahar, 2013) one-way MANOVA showed no significant sex differences for standardised scores.

Table 4.2. Mean HRF scores according to sex

						Sex Difference	
	All (n=262)	**Males (n= 129)**	**Females (n=133)**	**F**	**η2**	**Absolute values**	**Fitnessgram norms**
VO2max (ml.kg.min)^F	49.66 (5.03)	51.11 (5.39)	48.21 (4.19)	20.2	0.08	m *	ns
Handgrip (kg)	17.73 (4.11)	18.10 (3.90)	17.34 (4.31)	1.7		ns	
HJ (cm)	37.21(23.28)	144.93(22.65)	129.85(21.49)	23.2	0.10	m *	
VJ (cm)	35.49 (6.87)	36.74 (7.31)	34.30 (6.22)	6.2		ns	
Push-upsF	8.68 (8.01)	11.27 (8.74)	6.09 (6.25)	23.9	0.10	m *	ns
Curl-upsF	13.54(10.77)	15.26 (11.88)	11.80 (9.23)	6.9		ns	m *
BS S&R (cm)^F	9.93 (7.64)	7.07 (7.13)	12.66 (7.11)	29.2	0.12	f *	ns

Data are shown as means with standard deviation in brackets.

*Significant at Bonferroni adjusted p-value < .017. η^2 = partial eta squared effect size

"m" or "f" in the sex difference column denotes the sex (m=male, f=female) that performed significantly better. **F =** included in Fitnessgram

Table 4.3. CFA fit statistics for HRF Models

Model	Description	χ^2	Df	Prob	NFI	TLI	CFI	RMSEA	SRMR
Model 1	4 Component model (CRE MS ME Flex)	31.91	12	0.001	0.91	0.90	0.94	0.080	0.057
Model 2	3 Component model (CRE MS ME)	17.74	7	0.013	0.95	0.93	0.97	0.077	0.045
Model 3	Reduced 3 Component model (CRE MS ME)	10.80	3	0.013	0.97	0.91	0.97	0.100	0.037
Model 4	1st Order Model	10.80	3	0.013	0.97	0.91	0.97	0.100	0.037

$\chi 2$ = Chi-square test. Df = degrees of freedom. Prob. = probability. NFI = Normed Fit Index; TLI = Tucker-Lewis Index; CFI = Comparative Fit Index; RMSEA: Root mean square error of approximation; SRMR = Standardized Root Mean Square Residual

Factor analysis results showed that all of the models tested fit the data well (Table 4.3), with NFI, TLI, and CFI all above 0.9 (Byrne, 2010; Schumacker and Lomax, 1996). In Model 1, a four component second-order model, HRF was described primarily by three components, CRE, MS and ME, with factor loadings ranging from 0.75 – 0.87; (Fig. 4.1). Given the low loading for flexibility (0.10) (Brown, 2006), it was removed as a component and a three-component model (Fig. 4.2: Model 2) was subsequently tested.

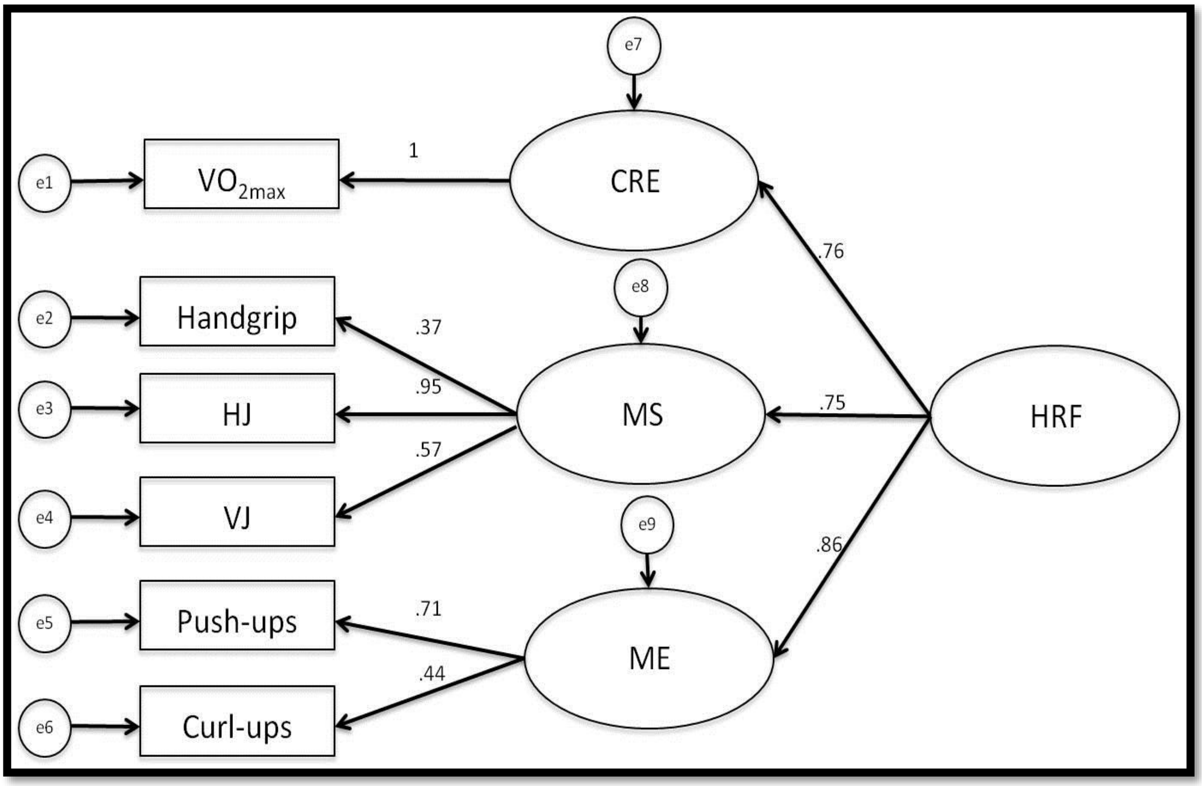


Figure 4.2. Model 2 – Three component HRF Model

Factor loadings remained similar for CRE (0.76), MS (0.75) and ME (0.86) in the three-component (Fig 4.2) compared to the four-component model (Fig 4.1). On reviewing the loadings on the manifest variables for the three-component model (Fig 4.2), grip strength was removed from MS due to its low loading (0.37). Removing grip strength did not have a negative effect on fit. A number of the fit indices improved slightly (NFI, SRMR) and a number decreased slightly (TLI, RMSEA). CFI, TLI, NFI and SRMR all remained within acceptable limits for a good fitting model (Byrne, 2010; Hu and Bentler, 1999; Schumacker and Lomax, 1996). An examination of the confidence intervals for RMSEA showed the lower confidence limit met the rules of thumb for fit. The reduced three component model (Fig 4.3) was therefore selected as it was a more parsimonious model.

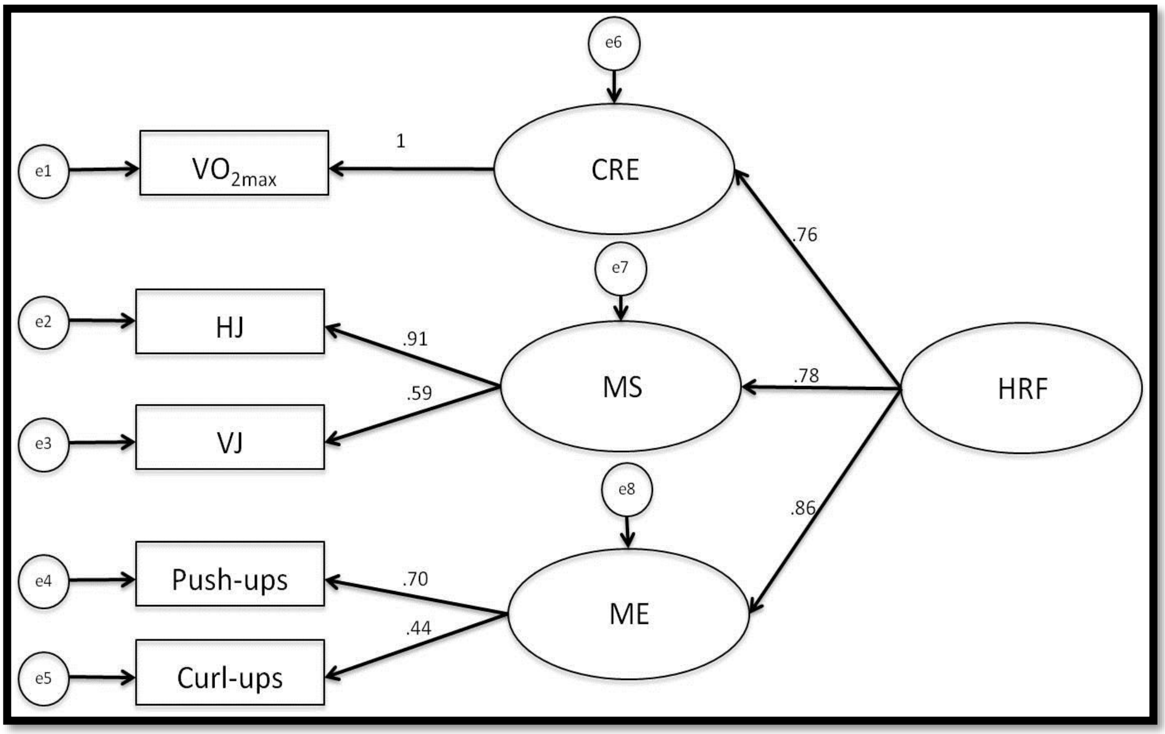


Figure 4.3. Model 3 – Reduced three component HRF model

The reduced 3 component model was then re-specified as a first-order model given the identification issues posed by single indicator latent variables (Kelloway, 1998; Kline, 2015) and with a view to identifying the factor loadings for each individual test in the overall HRF construct (Fig. 4.4). Error terms for HJ and VJ, and push-ups and curl-ups were correlated (Fig 4.4; Model 4) since HJ and VJ both measure MS, and push-ups and curl-ups both measure ME. The fit indices were identical for the second-order reduced 3 component model (Fig 4.3), and the first-order model (Fig 4.4). This is expected, given that correlating the errors on the two MS and two ME indicators in the first-order model in effect connects these indicators in the same way as having them as indicators within a component i.e. MS or ME.

Multiple-group analysis of the re-specified first-order HRF model (Fig. 4) showed good fit (Table 4.3). This HRF model was invariant across sex (CMIN = 5.547; p = 0.236) for factor loadings. As expected, measurement intercepts were significantly different between males and females (CMIN = 51.618; p = 0.000), but the overall pattern of factor loadings was invariant (Table 4.4).

Table 4.4. Factor loadings (β) for indicators of HRF by sex

	Male	**Female**
VO_{2max}	0.68	0.80
HJ_{max}	0.61	0.76
Push-ups	0.61	0.47
VJ_{max}	0.40	0.45
Curl-ups	0.28	0.43

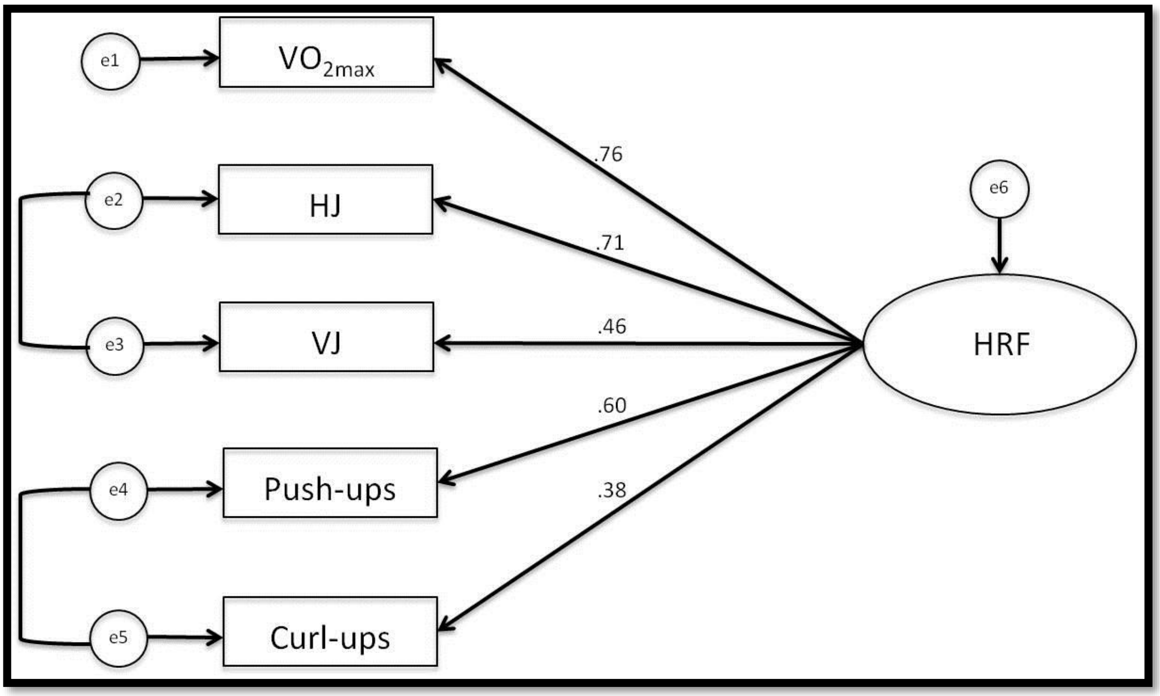


Figure 4.4. Model 4 – First order HRF model

4.6 Discussion

The primary purpose of this study was to test the factor structure of a four component HRF construct, based largely on the dominant definition of HRF (Caspersen et al., 1985), but excluding body composition as a component due to the aforementioned problems associated with its inclusion. The underlying factor structure of the hypothetical HRF construct has not been reported in youth. Testing the structure of this construct was therefore important considering the widespread research in this area, and the need to present HRF as a construct that makes both theoretical and statistical sense.

Results from this study suggest a different definition of HRF to the five-component HRF construct most frequently referred to in the literature. Prior to model testing body composition was excluded as a component of HRF. It is reasonable to argue that due to the difference in nature between assessments of body composition and the remaining HRF components, and the frequent positioning of body composition as the dependent variable when HRF is an independent variable, that the inclusion of body composition in an overall HRF construct makes neither theoretical nor statistical sense. Thus, the initial statistical testing of the HRF construct was of a four-component construct containing indicators of the components CRE, MS, ME, and flexibility.

The best fitting model (Hu and Bentler, 1999) proved to be a reduced three-component construct (Fig. 4.3), which, given the known identification problems posed by single-indicator latent variables (Kelloway, 1998; Kline, 2015) (CRE in this case), was re-specified as a first-order model (Fig. 4.4). Correlating the errors for the two MS indicators (HJ and VJ) and the two ME indicators (push-ups and curl-ups) in effect combined these into separate MS and ME components, highlighted by the identical fit statistics for the first-order and second-order models (Table 4.3). This model suggests then that HRF in youth is best represented by three rather than four components, where indicators with higher loadings (VO_{2max}, HJmax, and push-ups) play a more important role. The three components retained in the HRF construct were CRE, MS, and ME. Flexibility was removed due to its low factor loading (0.10). The removal of flexibility as a component of HRF is supported by previous research which has highlighted the lack of association between flexibility and health in youth (Casonatto et al., 2016; Stodden et al., 2015). In their analysis of the factor structure of motor performance ability (MPA) in youth, a construct not dissimilar to HRF, Lämmle et al., (2010) also found a similarly low contribution of flexibility to the overall MPA construct. Results from Lammle and colleagues (2010), and findings from the present study, suggest that flexibility might be better considered as an independent element rather than being included in an overall fitness construct.

Analysis of the factor loadings within the first-order model in the current study shows that VO_{2max}, as a measure of CRE, is the most important indicator, with a loading of 0.76. The fact that a measure of CRE is of such significance to the overall HRF construct is not surprising, given the widely reported association between CRE and health in youth (Corbin et al., 2014; Ortega et al., 2008; Pate, Oria, Pillsbury, et al., 2012), and the importance placed on this component in studies of youth health and fitness. In fact, CRE is the most extensively measured component of HRF, with researchers often choosing to test CRE exclusively as a measure of HRF when there is a desire to limit the number of tests in a research protocol. Results from this study however strongly suggest that HRF cannot be described by just one component. Recently, MF has begun to receive more attention in the health research field, with studies showing positive associations between muscular fitness and health in youth (Benson et al., 2006; Grøntved et al., 2015a; Janz et al., 2002). Therefore, including measures of both MS and ME make sense not only from a statistical, but from a theoretical perspective. If CRE alone is used as a measure of HRF, as has been the case in many studies (Barnett et al., 2008; Kriemler et al., 2010; Woods et al., 2010), then the important contribution of MS and ME would be ignored.

Results presented in this paper demonstrate that HJ as a measure of MS, and push-ups as a measure of ME, both have relatively high factor loadings (r = .71 and r = .60 respectively) within the HRF construct. Despite their lower factor loadings, VJ (r = .45) and curl-ups (r = .38), as measures of MS and ME respectively, also contribute to overall model fit. HJ has been previously identified as a good overall measure of MS, with strong associations between it and other lower body (R^2 = 0.829–0.864) and upper body (R^2 = 0.694–0.851) strength tests (Castro-Pinero et al., 2010). What is more, HJ as a measure of MS has been found to negatively correlate with BMI (Brunet et al., 2007; Riddiford-Harland et al., 2006), a well-established marker of health (Baker et al., 2007), which further lends support to the relevance of HJ within the HRF construct. VJ has also been associated with body composition in youth, with performance on the VJ test significantly and inversely associated with body fatness (Minck et al., 2000) and BMI (Riddiford-Harland et al., 2006).

Push-ups and curl-ups as measures of ME are less well-researched, with limited studies examining the association between push-up performance and health outcomes in youth. Despite this lack of research, it has been recommended by previous authors to include tests of ME when measuring HRF to give an overall picture of HRF (Plowman and Mahar, 2013). Grip strength was originally included as an indicator of MS in this study but was removed, with a resultant improvement in model fit, due to its relatively low factor loading (r = .37) (Brown, 2006), and the contrasting nature of grip strength with the remaining indicators in the HRF model. Grip strength, while included in many HRF test batteries (Council of Europe, 1983; Ortega et al., 2011) and frequently tested as a marker of MS (Francis et al., 2016; Moliner-Urdiales et al., 2011; Ortega et al., 2011), is found to positively correlate with BMI, with children who have a higher BMI performing better on this test (Artero et al., 2010). In children tests of MS have generally been found to correlate positively with BMI, while tests of ME have shown a negative correlation with BMI (Hassan et al., 2016). It is reasonable to suggest that MF tests which require the individual to support and move their own body weight (such as HJ, VJ, push-ups and curl-ups) may be more poorly performed by those with higher mass, whereas a test such as the hand grip strength test is less likely to be affected in this way as it requires minimal movement of the body. It is possible then that grip strength may have contributed to poorer model fit due to an opposing relationship with weight status compared to other tests used in this study.

Of further importance in testing the structure of the HRF construct in youth is assessing the degree to which the construct is the same for males and females. In the current study a multiple-group analysis of the first-order HRF model showed that while there were significant differences between males and females for absolute scores in all individual HRF tests, the structure of the proposed HRF construct was invariant across sex. This is to be expected, given that in studies on HRF in youth, males and females are typically measured on the same tests despite sex differences in absolute scores on HRF test (Ortega et al., 2011; Santos et al., 2014). While the current study assessed the factor structure of HRF cross-sectionally to produce a HRF composite that proved to be invariant by sex, the sample is limited in terms of age-range. Future studies should test this composite across a broader age range, and longitudinally, to determine if this five-indicator HRF composite is invariant by age-group and by time.

4.7 Conclusion

HRF is a positive predictor of health in youth (Ortega et al., 2008). The association between CRE and health is well-established (Corbin et al., 2014; Pate, Oria, Pillsbury, et al., 2012), and there is now a growing body of research identifying the positive effect of MS and ME on health outcomes in youth (Smith et al., 2014). As such, HRF is a primary construct of interest in youth health-promotion research. Previously, many studies examining associations between HRF and other health-related variables have chosen to measure just one component, with CRE frequently the component of choice (Kriemler et al., 2010; Woods et al., 2010). Considering the strong positive association of MS and ME with health however, excluding these components is not ideal. The problem that arises with a multi-component construct like HRF, is how to combine the relevant components into a single score which reflects the construct and can be used in research examining associations between HRF, as a composite, and other variable. This study addresses these issues and provides researchers with a concise selection of tests that represent the HRF construct in youth, and that are suitable for use in a field-based setting. Findings from this study provide researchers with an effective method to measure HRF. Empirical evidence from this study suggests that HRF in youth is best represented by five indicators representing three components of fitness (CRE, MS and ME). These five indicators involve HRF tests that are widely used (Ortega et al., 2011; Ruiz, Castro-Piñero, et al., 2011; Santos et al., 2014), valid and reliable (Artero et al., 2011; Morrow et al., 2010; Ortega et al., 2008) and, easily administered in a field-based setting.

CHAPTER 5

The role of health-related fitness and perceived athletic competence in mediating the physical activity-motor competence relationship during the transition from primary to secondary school

Chapter 5 Study 2

5.1 Purpose of the Chapter

5.1.1 Rationale

The role of HRF and PC as mediators within Stodden et al.’s (2008) conceptual model is not fully understood. There is a paucity of research examining how HRF mediates the primary MC-PA relationship depicted in the model. In addition, the composite nature of HRF has rarely been considered when examining relationships between HRF and PA, MC, or PC. The reciprocal pathways outlined in Stodden et al.’s (2008) model are also not well understood, in part due to a lack of longitudinal studies addressing this aspect of the model. The study outlined in this chapter used the HRF composite developed in Chapter 4 to address gaps in knowledge regarding HRF as a mediator within Stodden et al.’s (2008) conceptual model, and regarding the reciprocal nature of the hypothesised relationships.

5.1.2 Contribution to the field

The study outlined in this chapter adds to the literature by evaluating aspects of Stodden et al.’s (2008) conceptual model that have not previously been tested in such a comprehensive manner. The longitudinal design allows for testing of the pathways hypothesised in the model during the transition from primary to secondary school, and the role of HRF and PC in mediating these pathways. In addition, it also allows for evaluation of the directionality of the pathways between MC, PA and the mediators HRF and PC.

5.1.3 Peer review status

The study outlined in this chapter is accepted for publication in *Journal of Sport Sciences* under the title: *Small Fish, Big Pond: the role of health-related fitness and perceived athletic competence in mediating the physical activity-motor competence relationship during the transition from primary to secondary school,* and was presented orally at the 2018 Children's Research Network PhD Symposium.

5.2 Abstract

This study investigates the role of Perceived Athletic Competence (PAC) and Health-Related Fitness (HRF) in mediating the reciprocal relationship between Motor Competence (MC) and Physical Activity (PA) during the transition from primary to secondary school. MC, PA, PAC and HRF were measured in 224 participants (baseline age 12.26 ± .037 years; 51% female) in final year of primary school and one year later in first year of secondary school. Path analysis in AMOS 23 was used to test the mediating influence of PAC and HRF on the MC-PA relationship. Fit indices showed that, in both directions, HRF and PAC mediated the relationship between MC and PA (PA predicting MC; $\chi 2 = 3.91$, $p = .272$, CFI = .99, RMSEA = .04. MC predicting PA: $\chi 2 = 6.46$, $p = .167$, CFI = .99, RMSEA = .04). Pathways were stronger through HRF than through PAC, indicating that HRF is the more substantial mediator of the MC-PA relationship during the school transition. Pathways were stronger in the direction of PA predicting MC than in the reverse direction. Interventions seeking to influence PA and MC across the school transition should focus on HRF as it is a primary mediator of the MC-PA relationship.

5.3 Introduction

Globally there is a trend of decreasing physical activity (PA) with increasing age (Borraccino et al., 2009; Corder et al., 2015). In Ireland it has been shown that older children and adolescents are less likely to be active compared to younger children (Gavin et al., 2014; Woods et al., 2010), and PA declines as children get older (Murphy et al., 2016). This is a worrying trend given the negative health outcomes associated with low levels of PA (Bailey et al., 2012; Ekelund et al., 2012; Warburton et al., 2006). The transition period between primary and secondary school has been identified as a specific period where changes in PA behaviour occur (De Meester et al., 2014; Jago et al., 2012; Marks et al., 2015). In general, this school transition occurs at a pivotal time in a child's life when they are entering adolescence. Notwithstanding the significant physical and psychological changes associated with this period, moving school environment appears to have an additional impact on PA, with children who change environment having a greater decrease in PA compared to the same age children who continue into secondary school in the same environment (Marks et al., 2015). While the decrease in PA over time is well-documented, what remains unclear is the mechanism behind this decrease in PA from childhood to adolescence.

A growing area of interest is the relative importance of motor competence (MC) in the development of lifelong healthy PA behaviours. MC reflects an individual's proficiency in fundamental movement skills (FMS) across three movement categories: locomotor, object control, and balance (Gallahue & Ozmun, 2012; Stodden et al., 2008). Research has highlighted a relationship between MC and PA, with higher MC associated with greater PA levels both in childhood, and longitudinally into adolescence and adulthood (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; D'Hondt et al., 2014; Green et al., 2011; Lloyd, Saunders, Bremer, & Tremblay, 2014). A conceptual model proposed by Stodden et al. (2008) suggests that a reciprocal relationship exists between MC and PA, and that the nature of this relationship can lead to either positive or negative spirals of engagement in PA, ultimately influencing health status over time. In early childhood the relationship is hypothesised to be dominated by the influence of PA on MC (Stodden et al., 2008). There is a developmental expectation that FMS can be mastered by the age of 7 – 9 years (Gallahue and Ozmun, 2012; Victoria Department of Education, 1996), therefore it is proposed that in the early years, PA provides the opportunity to develop MC. In later childhood, it is proposed that the relationship becomes more reciprocal as children with superior MC are more likely to be active, which in turn will further increase MC. Research in young children lends support to this hypothesis with time in PA associated with increased proficiency in MC (Babic et al., 2014). In adolescents research partially supports Stodden et al.'s (2008) model, with a reciprocal relationship observed for object control but not locomotor MC (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011), and for males but not for females (Jaakkola and Washington, 2012).

According to Stodden's model (Stodden et al., 2008), the MC-PA reciprocal relationship is mediated by two other important variables – health-related fitness (HRF) and perceived competence (Stodden et al., 2008). Perceived competence influences motivation and behaviour in three domains (social, cognitive, and physical) (Harter, 1978). Perceived competence in the physical domain refers to an individual's belief in their ability to perform sports and physical activity-related skills (Harter, 2012). Perceived athletic competence (PAC) or perceived sport competence (PSC) are common terms for perceived competence in the physical domain. In this study, PAC was measured and therefore perceptions of competence in the physical domain will be referred to henceforth as PAC, unless citing studies that specifically use a different term when measuring self-perceptions in the physical domain. PAC is often lower in older compared to younger individuals (Piek et al., 2006), and tends to decrease over time (Shapka and Keating, 2005). Differences between males and females are also frequently reported for PAC , with males having higher self-perceptions than females (Piek et al., 2006; Shapka and Keating, 2005). In one of the few longitudinal studies examining perceived competence as a mediator of the MC-PA relationship, PSC was found to mediate for object control MC (Barnett, Morgan, van Beurden, & Beard, 2008). This suggests that being competent in object control skills in childhood had a significant and positive effect on PSC in adolescence, which in turn had a significant and positive effect on adolescent PA (Barnett et al., 2008). The same mediated pathway was not found for locomotor MC in this study. In keeping with Stodden et al.'s (2008) developmental framework, studies have found that the mediating effect of PAC on the MC-PA relationship appears to be influenced by an individual's stage of development. PAC was not found to be a significant mediator of the relationship between MC and PA in younger children (Crane et al., 2015), but has been found to act as a mediator in older children (Khodaverdi et al., 2015) and adolescents (Barnett et al., 2011). This indicates that there may be age-related differences in the role of PAC in mediating the MC-PA relationship which need to be further investigated. The transition from primary to secondary school could be a key timeframe for examining these relationships, at a stage when children are transitioning into adolescents.

Health-related fitness (HRF) is the other proposed mediator in Stodden et al.'s (2008) model. HRF is a powerful indicator of health among children and adolescents, with higher fitness levels associated with positive health outcomes (Ortega, Ruiz, Castillo, & Sjöström, 2008; Ruiz et al., 2009). The theoretical definition of HRF (Caspersen et al., 1985) refers to a multidimensional construct consisting of five components: cardiovascular endurance (CRE), muscular strength (MS) and muscular endurance (ME), flexibility, and body composition. In practice, researchers frequently choose individual components to represent the overall HRF construct (Lima, Pfeiffer, et al. 2017). Irrespective of which component is measured, across all components of fitness there is a trend for increasing fitness with increasing age (Ortega et al., 2011; Santos et al., 2014). Sex differences are also seen in HRF, with males having higher fitness levels than females across most components of HRF, flexibility being the exception (Ortega et al., 2011; Santos et al., 2014; Woods et al., 2010). For CRE especially, the gap between males and females tends to widen with increasing age (Irish Life

Schools Fitness Challenge, 2016; Pate et al., 2006). Research that looks specifically at the mediating aspect of HRF on the developmental MC-PA relationship, as presented in Stodden et al.'s (2008) model, is limited (Robinson et al., 2015). Cross-sectionally, in addition to examining PAC as a mediator, Khodaverdi et al. (2015) also examined, separately, the roles of CRE, ME, flexibility, and body composition as mediators in the MC-PA relationship (Khodaverdi et al., 2015). CRE was the only HRF component that acted as a mediator, and mediated specifically the relationship between locomotor MC and PA (Khodaverdi et al., 2015). An age-related effect has been found for the relationships between HRF and MC (Stodden, 2014), and it is likely that the age of the participants in Khodaverdi et al.'s (2015) study had a bearing on the associations found. The relationship between HRF and MC has been found to be stronger in later childhood and early adolescence than in early childhood (Stodden, 2014). In addition, at a young age associations between HRF and MC are found for locomotor skills, while in older children and adolescents it is object-control proficiency that is more strongly associated with HRF (Stodden, 2014). It may be that at an older age, being proficient in object-control skills, which are required for numerous competitive sports, allows individuals to participate in a wide selection of sports and PA which require fitness across multiple components (e.g. MS is important for jumping in basketball) and not just CRE. In the reverse, having the fitness to participate in these activities will allow for opportunities to further develop object-control MC. Within the older children and adolescent population there is a lack of research looking at the mediating effect of HRF as a whole on the MC-PA relationship in older children and adolescents.

Each of the variables in Stodden et al.'s (2008) conceptual model are widely accepted as being influential in developing positive, or negative, health trajectories throughout childhood. However, if Stodden et al.'s (2008) conceptual model is to be used to guide research, it needs to be fully tested including all variables identified in the model, and within the proposed developmental framework. There is a need to address the gaps in Stodden et al.'s (2008) model to examine if the proposed reciprocal MC-PA relationship is influenced by age or sex, and if the proposed relationships vary for each MC component. In addition, changes in interactions between the variables during the transition from primary to secondary school need to be examined to better understand the nature of the relationships proposed as children leave childhood and enter adolescence.

5.4 Materials and Methods

5.4.1 Participants

Data were collected from participants in 6th class of primary school (January – April 2017), and a year later in 1st year of secondary school (January – May 2018). In 6th class, 261 children (53% female and 47% males; mean age 12.22 ± 0.48 years) participated. Of the participants involved in 6th class, 37 did not transfer into the secondary schools within the catchment area which had been selected for data collection and were therefore not tested in 1st year. In 1st year, 299 adolescents (48% female and 52% male; mean age: 13.91 ± 0.58 years) participated. Participants in 1st year included an additional 75 students who had not attended the initial feeder primary schools. Of the total number of participants involved in the study, 224 participants (51% female and 49% male; mean age: 12.26 ± .037 years at baseline) had data at both time points and were included in analysis.

5.4.2 Measures

PA was measured using Actigraph (models: GT1M, GT3X, GT3X+, wGT3X-BT) accelerometers. Validation studies have found that these four Actigraph models are comparable (Grydeland et al., 2014; Kaminsky and Ozemek, 2012; Powell et al., 2016). Data was captured in 10-second epochs (Esliger et al., 2005). Participants wore the accelerometer for nine consecutive days during waking hours. The first and last days of the wear period were omitted from analysis to account for subject reactivity (Dossegger et al., 2014). To increase compliance a reminder text message was sent each morning to participants who had provided a contact phone number (Belton et al., 2013).

Three components of MC were assessed; 1) object control skills: kick, catch, overhand throw, one-hand strike, and two-hand strike, 2) locomotor skills: run, skip, horizontal jump, and vertical jump, 3) balance: two-board balance, zigzag hop, and walking toe-heel backwards. Object control and locomotor skills, except for the vertical jump, were assessed according to the Test of Gross Motor Development III (TGMD-III (Ulrich, 2016). The vertical jump was assessed in accordance with the Victoria Department of Education training manual (Victoria Department of Education, 1996). For both manuals, each locomotor and object control skill is made up of specific movement components, with presence or absence of a component scored as 1 or 0 respectively. Participants were videoed performing each of the object-control and locomotor skills and scoring of these skills was done at a later date by trained field staff. All balance skills were assessed according to the criteria set out in the Movement Assessment Battery for Children-2 (MABC-2(Barnett et al., 2007)).

PAC was assessed using the Self-Perception Profile for Adolescents (SPP-A (Harter, 2012)). The PAC subscale contains five items scored on a four-point scale, with higher scores indicating more positive self-perceptions (Harter, 2012).

A composite HRF score was calculated from five tests measuring three components (CRE, MS, ME) of fitness (Table 5.1). Tests were selected following a review of methodologies in recent large-scale studies of HRF in youth (Ruiz et al., 2011; Santos et al., 2014; Ortega et al., 2011). Protocols for each HRF test can be found in the FITNESSGRAM manual (Plowman and Mahar, 2013), the EUROFIT manual (Council of Europe, 1983), and the HELENA study (Ortega et al., 2008; Ortega et al., 2011) (Table 5.1). A previous confirmatory factor analysis (CFA) found these five tests gave the best representation of the overall HRF construct (Britton et al., 2018). Results from the CFA were used to form a weighted HRF composite score (Britton et al., 2018).

Table 5.1 Measurement of HRF

HRF Component	Test	Source
CRE	20MST	FITNESSGRAM; EUROFIT
MS	HJ	EUROFIT; HELENA Study
	VJ*	HELENA Study
ME	Push-ups	FITNESSGRAM
	Curl-ups	FITNESSGRAM

20MST=20metre shuttle run test; HJ=horizontal jump; VJ=vertical jump; FITNESSGRAM (Meredith & Welk 2010). The HELENA Study (Ortega et al. 2008). *VJ was assessed using the Abalakov jump test protocol outlined in the HELENA study (Ortega et al. 2008) and using a jump mat and belt (Coulson & Archer 2009) in place of an infrared jump platform.

5.4.3 Data Processing

Accelerometer data was processed in Actilife version 6.13.3. Minutes of moderate-vigorous PA (MVPA) per day were calculated using Evenson et al. (2008) cut-points. Greater than 20 minutes of zero-counts were identified as non-wear time, and activity count values of <0 and ≥15,000 counts per minute were excluded as these values are deemed biologically impossible (Esliger et al., 2005). In line with other studies assessing PA across a transition period, a valid day was deemed as having wear-time of greater than or equal to 8 hours (Jago et al., 2012; Marks et al., 2015) and the minimum number of valid days required to be included in the analysis were two weekdays and one weekend day (Marks et al., 2015).

Videos for each participant for the nine skills taken from the TGMD-III (Ulrich 2016) and Victoria Department of Education (1996) manuals were viewed and analysed by trained field staff after testing was completed. The number of components present over two trials was summed for each participant creating a total score for each skill. A minimum inter-observer agreement between trained field staff of 95% was required for scoring each skill. Total category scores for locomotor MC and object control MC were calculated by summing the skill totals for each, with a maximum score of 34 for locomotor and 40 for object control MC. Balance skills were scored using the MABC-2 manual (Barnett et al. 2007). Using the participant's age in years and months each raw score was converted to a standard score. Standard scores were summed to produce a total score which was also converted into a percentile score.

Scores for the five items in the SPP-A measuring PAC were averaged to give a mean PAC score (Harter 2012).

Maximum running speed on the 20MST, taken as the speed in km/hr of the participant's last completed shuttle, was used to calculate VO_{2max} (Léger et al., 1988). Maximum height (VJ) and distance (HJ) jumped was calculated, as well as the total number of curl-ups and push-ups achieved. A composite HRF score was formed by combining and weighting each test based on factor loadings from a previous confirmatory factor analysis for HRF in youth (Britton et al., 2018).

5.4.4 Analysis

Data were analysed using SPSS and AMOS versions 23. Scores for MVPA, MC, PAC, and HRF were entered into SPSS. Means and standard deviations were calculated for each variable at both time points. One-way repeated measures ANOVAs were conducted to investigate the effect of time, and time*sex, on each variable. Effect sizes were calculated according to Cohen's (1988) (Cohen, 1988) criteria where 0.01, 0.06 or 0.14 represented small, medium and large effect sizes respectively.

Following analysis of the basic descriptive statistics, maximum likelihood structural equation modelling (SEM) was conducted in AMOS to assess pathways between PA and MC. First, direct reciprocal relationships between PA and MC over time were analysed. The ability of MVPA in 6th class to predict MC (object, locomotor, and balance) in 1st year was specified. The reverse pathway was then specified, with MC in 6th class predicting time in MVPA in 1st year. Variables between which significant correlations were found were allowed to covary in the models.

Next, the mediators (PAC and HRF) were entered into the models and a nested model comparison was used to determine significant differences in model fit based on the addition of mediators (Fig 1 & 2). Only direct pathways that were significant in the non-mediated analysis were included in these models. A nested model comparison using model trimming was conducted to compare a two-mediator model (PAC and HRF together as mediators) with two single-mediator models (PAC as a mediator, and then HRF as a mediator) (Hutchens, 2017; Kline, 2015). Comparisons were conducted for both directional pathways. A Chi-square (χ^2) difference test was used to determine if either of the single-mediator models had significantly different fit to the two-mediator model. A significant χ^2 test indicates that there is a significant difference in model fit between two models (Kline, 2015).

Fit indices for the best fitting mediation models were reported. Goodness of fit was examined using the Chi-square (χ^2) test, the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA), as recommended by Garson (2009). A non-significant χ^2 indicates good fit. CFI values of > 0.9 signify acceptable model fit (Byrne, 2010; Schumacker and Lomax, 1996), with values of > 0.95 for CFI considered to signify superior fit (Hu and Bentler, 1999). RMSEA values below 0.06 indicate good fit (Hu and Bentler, 1999).

Finally, a multigroup analysis to assess differences by sex in the models was conducted. A Chi-square (χ^2) difference test was used to determine if there was a significant difference in model fit between males and females with a significant χ^2 test indicating variance between sexes for the model (Kline, 2015). Critical ratios for each regression path were also inspected. A critical ratio of > 1.96 for a given pathway indicates a significant difference between groups in this pathway (Arbuckle, 2014).

5.5 Results

5.5.1 Longitudinal changes

Mean scores by sex for each variable are given in Table 5.2. The repeated-measures ANOVA revealed a significant and large ($\eta^2 = .19$) effect for time on MVPA (F (1, 52) = 12.06, $p < .01$, Wilk's lambda = .81), with MVPA decreasing from 6th class to 1st year. No significant time*sex interaction was found. Mean time in MVPA was significantly higher for males at both time points (6th class: t (133) = 2.87, $p < .01$; 1st year: t (101) = 3.04, $p < .01$).

Time and sex effects were measured for all three components of MC. A significant and medium effect ($\eta^2 = .09$) for time on balance was found (F (1, 154) = 14.86, $p < .001$, Wilk's lambda = .91), with an increase in mean balance score from 6th class to 1st year. A mean increase in balance from the 76th to 84th percentile was evident. No significant time*sex interaction was found for balance. For locomotor MC the effect of time was medium and significant ($\eta^2 = .08$; F (1, 124) = 11.09, $p < .01$, Wilk's lambda = .92). A significant but small ($\eta^2 = .04$) interaction effect for time*sex (F (1, 124) = .96, $p < .05$, Wilk's lambda = .96) on locomotor MC was found. Mean locomotor MC increased for males but did not change significantly for females over time. Males had significantly higher locomotor MC compared to females in 1st year (t (185) = 2.46, $p < .05$), but not in 6th class (t (238) = .55, $p > .05$). There was a significant and large effect ($\eta^2 = .39$) for time on object control MC (F (1, 78) = 49.43, $p < .05$, Wilk's lambda = .61). Mean object control MC increased from 6th class to 1st year. No significant interaction effect between time and sex was found for object control MC. Males had significantly higher object control MC at both time points (6th class: t (245) = 7.17, $p < .01$; 1st year: t (101) = 8.04, $p < .01$).

There was a significant and medium effect ($\eta^2 = .06$) for time on PAC (F (1, 185) = 12.08, $p < .05$, Wilk's lambda = .94) with PAC decreasing from 6th class to 1st year. A significant but small ($\eta^2 = .03$) time*sex interaction was found (F (1, 185) = 5.63, $p < .05$, Wilk's lambda = .97), with PAC decreasing to a greater extent in females compared to males. PAC was significantly higher for males compared to females in 1st year *(t* (252) = 3.60, $p < .01$) but not in 6th class *(t* (245) = 1.94, $p > .05$).

For HRF the effect of time alone was not significant. A significant and large interaction effect ($\eta^2 = .24$) for time by sex was found however (F (1, 122) = .318, $p < .001$, Wilk's lambda = .77). HRF increased for males, but decreased for females, over time. Males had significantly better HRF than females at both time points (6th class: t (259) = 7.02, $p < .01$; 1st year: t (297) = 8.21, $p < .01$).

Table 5.2. Mean scores for PA, MC, PAC and HRF

		T1			T2		
	N	**Male**	**Female**	**Sex Difference**	**Male**	**Female**	**Sex Difference**
MVPA (mins)	53	54.41 ± 26.27	46.26 ± 16.04	m**	44.19 ± 19.21	37.07 ± 11.74	m**
Locomotor	126	29.58 ± 3.50	29.23 ± 3.62	ns	31.08 ± 2.84	29.52 ± 3.31	m*
Object control	80	33.19 ± 4.23	26.08 ± 7.01	m***	36.42 ± 2.35	30.54 ± 4.60	m***
Balance	155	36.58 ± 8.12	36.38 ± 8.74	ns	38.63 ± 6.72	39.16 ± 6.68	ns
PAC	186	3.00 ± 0.62	2.78 ± 0.75	ns	2.96 ± 0.68	2.54 ± 0.81	m***
HRF	224	1.61 ± 3.12	-1.40 ± 2.44	m***	1.80 ± 3.47	-1.57 ± 2.68	m***

r = Pearson's correlation coefficient. *significant at p <.05; **p < .01; ***p < .001

5.5.2 Direct Reciprocal Relationships

Regression analyses revealed a direct relationship from 6th class PA to 1st year object control MC ($\beta = .354$, $p < .01$). MVPA in 6th class accounted for 12.6% of the variance in 1st year object control MC ($R^2 = .126$). None of the other direct pathways between PA and MC were significant.

5.5.3 Mediation: Nested Model Comparisons

Following the assessment of direct relationships, the mediation models were specified in AMOS. Significant direct pathways and significant correlations were included. Model 1 predicted MC in 1st year from PA in 6th class (Figure 5.1). Model 2 looked at the reverse relationship, predicting PA in 1st year from MC in 6th class (Figure 5.2). For both models PAC and HRF in 6th class were entered as mediators of the MC-PA relationships (Table 5.3: Model 1a and Model 2a). The models were then constrained to assess changes in model fit when PAC alone mediated the PA-MC relationship (Table 5.3: Model 1b and Model 2b), and when HRF alone mediated (Table 5.3: Model 1c and Model 2c). A χ^2 difference test for Model 1 showed that both the HRF-only and PAC-only models had significantly poorer fit than the model including both HRF and PAC as mediators (PAC-mediated: CMIN = 73.36; $p = .000$. HRF-mediated: CMIN = 36.83; $p = .000$; Table 5.3). For Model 2, the χ^2 difference test also showed that both the HRF-only and PAC-only models had significantly poorer fit than the model including both HRF and PAC as mediators (PAC-mediated: CMIN = 104.91; $p = .000$. HRF-mediated: CMIN = 35.76; $p = .000$; Table 5.3). Version a) of both models (Figure 5.1 and 5.2) where HRF and PAC were both included as mediators of the PA-MC relationship was therefore retained for further analysis. Fit indices for Model 1a and 2a (Table 5.4) showed acceptable fit for both models.

Table 5.3 Nested Model Comparison

Mediator	Model	χ2	df	Sig.	χ2	
					CMIN	Sig.
HRF&PAC	1a	11.82	3	.008		
PAC Only	1b	43.83	7	.000	39.91	.000
HRF Only	1c	25.75	7	.001	21.36	.000
HRF&PAC	2a	6.46	4	.167		
PAC Only	2b	109.09	8	.000	102.63	.000
HRF Only	2c	39.54	8	.000	33.08	.000

χ^2 = Chi-square; df = degrees of freedom; Sig. = significance level;

CMIN = Chi-square equivalent; RMSEA = Root mean square error of approximation

Table 5.4 Fit Indices for Mediated Models (Model 1a and 2a)

Direction	Model	χ2	df	Sig.	CFI	RMSEA		
						RMSEA	LCI	UCI
PA to MC	1a	3.91	3	.272	.99	.04	.00	.14
MC to PA	2a	6.46	4	.167	.99	.04	.00	.10

χ^2 = Chi-square; df = degrees of freedom; Sig. = significance level;

CFI = Comparative Fit Index

RMSEA = Root mean square error of approximation; LCI = lower confidence interval;

UCI = upper confidence interval

5.5.4 Mediated Reciprocal Relationships

The structural equation models for Model 1a and 2a revealed that reciprocal relationships, mediated by HRF, existed for PA with all three MC components (Figure 5.3). There were unidirectional but not reciprocal pathways between MC and PA mediated by PAC (Figure 5.3). MVPA accounted for 22% of the variance in locomotor MC (R^2 = .219) with both PAC and HRF mediating the relationship. MVPA accounted for 32% of the variance in object control MC (R^2 = .313) and 14% of the variance in balance MC (R^2 = .135) but these pathways were mediated only by HRF. In the reverse direction, MC accounted for 24% of the variance in MVPA (R^2 = .238). This pathway was mediated through HRF only.

Pathways were stronger from MVPA to MC rather than in the reverse direction (Figures 5.1 and 5.2).

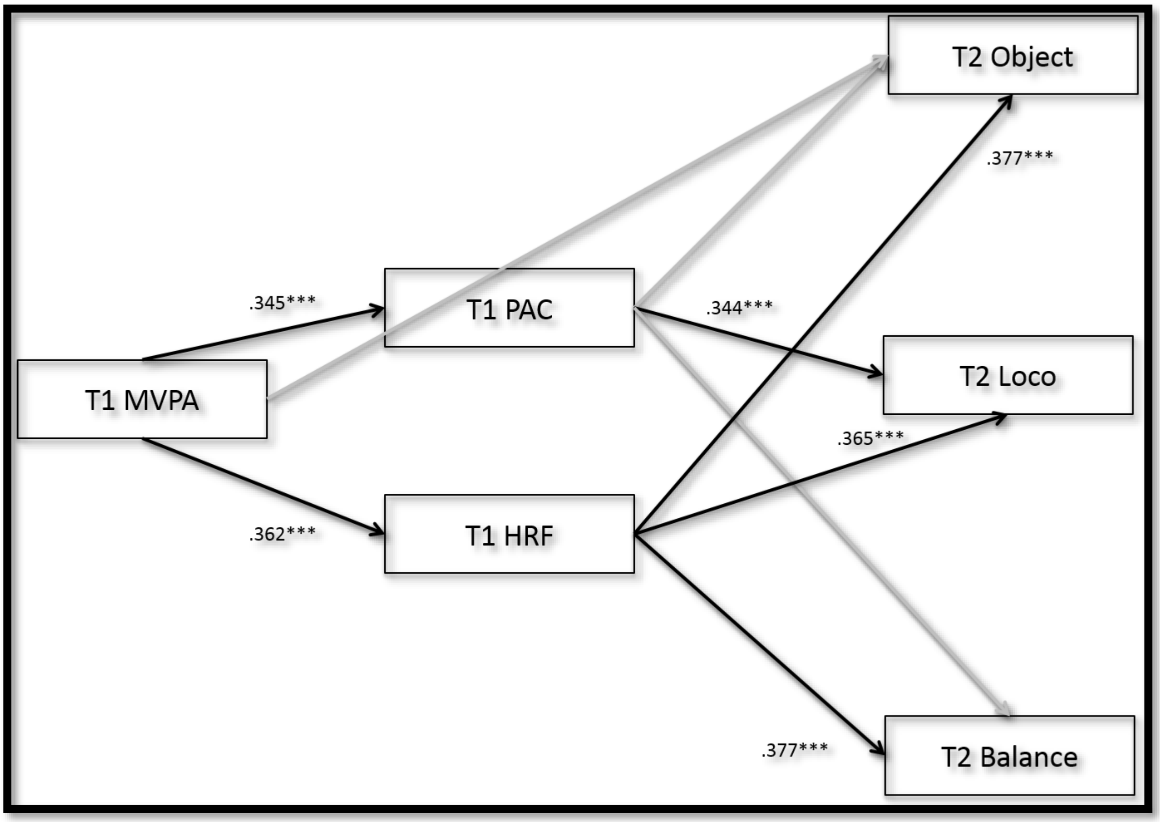


Figure 5.1 MVPA predicting MC

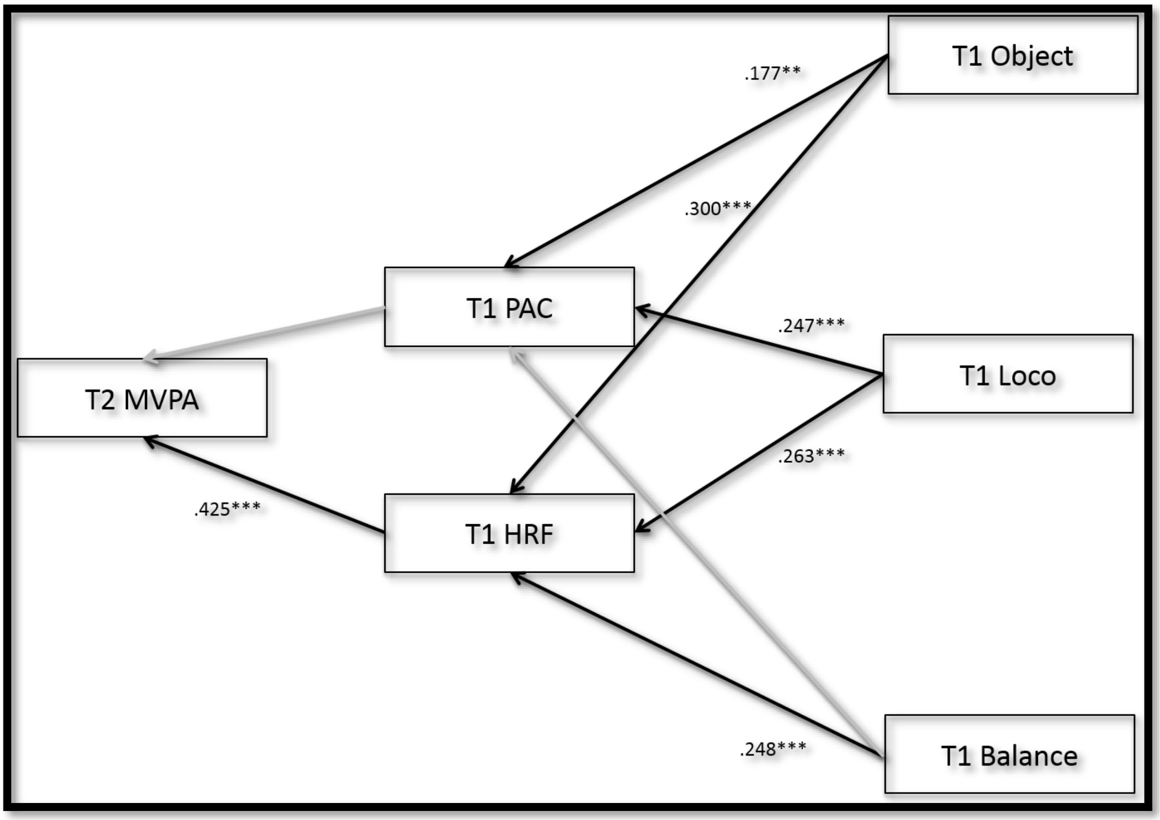


Figure 5.2 MC predicting MVPA

5.5.5 Sex Differences

A multigroup analysis examined differences between males and females for both directional models. (Models 1a and 2a) there were no significant differences in the overall model fit between males and females (Model 1a: CMIN = 8.82, p = .512. Model 2a: CMIN = 15.16, p = .056). Further inspection of the critical ratios table revealed that critical ratios for all regression pathways in both models were below the threshold of 1.96 indicating that there are no significant differences in pathways between males and females (Arbuckle, 2014).

5.6 Discussion

Results from this study identified a reciprocal longitudinal relationship between PA and MC that was mediated by HRF. PAC did not mediate reciprocal relationships between PA and MC but did act as a mediator for some unidirectional relationships. Reciprocal relationships were stronger in the direction of MVPA predicting later MC, compared to the reverse direction. These results partially support the hypothesised relationships depicted in Stodden's model (Stodden et al., 2008), whereby HRF acts as a mediator of the MC-PA relationship. In comparison, PAC was not as influential in mediating the relationships depicted by Stodden. In addition, contrary to the developmental expectation proposed by

Stodden and colleagues that MC will have a stronger bearing on PA in later childhood (Stodden et al., 2008), in this study the reverse was true, with 6^{th} class MVPA having a more dominant bearing on later MC than the reverse relationship.

MVPA decreased for both males and females across the transition from primary to secondary school, consistent with previous research (De Meester et al., 2014; Marks et al., 2015). In terms of MC, an increase in mean object-control was seen over time for both for males and females. For males, locomotor proficiency increased, but for females there was no significant change in locomotor skill level over time. There is a developmental expectation that MC will improve with age (Barnett et al., 2016; D'Hondt et al., 2014). Children also have the developmental potential to reach proficiency in most FMS by the age of 7-9 years (Gallahue and Ozmun, 2012). However, FMS are not innate and must be learned. Thus, children can only be expected to master these basic building block movements if they are given the opportunity to develop them. In fact, recent studies examining MC in late childhood and adolescence have found that participants often do not achieve mastery/near mastery (Van Beurden et al., 2003) in many FMS at this development stage (Mitchell et al., 2013; O' Brien et al., 2015a; O'Brien et al., 2018; Okely and Booth, 2004). Therefore, while children and adolescence may have the developmental potential to proficiently execute the performance criteria of most FMS by early adolescence (Gallahue & Ozmun 2012), numerous recent studies have documented how this is not a common occurrence. Except for catch and run, results from our study also indicate that youth who have progressed beyond the age of expected FMS-mastery, as per the performance criteria set out in the TGMD-III, are not fully proficient in many locomotor and object-control skills. This is in keeping with other studies that have reported lower than expected levels of MC in Irish adolescents (O' Brien et al., 2015a; O'Connor et al., 2018). Evidently many adolescents are not demonstrating mastery of numerous basic "building block" movement skills as is often expected of this age group. The same trend seen in locomotor and object-control skills for increasing proficiency with increasing age was also seen for balance scores, with an increase in mean balance from 6^{th} class to 1^{st} year. In addition, a mean increase from the 76^{th} percentile in 6^{th} class to the 84^{th} percentile in 1^{st} year was seen for balance skills. Given that the percentile score considers age by standardising scores, this percentile increase is significant and indicates that, like other categories of FMS, balance skills are still developing in late childhood.

PAC decreased across the transition from primary to second level, with a greater decrease observed in females compared to males. As children age they begin to more accurately link

PAC to actual competence, or compare themselves to others, which can lead to a decrease in PAC (Harter 2006). This is likely what occurs in the transition from primary to secondary school. A sex difference in PAC is frequently reported, with males having more positive self-perceptions in the PA domain than females (Barnett et al. 2008; Piek et al., 2006; Shapka & Keating, 2005b). One of the most interesting results from the current study is that while there was a trend for decreasing PAC over time for both males and females, and males exhibited higher PAC at both time points (significant in 1st year, but not 6th class), the extent of the decrease over time was greater for females than males.

HRF increased for males but decreased for females across the transition. It is generally expected that fitness in all components should increase from childhood to adolescence (Ortega et al., 2011; Santos et al., 2014). Mean scores across four of the five tests (HJ, VJ, push-ups, curl-ups) included in the HRF composite score increased over time, while VO_{2max} decreased. Research on changes in CRE has found that VO_{2max} tends to increase from childhood into adolescence (Janz et al., 2000; Kemper et al., 2013). This increase lasts into late adolescence for males, but for females a plateau in VO_{2max} is frequently reported much earlier in adolescence at about 13 or 14 years (Janz et al., 2000; Kemper et al., 2013). In the current study, both male and female participants showed a decrease in VO_{2max} at a younger age than would be expected. One explanation for this decrease in VO_{2max} may come from the PA data. Both males and females significantly decreased their MVPA over time, which could potentially explain a decrease in CRE. However, limitations of accelerometery, such as the number of participants with valid wear-time for analysis, should be considered when interpreting these results. The specific context of PA engaged in may also contribute to changes in overall HRF, and indeed MC, in males and females over time. For overall HRF, a mean increase was seen for males, compared to a mean decrease for females. Organised sport provides individuals with opportunities to develop HRF and MC. In Ireland, youth participation in both club and extra-curricular sport is higher in males compared to females (Hardie Murphy et al., 2017). In addition, across a span of five years, females were significantly more likely to drop out of sports than males, and significantly less likely to take up a new sport (Hardie Murphy et al., 2017). Therefore, while not within the scope of this research, previous Irish data suggests that the decreasing HRF levels seen in females in the current study may be reflective of a decrease in female sport participation, and thus a decrease in opportunities to develop aspects of HRF and MC beyond simply CRE, during this period.

5.6.1 Reciprocal Relationships

A primary assumption of Stodden's model is the existence of a reciprocal relationship between MC and PA (Stodden et al., 2008). In the current study, there are no direct reciprocal relationships between MC and PA in either direction. However, when the mediators proposed by Stodden are included, reciprocal relationships are evident for PA and MC, via HRF. With HRF acting as a mediator, MVPA in 6^{th} class predicted competence in 1^{st} year object-control, locomotor, and balance MC. Likewise, in the reverse direction, MC in 6^{th} class predicted 1^{st} year MVPA. Interestingly, although adding to the overall model fit, and mediating the unidirectional pathway between 6^{th} class PA and 1^{st} year locomotor MC, PAC did not act as a mediator for any of the reciprocal relationships in Stodden's model. Therefore, in terms of testing Stodden's theoretical model, findings from this study suggest that reciprocal relationships in this sample are mediated through HRF and not PAC.

When looking at the strength of the pathways in the current study, the reciprocal relationship between MC and PA is driven from PA to MC i.e. pathways from PA via HRF to MC are stronger than pathways in the reverse direction. From a developmental perspective, Stodden's model hypothesises that in early childhood the MC-PA relationship is dominated by the impact of PA on MC, i.e. younger children develop their MC by participating in PA. In one of the few longitudinal studies evaluating the MC-PA relationship in younger children, Burgi et al. (2011) lent support for Stodden et al.'s (2008) hypothesis, with the MC-PA relationship in younger children dominated by the impact of PA on MC. The MC-PA relationship is expected to become more reciprocal as children enter middle and late childhood, where increasing importance may be placed on MC for providing the necessary skills to continue PA (Fisher et al., 2005; Holfelder & Schott, 2014; Stodden et al., 2008; Williams et al., 2008). Thus, among older children and adolescents in this study there exists a relationship that is generally only hypothesised to exist in earlier childhood. Other recent studies have also noted this phenomenon in older children, with the MC-PA reciprocal relationship among 12-13 year old girls dominated by the impact of PA on MC rather than the reverse (Jaakkola et al., 2018). Together this suggests that even in late childhood and early adolescence PA is influencing development of MC, despite the general expectation that by this age children will have mastered most FMS (Gallahue and Ozmun, 2012; Victoria Department of Education, 1996). Therefore, practitioners may need to rethink the expectation that older children and adolescents have sufficient MC to engage in adequate levels of health-enhancing PA.

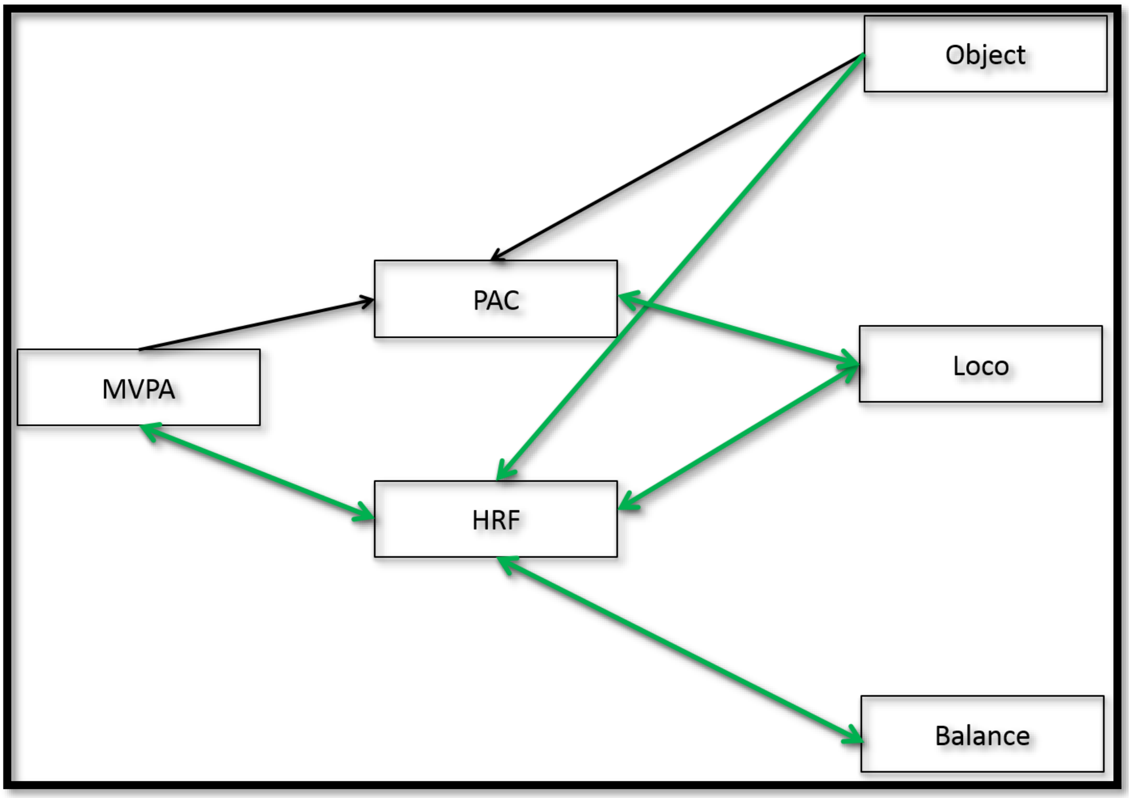


Figure 5.3 Pictorial representation of mediated pathways

5.6.2 Role of the mediators

Results from the present study found HRF to mediate the reciprocal MC-PA relationship across the transition from primary to second level school. Previous studies have identified positive relationships for HRF with both MC and PA. Cross-sectionally CRE and PA have been found to be positively correlated among children, with higher levels of CRE associated with increased time in MVPA (Bailey et al., 2012). Haugen et al. (2013) found that, in adolescents, higher self-reported PA (a composite of MVPA, moderate PA, and strength training) was associated with better HRF levels across all components of fitness, indicating that enhancements in HRF may be brought about by increases in PA (Haugen et al., 2013). A positive relationship between HRF and MC in adolescents has also been found. Hands et al. (2009) found that all HRF components significantly contributed to variance in MC. The relationship between HRF and PA was also measured by Hands et al. (2009) and results showed that HRF was more strongly associated with MC than with PA (Hands et al., 2009). Results from our study show a similar trend, with pathways from HRF to MC stronger than pathways from HRF to MVPA. HRF and MC are multifaceted constructs, whereas PA is frequently assessed in a singular way, in minutes of activity or step counts. To adequately perform some FMS, a degree of MS or ME may be needed, thus resulting in a stronger relationship between these two variables (Utesch et al., 2019). In contrast, minutes of MVPA, or step-counts, may be associated with CRE (Hands et al., 2009) and a limited range of FMS (e.g. run, skip) but may not relate as strongly to other locomotor skills (e.g. HJ, VJ), object-control skills or components of fitness such as MS and ME.

In addition to identifying relationships between PA, HRF and MC individually, our results show the role of HRF as a significant mediator of the MC-PA relationship during an important transition from primary to second level school. Being more physically active in 6th class is associated with better HRF in 6th class, which in turn predicts better MC in 1st year. In the reverse, being more proficient in FMS in 6th class is also positively associated with HRF in 6th class, which in turn predicts higher PA levels in 1st year. Interestingly, pathways from HRF to both MC and MVPA are stronger than pathways from MC and MVPA to HRF (Figure 5.1 and 5.2). HRF in this study encompasses CRE, MS and ME. Being proficient in these three components of fitness may enable youth to have the physical capacity to engage in a range of activities at a relatively high intensity, allowing for development of MC (Ré et al., 2016) and likely resulting in youth engaging in adequate levels of MVPA. Evidently, HRF is playing a key role in this MC-PA relationship as children transition from childhood to adolescence.

Previous studies which measured individually the effect of PAC and/or HRF on the MC-PA relationship have found perceived competence to be a significant mediator in older children and adolescents (Barnett et al., 2011; Barnett et al., 2008; Khodaverdi et al., 2015). However, to the author's knowledge, no previous study has tested the mediating effects of both PAC and HRF in the MC-PA relationship within the same model. Results from the current study showed reciprocal relationships existed through mediation by HRF but not by PAC. In addition, direct pathways mediated by HRF were stronger than those mediated by PAC. With HRF as a mediator, MVPA in 6th class predicted all three MC components in 1st year, and in the reverse direction, 6th class MC also predicted 1st year MVPA. With PAC as a mediator, MVPA in 6th class predicted locomotor MC in 1st year, but no other pathways in either direction were significant. Thus, it appears that actual fitness is more important than perceptions of competence for the mediating aspect of Stodden's model in this age group. The method of PA measurement could go some way to explaining the discrepancy in our findings and that of previous studies (Barnett et al. 2011; Barnett et al. 2008; Khodaverdi et al. 2015). Previous studies which have found PC to act as a mediator assessed PA via self-report, whereas our study used accelerometery. The link between perception of activity level, and perception of competence in the activity domain, may lead to differing results when analysing mediation effects. In addition, accuracy of perceptions, or lack thereof, may diminish the strength of PAC as a mediator when compared to a more objectively measured construct like HRF. Although perceptions of competence generally align more with actual competence as children enter into adolescence and become more cognitively developed, recent studies on Irish children and adolescents have highlighted a mismatch between perceived and actual competence within the physical domain (Farmer et al., 2017; O'Brien et al., 2018).

The current study examines mean changes in Stodden's variables across a key transition. It is important to acknowledge that individual differences in developmental trajectories will likely provide additional information with which to progress our understanding of the pathways depicted in Stodden's model (Luis P. Rodrigues et al., 2016). Future longitudinal studies should consider tracking changes over three or more timepoints to allow for this depth of analysis (King et al., 2018; Rodrigues et al., 2016). In addition, future studies could examine the context of PA to further our understanding of how specific types of PA may promote specific FMS or HRF development.

5.7 Conclusion

In conclusion, reciprocal relationships mediated by HRF existed for MC and PA across the transition from primary to second level school. Because of the mediating role played by HRF in the MC-PA relationship, and its positive association with both PA and MC, improving and developing HRF in the broad sense (targeting MS and ME along with CRE) will likely have a positive impact on both PA and MC in older children and adolescents. It is important to recognise that while the expectation is for MC to drive involvement in PA during late childhood and early adolescence, in this and other recent studies on older participants, the relationship from PA to MC is more dominant. Therefore, older children and adolescents may still be developing their MC through engaging in PA, albeit at a later age than expected. This makes the decrease in PA at this age even more worrying, given that these individuals may not have the necessary skills to enable them to engage in PA opportunities later in life.

CHAPTER 6

Predicting physical activity, motor competence, health-related fitness, and perceived competence in adolescents after the transition from primary to secondary school.

Chapter 6 Study 3

6.1 Purpose of the Chapter

6.1.1 Rationale

In chapter 5, HRF was found to be a significant mediator of the MC-PA relationship. In addition, strong pathways from HRF to both PA and MC, rather than the reverse, were found. The purpose of Chapter 6 was to build on these findings and determine the relative importance of each variable included in Stodden et al.'s (2008) model for predicting future behaviour across the school transition.

6.1.2 Contribution to the field

This study contributes to knowledge in the field as it is the first study to longitudinally assess all of the variables included in Stodden et al.'s (2008) conceptual model across a significant life transition. As such, it is possible to identify the relative importance of each of the variables in predicting future behaviour. The longitudinal design allows for a comprehensive test of the predictive and reciprocal pathways outlined in Stodden et al.'s (2008) model.

6.2 Abstract

Physical activity (PA) decreases with age, and the school transition is noted for significant changes in PA behaviour. Motor competence (MC), health-related fitness (HRF), and perceived competence (PC) are generally positively associated with physical activity (PA). This study investigated how PA, MC, HRF, and PC in final year of primary school were predictive of these variables post school transition in first year of secondary school. PA (accelerometery), object-control and locomotor components of MC (TGMD-III; Ulrich, 2016), PC (perceived athletic competence subscale of the Self-Perception Profile for Adolescents; Harter, 2012), and HRF (20m shuttle run, horizontal jump, vertical jump, push-ups, curl-ups) were measured in final year of primary school (6th class) and first year of secondary school (1st year). In 6th class, 261 participants (53% female and 47% males; mean age 12.22 ± 0.48 years) were tested. In 1st year, 299 participants (48% female and 52% male; mean age: 13.91 ± 0.58 years) were tested. In total, 224 participants were involved in the study at both timepoints. Cross-lagged regression in AMOS23, using full information maximum likelihood estimation, was conducted to test reciprocal and predictive pathways between variables in 6th class and 1st year. The full cross-lagged model showed acceptable fit ($\chi2 = 69.12$, df = 8, $p < .01$, NFI = .93, CFI = .94). HRF was the strongest predictor of future PA ($\beta = .353$), and also predicted PC ($\beta = .336$) and MC ($\beta = .163$). Object-control MC predicted future PA ($\beta = .192$). Reciprocal relationships existed between object-control MC and PA, and between object-control MC and PC. HRF was the strongest predictor of PA post-transition. Object-control MC also predicted PA. PA promotion strategies should target the development of HRF and object-control MC in primary school to reduce the decline in PA frequently observed after the school transition.

6.3 Background

Physical activity (PA) is associated with positive health outcomes in youth (Bailey et al., 2012; Ekelund et al., 2012), but globally there is a trend for decreasing PA with age (Corder et al., 2015). Despite recognition of the importance of PA, and subsequent public health initiatives targeting the problem of youth physical inactivity, there is little to suggest this decline in PA is being reversed. A key period where substantial changes in PA are often reported is the transition from primary to secondary school (Inchley, Kirby and Currie, 2008; De Meester *et al.*, 2014; Marks *et al.*, 2015). In Irish youth, students in secondary school have been found to be significantly less active than their primary school counterparts (Gavin et al., 2014; Woods et al., 2010). The school transition in Ireland, as in several other countries, occurs at the age of approximately 12 years, often coinciding with the onset of puberty. Notwithstanding the significant physiological changes that occur at this time, changing school environment, as an independent factor, has been shown to impact on PA behaviours (Lau et al., 2017; Marks et al., 2015; Taymoori et al., 2011).

Numerous factors are associated with youth engagement in PA (Robinson et al., 2015; Stodden et al., 2008). A seminal model published by Stodden and colleagues in 2008, which includes motor competence (MC), health-related fitness (HRF), and perceived competence (PC) as factors associated with PA, has since guided a body of research within the PA domain seeking to understand pathways that promote engagement in PA. Within this model MC is positioned as a primary determinant of PA, with HRF and PC proposed to mediate the relationship between MC and PA (Stodden et al., 2008). Pathways between each of the variables are hypothesised to be reciprocal and developmental, in that each variable has an impact on each other variable and the strength of these associations is likely to change with age (Robinson et al., 2015; Stodden et al., 2008).

MC is generally used to describe goal-directed movement requiring coordination of the body (Cattuzzo et al., 2014). An important aspect of MC is proficiency in fundamental movement skills (FMS) (Stodden et al., 2008). FMS are considered the basic building blocks needed for future PA (Clark and Metcalfe, 2002) and include locomotor skills, such as running, skipping and jumping, and object-control skills such as kicking, throwing and striking (Gallahue and Ozmun, 2012). Longitudinally, MC has been shown to be positively associated with PA, with low-MC children often becoming low-active adolescents (Barnett et al., 2009; Lloyd et al., 2014; Lopes et al., 2011). It is generally accepted that children have the capacity to master the basic components of most FMS by the age of between 6 and 9 years (Gallahue and Ozmun, 2012). Recent research however shows that many young people are not reaching the expected level of FMS mastery, both nationally (Belton et al., 2014; O' Brien et al., 2015a; O'Connor et al., 2018) and internationally (Mitchell et al., 2013).

HRF, a proposed mediator in Stodden et al.'s (2008) model, generally refers to a multidimensional construct consisting of cardiorespiratory endurance (CRE), muscular strength (MS), muscular endurance (ME), and flexibility (Caspersen et al., 1985). Often researchers choose just one component of HRF as a measure of fitness, with CRE most frequently assessed (Barnett et al. 2008 Kriemler et al. 2010; Woods et al. 2010) due to the well-established positive association between CRE and health (Ortega et al. 2008). There is a growing body of evidence that supports a positive association for MS and ME with health (Smith et al., 2014), indicating that MS and ME, in addition to CRE should be measured in youth. Longitudinally, childhood HRF is found to be a positive predictor of adolescent PA (Aires, Andersen, et al., 2010; Larsen et al., 2015), while cross-sectionally, HRF is also positively associated with MC in youth (Cattuzzo et al., 2014). Current trends for HRF report that the majority of youth (> 60%) are achieving acceptable levels of CRE (Belton, Issartel, et al., 2018; Santos et al., 2014; Tomkinson et al., 2018). That being said, Tomkinson et al. (2018) found that for every year from the age of nine, the percentage of males and females achieving a healthy CRE level decreased by 3% and 7% respectively. Considering the strong evidence for a positive association between HRF and health in youth, and cognisant of the drop-off in PA frequently reported during adolescence, establishing the role of HRF at this stage of development may be an important step in understanding how and why youth disengage from PA.

PC refers to an individual's ability to effectively master a task (Feltz, 1988) and, like HRF, is positioned as a mediator of the MC-PA relationship within Stodden et al.'s (2008) conceptual model. Cross-sectionally, positive associations between PC and self-report PA in youth have frequently been reported (De Meester, Maes, et al., 2016; Masci et al., 2017). When assessing PA using objective measures however, the same positive association has not always been found (Crane et al., 2015; Kavanaugh et al., 2015). In relation to MC, a positive association between PC and MC has been identified in youth, with some longitudinal studies finding that MC positively predicts PC in older adolescents (Cantell et al., 2003). PC has been found to be higher in younger compared to older youth (Piek et al., 2006), and, in some cases, has been found to be negatively affected by school transition (Arens et al., 2013). However, a review of the effects of school transition on psychological development generally highlighted how there are numerous interacting factors which determine whether the school transition has a positive or negative impact on individuals (Symonds and Galton, 2014). Research on the development of PC in the physical domain within an Irish setting is scarce, particularly in relation to changes during the school transition. Considering the significant impact that the school transition may have on PC (Arens et al., 2013) and the role that PC may play in promoting future PA (Stodden et al., 2008), it is important to establish the nature of the relationship between PC and PA over the course of the school transition, with a view to reducing the negative impact of this transition on future PA.

Individual pathways outlined in Stodden et al.'s (2008) conceptual model have been tested, both cross-sectionally and longitudinally. However, the complexity of the proposed model, particularly the hypothesised reciprocal pathways, requires a longitudinal design including all the variables identified by Stodden et al. (2008) to fully understand the predictive and reciprocal nature of the pathways. The current study aims to evaluate the pathways outlined in Stodden et al.'s (2008) conceptual model during a critical period in a child's life, the transition from primary to secondary school, with a view to understanding the primary predictors of PA post school transition.

6.4 Materials and Methods

6.4.1 Participants

Data were collected from participants in 6th class of primary school (January – April 2017), and one year later in 1st year of secondary school (January – May 2018). Participant recruitment began with contacting secondary schools which fit the criteria of having a maximum of three main feeder primary schools. Two secondary school principals consented for their schools to be involved in the study. Following this, the main feeder primary schools for both consenting secondary schools were contacted. Six primary school principals (three feeder schools for each secondary school) provided consent. Parental consent and participant assent were obtained in 6th class of primary school for each participating student. At baseline, 261 participants were tested (53% female and 47% males; mean age 12.22 ± 0.48 years). Of these, 37 participants were not available for testing in 1st year of secondary school as they did not transfer into the catchment area schools selected for data collection. In 1st year, 299 participants (48% female and 52% male; mean age: 13.91 ± 0.58 years) were tested. The sample in 1st year included an additional 75 students who had not attended the feeder primary schools. In total, 336 participants were involved in the study for at least one timepoint, and 224 of these participated at both timepoints. Ethical approval for all measures was obtained from the authors' institutional ethics committee.

6.4.2 Measures

Actigraph accelerometers (models: GT1M, GT3X, GT3X+, wGT3X-BT), set to capture data in 10-second epochs, were used to measure PA (Esliger et al., 2005). Participants wore the accelerometer for nine consecutive days during waking hours. To account for subject reactivity the first and last days of the wear period were excluded from analysis (Dossegger et al., 2014). A reminder text message was sent each morning to participants who had provided a contact phone number to increase compliance (Belton et al., 2013). Minutes of moderate-vigorous PA (MVPA) per day were calculated using Evenson et al. (2008) cut-points using Actilife version 6.13.3. Non-wear time was identified as greater than 20minutes of zero-counts, and count values of <0 and ≥15,000 per minute were excluded (Esliger et al., 2005). Similar to other studies measuring PA across school transition, greater than or equal to 8 hours was considered a valid day (Jago et al., 2012; Marks et al., 2015). The minimum number of valid days required for inclusion in analysis were two week- and one weekend day (Marks et al., 2015).

MC was assessed using skills selected from the TGMD-III (Ulrich, 2016) and the Victoria Department of Education (1996) manual: 1) object control skills: kick, catch, overhand throw, one-hand strike, and two-hand strike, 2) locomotor skills: run, skip, horizontal jump, and vertical jump. Each skill is made up of movement components. Presence or absence of a component is scored with a 1 or 0 respectively. Participants were videoed performing each skill and these videos were later scored by trained researchers.

Harter's Self-Perception Profile for Adolescents (SPPA) (Harter 2012) was used to measure perceived athletic competence (PAC). Athletic competence is one of nine dimensions in the SPPA, with the others being scholastic competence, social competence, physical appearance, job competence, romantic appeal, behavioural conduct, close friendship, and global self-worth. Each dimension is measured using five items scored with a structured alternative format scale designed to reduce social desirability (Harter, 2012). Each item has two criteria, e.g., "Some kids feel that they are better than others their age at sports BUT Other kids don't feel they can play as well". Participants first select which criteria they fit best with, then score this as either "sort of true for me" or "really true for me", creating a four-point scale. In the PAC dimension, items regard how well participants feel they do at sport, and how athletic they are in general. Higher scores indicate more positive self-perceptions (Harter, 2012). At both timepoints the PAC subscale showed satisfactory internal reliability (Cronbach's alpha coefficient; .83 and .87 in 6th and 1st year respectively).

HRF was measured using five tests (20metre shuttle run, horizontal jump, vertical jump, push-ups and curl-ups). A previous confirmatory factor analysis (CFA) showed these five tests give a fair representation of HRF in youth (Britton et al., 2018). Protocols for each

HRF test can be found in manuals for FITNESSGRAM (Plowman and Mahar, 2013) and EUROFIT (Council of Europe, 1983), and in the HELENA study (Ortega et al., 2008; Ortega et al., 2011) (Table 6.1).

Table 6.1 Measurement of HRF

Test	**Source**
20MST	FITNESSGRAM; EUROFIT
Grip strength	EUROFIT; HELENA Study
HJ	EUROFIT; HELENA Study
VJ*	HELENA Study
Pushups	FITNESSGRAM
Curlups	FITNESSGRAM
BS S&R	FITNESSGRAM

20MST=20metre shuttle run test; HJ=horizontal jump; VJ=vertical jump; BS S&R=backsaver sit-and-reach; EUROFIT (Council of Europe 1983). FITNESSGRAM (Meredith & Welk 2010). The HELENA Study (Ortega et al. 2008). *VJ was assessed using the Abalakov jump test protocol outlined in the HELENA study (Ortega et al. 2008) and using a jump mat and belt (Coulson & Archer 2009) in place of an infrared jump platform.

6.4.3 Data Processing

Due to the longitudinal study design, a missing data analysis was conducted. All variables had some degree of missingness at both timepoints. In 6th class 220 participants (65%) had missing data on at least one variable. In 1st year 295 participants (88%) had missing data on at least one variable. A large proportion of this missing data was due to accelerometer non-compliance. Excluding MVPA, 68% of participants in 6th class had complete data, while 34% of participants had complete data in 1st year. Little's "missing completely at random" (MCAR) test was conducted to determine the nature of missingness for data at each timepoint. Little's MCAR test was insignificant for data in 6th class (Little's MCAR χ^2 (33) = 22.05, p = .93) and 1st year (Little's MCAR χ^2 (37) = 52.28, p = .05) indicating that missing data was MCAR (Tabachnick and Fidell, 2007). Given the random nature of the missing data, path analysis using full information maximum likelihood estimation in AMOS version 23 was chosen as a means to estimate cross-lagged and autoregressive pathways between variables in 6th class and 1st year (Arbuckle, 2014). Maximum likelihood estimation is recommended for longitudinal data with missing values that are MCAR as it uses all available data for each participant to estimate model pathways (Enders et al., 2001; Shin et al., 2016).

Confirmatory factor analyses (CFA) were conducted in AMOS version 23 to create latent variables for locomotor MC, object-control MC, AC, and HRF. First, the measurement models for each latent variable in 6th class were tested. All items tested for each variable were included in the initial CFA's. Following statistical and theoretical analyses, catch was removed from the object-control MC latent variable due to both its relatively low loading (0.43; Brown, 2006), and the nature of its assessment within the TGMD. The success criteria for the catch include using two hands to catch a tennis ball. For older children and adolescents, advanced execution of the skill generally results in catching with one hand. Therefore, if evaluating the catch as directed in the TGMD manual, participants with more advanced skill levels who catch the ball with one hand will ultimately fail on the "catch with two hands" criteria. This indicates a clear issue with the inclusion of catch within the object-control MC latent variable when evaluating this skill in older children and adolescents. The removal of the catch resulted in an improvement in model fit in the object-control MC latent variable. All individual items were retained for locomotor MC, PAC, and HRF. Each of the latent variables showed acceptable model fit in 6th class (Table 6.2). Following this, measurement invariance from 6th class to 1st year was assessed and showed all latent variables to be invariant over time (Table 6.3).

Table 6.2 Fit indices for latent variables in 6th class

Variable	$\chi 2$	df	Sig.	CFI	RMSEA		
					RMSEA	**LCI**	**UCI**
AC	5.56	5	0.352	0.990	0.040	0.020	0.070
Object-Control*	1.1	2	0.576	1.000	0.000	0.000	0.090
Locomotor	2.65	2	0.266	0.980	0.031	0.000	0.117
HRF	14.26	3	0.003	0.960	0.106	0.055	0.164

*catch removed due to low loading

Table 6.3 Measurement invariance for latent variables

Variable	χ^2	df	Sig.
PAC	6.33	4	0.176
Object-Control*	7.33	3	0.062
Locomotor	5.291	3	0.152
HRF	7.786	4	0.100

*catch removed due to low loading

6.4.4 Analysis

A cross-lagged regression model was specified consisting of four latent (locomotor MC, object-control MC, AC, and HRF) and one observed (MVPA) variable, each measured in 6th class and again in 1st year. Full panel analyses in AMOS, using maximum likelihood estimation, was used to test all hypotheses simultaneously. The model included autoregressive paths for each variable over time and cross-lagged paths from each variable in 6th class to each other variable in 1st year. As measurement invariance was satisfied the full cross-lagged regression model was specified with observed variables to allow for a more parsimonious model fit (Harju et al., 2016). Variables that had a correlation of $\geq .30$ within timepoints were allowed to correlate.

Goodness of fit for the full model, was examined using the Chi-square (χ^2) test, the Comparative Fit Index (CFI), and the Normed Fit Index (NFI). Along with CFI, Root Mean Square Error of Approximation (RMSEA) is another of the most frequently reported fit statistics (Tabachnick and Fidell, 2007). In models with few degrees of freedom (df) interpretation of RMSEA can however result in rejecting a good-fitting model (Hu and Bentler, 1999) A non-significant χ^2 indicates good fit. CFI and NFI values of > 0.9 show acceptable model fit (Byrne, 2010; Schumacker and Lomax, 1996), while values of > 0.95 for CFI are considered to show superior fit (Hu and Bentler, 1999).

Using multigroup analysis, a Chi-square (χ^2) difference test was conducted on the full model to identify any sex differences in pathways. A significant χ^2 test indicates variance between sexes for model fit (Kline, 2015). The table of critical ratios was also inspected. Values >

1.96 for a given pathway indicate a significant difference between groups for this pathway (Arbuckle, 2014).

6.5 Results

The full cross-lagged model showed acceptable fit ($\chi^2 = 69.12$, df = 8, $p < .01$, NFI = .93, CFI = .94). Pathways with standardised regression coefficients greater than .10 are shown in Figure 6.1.

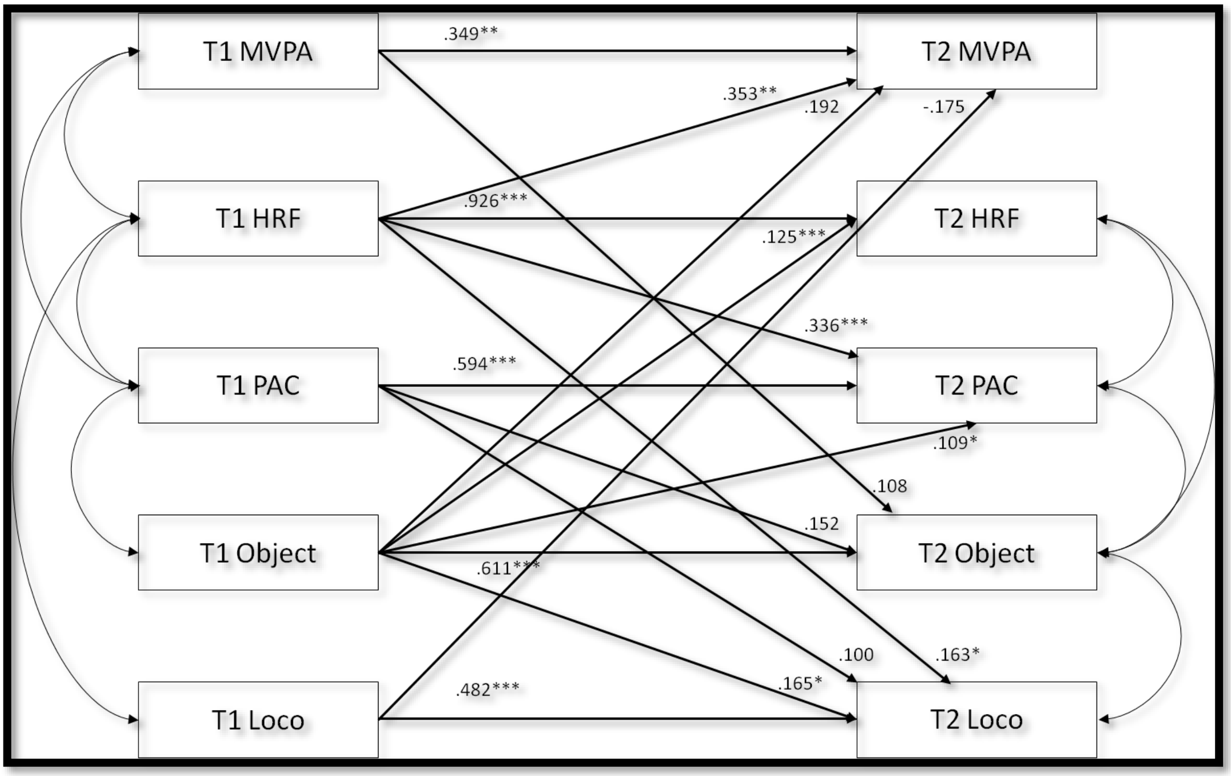


Figure 6.1 Autoregressive and cross-lagged pathways

Each variable in 6th class significantly and positively predicted itself in 1st year (Figure 6.1). HRF and object-control MC were highly stable over time, while all other variables showed moderate stability over time. MVPA was the least stable over time.

HRF was a moderate and significant predictor of MVPA ($\beta = .353$) and PAC ($\beta = .336$) in 1st year, and significantly predicted 1st year locomotor MC ($\beta = .163$), though this association was small. Other than the associations between 6th class HRF and 1st year MVPA and PAC, all other pathways from 6th class to 1st year variables were small (0.10 – 0.29). Reciprocal relationships between object-control MC and MVPA, and object-control MC and PAC were found. In addition, object-control MC in 6th class was a significant predictor of HRF (β = .125) and locomotor MC ($\beta = .165$) in 1st year. Locomotor MC in 6th class negatively predicted MVPA in 1st year, though this association was small and insignificant (β = -.175). PAC in 6th class was a predictor of locomotor MC in 1st year (β = .100).

For variance in 1st year variables, the overall model predicted 81% variance in HRF, 61% variance in PAC, 44% variance in object-control MC, 39% variance in locomotor MC, and 34% variance in MVPA. Excluding autoregressive pathways, HRF was the only 6th class variable to exhibit moderate associations with multiple variables in 1st year. Object-control MC also contributed to a variance in multiple factors in 1st year, but these associations were small.

Significant differences in model fit for males and females were found following a χ^2 difference test (CMIN = 48.02, df = 25, $p < .004$). Inspection of the critical ratios table showed differences in regression coefficients for several pathways in the model (Table 6.4). A moderate autoregressive pathway was found for MVPA in males, but the same pathway in females was extremely weak. A strong autoregressive pathway was found for object-control MC in females, but the same pathway for males was small. A small positive pathway from 6th class MVPA to 1st year object-control MC was found for males, but for females the pathway was negative, and much stronger. Similarly, the pathway from 6th class MVPA to 1st year locomotor MC in females was moderate and negative, whereas for males there was no visible pathway between 6th class MVPA and 1st year locomotor MC.

Table 6.4 Pathways by sex

	Males		Females	
Pathway	**β**	**Sig**	**β**	**Sig**
T1 MVPA - T2 MVPA	0.590	***	0.019	NS
T1 Object-T2 Object	0.298	**	0.654	***
T1 MVPA-T2 Object	0.144	NS	-0.329	**
T1 MVPA-T2 Loco	-0.004	NS	-0.358	**

6.6 Discussion

The purpose of this study was to identify pathways between PA, MC, HRF and PAC, across the transition from primary to secondary school in a cohort of adolescent Irish youth. Building on previous research (Britton et al., 2019) which identified baseline HRF as a strong mediator between MC and PA, the current research sought to better understand the predictive role of each of the variables identified in Stodden et al.'s (2008) model. A significant finding from this research is the role of HRF in predicting future PA, PAC and MC. Even when accounting for baseline PA, HRF was the strongest predictor of 1st year MVPA. HRF also positively predicted 1st year PAC and locomotor MC. Britton et al. (2019) demonstrated that pathways were stronger in the direction of HRF to MC and PA rather than in the reverse direction. Results from the current study support these findings providing evidence for the important role of HRF in predicting future PA. Indeed, contrary to Stodden et al.'s (2008) model, where MC is hypothesised as the driving force for engaging in PA, in this sample, HRF is the primary factor positively predicting MVPA post school-transition.

A positive association between HRF and PA in youth has frequently been reported, both cross-sectionally (Bailey et al., 2012; Burgi et al., 2011; Haugen et al., 2013) and longitudinally (Aires et al., 2010; Jaakkola et al., 2016). Jaakkola *et al.* (2016) found both MC and fitness in early adolescence to have a significant impact on self-report PA in young adulthood, with the association with moderate PA stronger for fitness than for MC (Jaakkola et al., 2016). In the current sample, compared to MC, HRF acted as a much stronger predictor of future PA. While MC is undoubtedly an important factor for PA engagement, it is possible that HRF is more important in promoting involvement in PA. Involvement in PA can of course in turn subsequently allow for development of MC (Jaakkola et al., 2018) and further enhancements in HRF (Bailey et al., 2012). In a study examining adolescents involvements with the ball during recreational soccer matches, Ré *et al.* (2016) found that HRF, along with agility, was the strongest predictor of involvements with the ball, while soccer specific technical skills did not significantly contribute to an individual's involvement. At a recreational level, having higher levels of HRF may enable youth to be more engaged within a PA setting, as demonstrated by Ré *et al.* (2016), which may then allow for subsequent development of MC, as well as promoting higher levels of MVPA.

In comparison to other cross-sectional studies examining associations between HRF and MC (Stodden et al., 2013), the longitudinal nature of the present study allows for analysis of predictive pathways between variables and clearly shows that HRF is a stronger predictor of MVPA compared to MC. Considering the potential importance of HRF in enabling youth to engage in MVPA, as demonstrated from the current findings, and the numerous health benefits associated with HRF (Ortega *et al.*, 2008), it is essential that practitioners seek to promote HRF development in youth. However, in the same way that repetitively striking a ball from a tee, such as outlined in MC test manuals, would not be recommended as a method to develop MC in youth, simply mimicking HRF tests as a means of developing HRF should also not be encouraged. Novel and fun programmes that develop HRF with a view to promoting lifelong engagement in PA are more likely to be successful (Belton, O'Brien, et al., 2018), rather than overly prescriptive methods of HRF promotion. Programmes that take this more holistic approach seem to be more likely to succeed in their goals of increasing HRF, PA and MC (Lai et al., 2014).

In addition to HRF, object-control MC was the only other variable in 6^{th} class that significantly and positively predicted MVPA in 1^{st} year. Similar to the current results, Barnett et al. (2009) found that object-control, but not locomotor MC, at age 10 significantly predicted self-report PA six years later (Barnett et al., 2009). Object-control MC appears to be more stable over time compared to locomotor MC (Barnett et al., 2010). The relationship between object-control MC and MVPA in the current sample was reciprocal, supporting the hypothesis outlined in Stodden et al.'s (2008) conceptual model. This is in keeping with a previous study which reported a positive reciprocal relationship in older adolescents for object-control MC and self-report MVPA (Barnett et al., 2011). Consistent with Barnett et al.'s (2011) findings, the current study found no reciprocal relationship between MVPA and locomotor MC. In the current sample object-control MC, more so than locomotor MC, was predictive of future PA. Object-control MC encompasses skills such as kicking, throwing, and striking. These skills are required for participation in many of Ireland's most popular youth sports (Hardie Murphy et al., 2017). Despite other forms of activity available to young people which require locomotor proficiency (cycling, walking, running), it is likely that activities which require object-control MC are more popular in an Irish adolescent population, and that, without proficiency in this component of MC, youth are likely to disengage from popular sports and thus fail to be sufficiently physically active for health. In addition to a reciprocal relationship between object-control MC and MVPA, a reciprocal relationship was also found between object-control MC and PAC. While PAC did not predict MVPA in this sample, similar to other studies using objective measures of PA (Kavanaugh et al., 2015), it did positively predict object-control MC. In fact, this reciprocal relationship was slightly stronger in the direction of PAC predicting object-control MC rather than the reverse. It may be that higher levels of PAC provide young people with the confidence to develop their skills, and that, in time the knock-on effect of higher PAC on MC would then promote future engagement in MVPA. Further research is required to fully investigate this pathway in adolescence.

6.6.1 Differences between males and females

Substantial differences in some of the pathways depicted in the model were seen between males and females in the current study. For males, MVPA in 6^{th} class was a strong predictor of 1^{st} year MVPA, whereas for females this pathway was virtually non-existent. This supports previous research nationally (Murphy, Rowe and Woods, 2016) and internationally (Anderssen, Wold and Torsheim, 2005) which has found PA to be more stable in males compared to females over time. In the current study, PA was less stable across the school transition compared to HRF, MC and PAC. PA is a behaviour, whereas HRF and MC are individual attributes (Hands et al., 2009). Compared to HRF and MC, PA is more likely to be influenced by psychosocial factors (Rowland, 2005), which can be magnified during major transitions such as the school transition (Anderssen et al., 2005). It is possible that the instability in PA seen in females during the school transition reflects a greater impact of school transition on females compared to males. In research on the effects of the school transition on adolescents, Anderson *et al.* (2000) found that the impact of the transition on self-perceptions was greater on females. It may be that the same holds true for PA behaviours during this transitional period.

While MVPA was less stable in females than males across the transition, the opposite was found for object-control MC, indicating that object-control MC is less likely to change in females compared to males across the school transition. A longitudinal study in Irish youth reported that, between the ages of 10 and 18, females were more likely to drop out of organised sport and less likely to take up a new sport compared to males (Hardie Murphy et al., 2017). Popular youth sports in Ireland, such as Gaelic games, soccer, and basketball (Hardie Murphy et al., 2017) provide the opportunity to develop many object-control skills. If females are more likely to drop out of sport during the adolescent years (Hardie Murphy et al., 2017), then it is likely they will not have the opportunity to further develop their object-control MC, potentially explaining the higher stability in this MC component over time.

Contrary to expectation, 6^{th} class MVPA negatively predicted 1^{st} year MC for females. In comparison, 6^{th} class MVPA did not have a substantial effect on 1^{st} year MC for males. MC has been identified as an important factor for social acceptance within peer groups for males (Grimminger, 2013). For females however, no positive association is seen between MC and popularity with peers (Grimminger, 2013). In fact, earlier studies found that sport competency was associated with being the least popular member in female peer groups (Feltz, 1978; Williams and White, 1983). This could potentially explain how MVPA in 6^{th}

class negatively predicted MC in 1st year for females in this sample. Female participants who were relatively active in primary school may recognise that being competent in sports or motor skills is not in fact conducive to being accepted within their peer group, and as a result may depress their abilities simply to "fit in".

That being said, HRF in 6th class was a positive predictor of MC for females in 1st year. HRF in females, and males, is highly stable over time. In comparison, MVPA for females is highly unstable. This lack of stability in MVPA compared to HRF for females may in part explain how MVPA could negatively predict MC while HRF positively predicts MC. Notwithstanding the significant mean change in MVPA in females across the school transition, significant intra-individual change is also occurring, as indicated by the low stability of MVPA. Thus, females who were highly active in 6th class may be low active in 1st year and vice versa. This may then have a knock-on effect on their execution of MC in 1st year. In comparison, HRF in females is much more stable indicating that fitness levels attained by 6th class of primary school carry through into 1st year of secondary school. In addition, compared to MVPA which is a singular variable, HRF is a multifaceted construct (Caspersen et al., 1985; Utesch et al., 2019). Having high levels of HRF indicates that an individual displays fitness across a range of different activity-types (e.g. activities requiring CRE, MS and ME). Higher levels of HRF in 6th class likely provide individuals with the tools to engage in numerous activities in 1st year that require proficiency in various FMS, thus enabling the development of MC (Hands et al., 2009). It is unlikely that females who were active in 6th class lose the capacity to successfully execute the basic components of many object-control and locomotor skills in 1st year. It is more likely that the perceived value of MC and PA within the female peer group impacts on the desire of some female adolescents to appear competent in what is often perceived as a male environment (Grimminger, 2013).

6.7 Strengths and limitations

This is the first study to explore the predictive pathways between all of the variables depicted in Stodden et al.'s (2008) model across the school transition. In addition, the use of CFA to check for measurement invariance in each variable over time in this study is a crucial yet often ignored practice in longitudinal analyses. Poor accelerometer compliance, and the subsequent loss of PA data, along with a high degree of missing data in general, is a limitation of this study, not uncommon in longitudinal research in this field. However, the use of full information maximum likelihood path analysis allowed for analysis on pathways between variables from primary to secondary school to be conducted, despite missing data.

6.8 Conclusion

Findings from the current study point to the importance of HRF for future PA engagement in adolescents. Whereas MC is commonly positioned as one of the primary predictors of PA, this study found HRF, measured as a composite, to be more important in predicting PA across the transition from primary to secondary school. Object-control proficiency, as a component of MC, was however found to have a positive effect on PA, and other factors shown to be associated with positive PA behaviour. From this perspective it would seem that developing HRF and object-control MC in primary school may be crucial factors to consider as we strive to address the frequently reported decrease in PA observed across the school transition.

CHAPTER 7

Changes in Physical Activity, Motor Competence, Perceived Competence, and Health-Related Fitness during the school transition: a longitudinal study

Chapter 7 Study 4

7.1 Purpose of the Chapter

7.1.1 Rationale

In chapters 5 and 6 pathways in Stodden et al.'s (2008) conceptual model were evaluated during the transition from primary to secondary school. While these chapters contributed to understanding of the pathways between the variables included in Stodden et al.'s (2008) model, little was known about the way in which each of these variables changed during the school transition, or the impact of the transition on these variables in the longer term, as youth progressed through secondary school. The purpose of the study in this chapter was to longitudinally assess changes in PA, MC, HRF, and PC immediately and one year after the school transition.

7.1.2 Contribution to the field

This study contributes to the field by presenting information on changes in seminal health-related variables at a critical time in an adolescent's life, that of the transition from primary to secondary school. This study measured a wide array of variables that are known to be associated with PA and health and provides an insight into how changes in health-related variables during the school transition differ between males and females.

7.1.3 Peer review status

The study in this chapter is currently under review in the *Journal of Physical Activity and Health* under the title: *Changes in Physical Activity, Motor Competence, Perceived Competence, and Health-Related Fitness during the school transition: a longitudinal study*

7.2 Abstract

School transitions can negatively impact PA. This study measured mean change in physical activity (PA), motor competence (MC), perceived competence (PC), and health-related fitness (HRF) across the primary to secondary school transition. PA (accelerometery), MC (TGMD-III (Ulrich, 2016)), PC (Perceived Athletic Competence, Perceived Physical Appearance, Global Self-Worth (Harter, 2012)), and HRF (20m shuttle run, horizontal jump, vertical jump, push-ups, curl-ups) were measured in participants (n = 85; baseline age 12.22 years) yearly for three years, from final year of primary to second year of secondary school. Mixed between-within ANOVA were used to analyse sex differences for changes in each variable over time. PA decreased significantly immediately post-transition but increased during secondary school for males. MC increased or remained stable in males post-transition. MC increased in females immediately post-transition but decreased during secondary school. perceived physical appearance and global self-worth decreased over time. perceived athletic competence decreased significantly for females. Performance on 20metre shuttle run decreased over three years, but other measures of HRF increased or remained stable. PA declined during the school transition. Changes in PA and other related variables were influenced by proximity to the school transition, and by sex.

7.3 Background

Globally, physical activity (PA) levels in children and adolescents are below the recommended guidelines (World Health Organization, 2010) of 60 minutes moderate-vigorous physical activity (MVPA) per day (Hallal et al., 2012). There is also a trend for decreasing PA with increasing age (Corder et al., 2015). Cross-sectional and longitudinal studies have found that PA is higher in younger compared to older children (Cooper et al., 2015; Corder et al., 2015) and tends to decrease from childhood into adolescence (Adamson et al., 2017). Low PA levels among children, along with a trend for decreasing PA into adolescence, is worrying given the positive association between PA and health (Bailey et al., 2012; Ekelund et al., 2012).

The transition from primary to secondary school is noted for significant changes in PA (De Meester et al., 2014; Inchley et al., 2008; Marks et al., 2015). In many countries, including Ireland, the school transition occurs at approximately 12 years. In Australian children, where the school transition occurs at a similar time to Ireland, significant reductions in accelerometer-measured MVPA (-4 minutes) and light PA (-23 minutes) and a significant increase in sedentary time (+16minutes) were seen six months post school transition, with no significant difference for sex (Marks *et al.* 2015). Notwithstanding physiological changes that occur around this time with the onset of puberty, changing school environment in itself was found to impact PA behaviours such as cycling to school and activity intensity at break times, independent of the effects of maturation (Marks et al., 2015). In comparison, in Belgian children (n = 420; mean age at baseline = 11.1 years) a mean increase in weekday MVPA was seen two years post school transition in males (34.55 ± 20.60 to 40.79 ± 26.57 mins) and females (19.78 ± 13.65 to 21.59 ± 15.40 mins) (De Meester et al., 2014). Proximity of the follow-up measure to the transition may have resulted in contrasting findings from these studies. The negative impact of school transition on PA may be more pronounced immediately post-transition, and may decrease as adolescents adjust to their new environment (Marks et al., 2015). Other studies measuring PA pre and post school transition have also reported significant changes in PA, with mean after-school MVPA decreasing in British boys (-16%) and girls (-12%) after the school-transition and mean weekend MVPA increasing (+24% for boys and +17% for girls) in this sample (Jago et al., 2012). In some countries school transitions take place earlier in childhood, or later into adolescence. Regardless of when the transition takes place, changes in PA have been found at the transition point, with a decrease in PA found when the transition takes place later in adolescence (Taymoori, Berry and Lubans, 2011) and earlier in childhood (Lau et al., 2017).

The reasons that youth engage in PA are numerous and studies show that many factors combine to promote PA (Robinson et al., 2015; Stodden et al., 2008). A conceptual model developed by Stodden et al. (2008) identified motor competence (MC), perceived competence (PC), and health-related fitness (HRF) as pertinent factors interacting with each other and PA to promote health in youth. MC contains three categories of fundamental movement skills (FMS) - stability, object-control, and locomotor skills, and reflects an individual's motor skill proficiency (Gallahue and Ozmun, 2012; Stodden et al., 2008). MC is positively associated with PA in childhood, and longitudinally into adolescence and adulthood (D'Hondt et al., 2014; Green et al., 2011; Lloyd et al., 2014). It is generally accepted that children have the physical capacity to successfully execute the performance criteria of most FMS by the age of 7 – 9 years (Gallahue and Ozmun, 2012), and that MC will improve with age (Barnett et al., 2016; D'Hondt et al., 2014). Whether this happens depends on children being given the opportunity to learn and practice FMS, as FMS are not innate but must be learned through practice (Clark, 2007). Previous research has lent support to the idea that MC generally increases with age (D'Hondt et al., 2013; Henrique et al., 2018; Lima et al., 2017). D'Hondt et al. (2013) measured changes in product-based FMS between age 6-8 and age 10-12 and found that mean performances improved over time. Henrique et al. (2018) also reported mean increases in product-based FMS from 6 – 9 years. Lima et al. (2017) tracked MC from childhood (age 6) into adolescence (age 13) and found a similar trend. Contrary to PA research, to the author's knowledge no research has looked at trends in MC development across a key transition such as the primary to secondary school transition. Given the known association between MC and PA (Barnett et al., 2009; D'Hondt et al., 2014; Green et al., 2011; Lloyd et al., 2014), and the impact that school transition may have on PA (Marks et al., 2015), monitoring both variables over the transition will allow for a better understanding of the nature of PA and MC change across the transition.

In addition to actual MC, perceived competence (PC), is identified as an important factor in youth engagement in PA (Stodden et al., 2008). PC in the physical domain is the belief in one's ability to perform physical activity-related skills (Harter, 2012). PC has been found to be positively associated with current and future PA (De Meester, Maes, et al., 2016; Zhang et al., 2015). Zhang et al. (2015) found PC to be a significant positive predictor of self-report PA in 10-12 year olds, while De Meester et al. (2016) found that, in adolescents, PC was significantly related to self-report weekly PA. Similar to PA, there is a trend for decreasing PC with age (Shapka and Keating, 2005) and for PC to be higher in males compared to females (Piek et al., 2006; Shapka and Keating, 2005). The impact of school transition on psychological constructs has been well researched, but findings are inconclusive as to whether the transition positively or negatively affects self-perceptions (Evans et al., 2018; Symonds and Galton, 2014). Because the transition generally coincides with the onset of puberty it can be difficult to separate the impact of the transition on PC from the impact of puberty. One study that managed to address this issue was carried out among German children, where the school transition occurs before puberty (after Grade 4; age approx. 10years) (Arens et al., 2013). Results showed that PC decreased post transition, despite these children likely having not reached puberty at the time of transition. Again, PC was assessed immediately pre and post the transition, perhaps accentuating the negative effect of the transition (Marks et al., 2015). Measuring additional timepoints post transition may show the longer-term impact of the transition on changes in PC.

Health-related fitness (HRF) is known to interact with both actual and perceived competence to promote PA (Ré et al., 2016; Stodden et al., 2008). HRF is a multidimensional construct generally referred to as consisting of five components; cardiorespiratory endurance (CRE), muscular strength (MS) and endurance (ME), flexibility, and body composition (Caspersen et al., 1985). HRF is a powerful marker of health in youth (Ortega et al., 2008; Ruiz et al., 2009), and is positively associated with PA (Burgi et al., 2011; Larsen et al., 2015). Childhood CRE has been identified as a strong determinant of obectively-measured MVPA in adolescence (Larsen et al., 2015), while high levels of vigorous PA in younger children (mean age at baseline = 5.2 years) have been shown to be positively associated with changes in CRE 9months later (Burgi et al., 2011). HRF generally increases for both males and females from childhood into adolescence (Ortega et al., 2011; Santos et al., 2014). For specific components of HRF, changes with age vary by sex. For example, VO_{2max}, a measure of CRE, tends to increase as children transition into adolescence (Janz et al., 2000; Kemper et al., 2013). For females, a plateau is then seen around the ages of 13-14 years, while for males the increase lasts into later adolescence (Janz et al., 2000; Kemper et al., 2013). MS and ME generally increase at a faster rate in males compared to females from around 12 years of age, reflecting physiological changes associated with the onset of puberty (Tomkinson et al., 2018). An increase in circulating testosterone in post-pubescent males results in rapid increases in MS and ME. In comparison to other components of HRF, flexibility develops at a similar rate in males and females (Tomkinson et al., 2018). While these changes in HRF components over time are well documented, there is little research on the nature of these changes at the time of the school transition. One study looking at changes in HRF across the school transition in Ireland reported an increase in HRF from final year of primary school to first year of secondary school for males, but a decrease in HRF for females (Britton et al., 2019). This change was identified directly post school transition. Identifying whether these trends continue further into secondary school for males and females could give a greater insight into the duration of the impact on changes in fitness.

The school transition is often cited as a key period when PA habits change for the worse. There is evidence to suggest that, irrespective of the onset of puberty, the school transition may have an effect on PA (Taymoori, Berry and Lubans, 2011; Jago, Page and Cooper, 2012; De Meester, Maes, et al., 2016; De Meester, Stodden, et al., 2016) and PC (Anderson et al., 2000; Arens et al., 2013). Taking the perspective of Stodden et al. (2008) whereby, in addition to PA and PC, MC and HRF are identified as key contributors to health, this study aims to develop a picture of trends for change in each of these variables during the school transition, and to identify if these trends are consistent as youth progress through secondary school.

7.4 Methods

7.4.1 Participants

Data were collected from participants in final year (6th class) of primary-level school (January – April 2017), 1st year (January – May 2018), and 2nd year (January-February 2019) of secondary school. Ethical approval was granted by DCU Research Ethics Committee (DCUREC2016_109). Informed consent was granted by all participating school principals, and individual parental/guardian consent was also obtained. Prior to testing, a physical activity readiness questionnaire was also completed for each participant by their parent/guardian. At baseline (6th class of primary-level school) 261 children (53% female; mean age 12.22 ± 0.48 years) participated. In 1st year of secondary school 37 participants were unavailable for data collection as they moved to schools not involved in the study. An additional 75 students who had not attended the initial feeder primary schools were included at this time point (n = 299; 48% female; mean age: 13.91 ± 0.58 years). At two-year follow up (2nd year of secondary school) students in one secondary school were unavailable for data collection because of administrative issues in the school. Therefore, 108 participants were available for testing (52% female; mean age: 14.18 ± 0.50 years). The total number of participants with data for at least one variable at three timepoints was 85. There were no significant differences for baseline age or sex between participants who attended one secondary school versus the other.

7.4.2 Measures

PA was measured using Actigraph (models: GT1M, GT3X, GT3X+, wGT3X-BT) accelerometers. Accelerometers were worn by participants for nine consecutive days during waking hours, with the first and last days omitted from analysis to account for reactivity (Dossegger et al., 2014). Data were captured in 10-second epochs (Esliger et al., 2005).

MC was assessed using Ulrich's (2016) Test of Gross Motor Development III for all object-control skills (kick, catch, overhand throw, one-hand strike, and two-hand strike) and for three of four locomotor skills (run, skip, and horizontal jump). The fourth locomotor skill, the vertical jump, was assessed in accordance with the Victoria Department of Education training manual (Victoria Department of Education, 1996). These manuals divide the skills into specific movement components, and participants are marked with a 1 for presence, or a 0 for absence, of each component for each skill. Participants were videoed performing each skill and scoring by trained field staff was done later. Balance skills were assessed using the Movement Assessment Battery for Children-2 (MABC-2; Barnett, Henderson. and Sugden, 2007).

PC was assessed using 3 subscales of the Self-Perception Profile for Adolescents (SPP-A (Harter, 2012) - perceived athletic competence (PAC), perceived physical appearance (PPA), and general self-worth (GSW). Each subscale contains five items scored on a four-point scale, with higher scores indicating more positive self-perceptions in that domain (Harter, 2012).

A review of methodologies from recent large-scale studies (Ortega et al., 2011; Ruiz, Castro-Pinero, et al., 2011; Santos et al., 2014) led to the selection of six tests for measurement of HRF (Table 7.1). Detailed protocols for each test area available from the test manuals (FITNESSGRAM (Plowman and Mahar, 2013); EUROFIT (Council Of Europe, 1983); Helena Study (Ortega *et al.*, 2008; Ortega *et al.*, 2011)).

Each of the variables was measured at each time-point, and data collection and analysis procedures were the same for each time-point.

Table 7.1 Selected HRF tests and source

HRF Component	Test	Source
Body Weight Status	BMI	FITNESSGRAM
CRE	20MST	FITNESSGRAM; EUROFIT
MS	HJ	EUROFIT; HELENA Study
	VJ*	HELENA Study
ME	Push-ups	FITNESSGRAM
	Curl-ups	FITNESSGRAM

20MST=20metre shuttle run test; HJ=horizontal jump; VJ=vertical jump; FITNESSGRAM (Meredith & Welk 2010). The HELENA Study (Ortega et al. 2008). *VJ was assessed using the Abalakov jump test protocol outlined in the HELENA study (Ortega et al. 2008) and using a jump mat and belt (Coulson & Archer 2009) in place of an infrared jump platform.

7.4.3 Data Processing

Actilife version 6.13.3 was used to process all accelerometer data. Mean daily minutes of MVPA were calculated using Evenson et al. (2008) cut-points. Periods of greater than 20minutes of zero-counts were considered as non-wear time and excluded. Count values of <0 or $\geq 15,000$ were considered implausible and excluded. Participants were included for analysis if they met the wear-time criteria of greater than or equal to 8 hours (Jago et al., 2012; Marks et al., 2015) for at least two days (Rich et al., 2013).

Videos for each of the object-control and locomotor skills were analysed by trained field staff. At each timepoint, prior to scoring, a minimum interrater agreement of 95% between the lead researcher and designated research team member was met. For each skill, the number of components present over two trials was summed to give a total skill score. For the object-control and locomotor component scores the total skill scores for the relevant FMS were summed to give a component score out of 34 for locomotor and 40 for object-control. Balance was scored using the MABC-2 manual (Barnett et al., 2007). Raw scores on each balance test were standardised by age and converted to standard scores. These were then summed to give a total score for balance.

Scores for PAC, PPA, and GSW were obtained by calculating the mean of the five items comprising each sub-scale (Harter, 2012).

Running speed on the last completed shuttle of the 20MST was used to calculate VO_{2max} using the equation outlined in Léger *et al.* (1988). Maximum jump height (VJ) and distance (HJ) was calculated, as well as the maximum number of push-ups and curl-ups completed. BMI was calculated using the equation weight/height^2.

7.4.5 Statistical Analysis

SPSS and AMOS (version 23) were used to analyse the data. Scores for each of the variables were entered in SPSS and descriptive statistics were calculated for each variable at each timepoint. Mixed between-within subjects ANOVA were conducted to investigate the effect of time, and the interaction of time with sex, on each variable across the school transition. Pairwise comparisons using a Bonferroni correction were used to identify significant differences between each of the three timepoints. If sphericity could not be assumed (Mauchly's Test of Sphericity, p > .05), degrees of freedom for the dependent variable were corrected using either the Hyunh-Feldt or Greenhouse-Geisser correction, depending on the value of epilson (Ɛ) given for each by Mauchly's Test of Sphericity (Field, 2013, p. 658). Effect sizes were calculated according to Cohen's (1988) criteria (0.01 = small, 0.06 = medium, 0.14 = large effect size).

7.5 Results

Mean scores and significant differences for sex for all measures at each time point are given in Table 7.2. Results from the mixed between-within ANOVA revealed a significant and large interaction effect between sex and time for MVPA (F (1.79, 48.44) = 4.43, $p < .05$, $\eta^2 = .14$). Pairwise comparisons showed a significant decrease in MVPA from 6th class to 1st year in males ($p < .001$). Mean MVPA from 1st to 2nd year increased for males but decreased for females, although these changes were not statistically significant. Mean MVPA for both males ($p < .001$) and females ($p < .001$) was significantly lower in 2nd year compared to 6th class.

There was no interaction effect for sex and time on object-control skills. There was a significant and large main effect for time (F (1.71, 42.8) = 9.7, $p < .05$, $\eta^2 = .28$). Pairwise comparisons showed that mean object-control proficiency increased significantly for males ($p < .05$) and females ($p < .01$) from 6th class to 1st year, and then decreased significantly for females ($p < .01$) from 1st to 2nd year, but not below 6th class levels. For both males and females there was no significant difference between 6th class and 2nd year object-control MC. For locomotor MC there was a significant and large interaction effect between sex and time (F (2, 74) = 4.86, $p < .05$, $\eta^2 = .17$). Locomotor MC did not change significantly from 6th class to 2nd year for males, but for females locomotor MC was significantly lower ($p < .01$) in 2nd year compared to 6th class. There were no significant interactions or main effects for balance.

Table 7.2 Mean scores for PA, MC, PC and HRF over time

		T1		T2		T3	
	N	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
MVPA (mins)	29	70.79 ± 33.46	49.51 ± 17.78*	28.27 ± 13.55	37.14 ± 22.61	37.35 ± 14.72	26.54 ± 10.85*
Locomotor	39	29.43 ± 3.20	30.12 ± 3.40	31.57 ± 2.06	29.56 ± 3.12*	30.50 ± 2.90	28.08 ± 3.68*
Object control	27	32.00 ± 4.79	27.72 ± 7.55	37.00 ± 2.35	31.89 ± 4.30**	36.89 ± 1.27	28.83 ± 5.40***
Balance	43	14.25 ± 4.19	14.74 ± 3.85	14.19 ± 4.52	14.74 ± 3.85	15.38 ± 4.32	15.48 ± 3.93
PAC	50	3.12 ± 0.55	2.73 ± 0.76*	2.97 ± 0.70	2.23 ± 0.74**	3.09 ± 0.62	2.31 ± 0.71***
PPA	49	3.30 ± 0.41	3.10 ± 0.63	3.07 ± 0.51	2.68 ± 0.69*	2.73 ± 0.61	2.61 ± 0.72
GSW	50	3.49 ± 0.39	3.42 ± 0.44	3.33 ± 0.34	2.99 ± 0.63*	3.21 ± 0.47	2.86 ± 0.60*
VO2max	46	48.51 ± 5.36	44.42 ± 3.49**	46.38 ± 5.11	42.72 ± 3.46**	45.32 ± 6.52	40.48 ± 4.53**
HJcm	50	139.01 ± 26.95	121.42 ± 17.12**	139.74 ± 30.28	126.36 ± 18.17	153.55 ± 35.91	121.00 ± 23.55***
VJcm	51	35.95 ± 7.10	33.87 ± 5.66	38.00 ± 6.73	33.65 ± 5.57	38.60 ± 9.94	31.39 ± 3.94
Pushups	40	9.31 ± 8.20	6.04 ± 5.65	12.13 ± 9.81	5.50 ± 5.21*	11.19 ± 8.89	4.08 ± 4.71**
Curlups	54	13.04 ± 9.88	8.45 ± 6.24*	28.09 ± 19.27	17.17 ± 13.27*	34.09 ± 21.01	19.65 ± 13.83**

*significant difference between males and females within time-point at p <.05; **p < .01; ***p < .001

HJ=horizontal jump; VJ=vertical jump

There was a significant and medium interaction effect for sex and time on PAC ($F\ (2, 96) = 1.07$, $p < .05$, $\eta^2 = .07$). Pairwise comparisons showed PAC decreased significantly for females from 6th class to 1st year ($p < .001$) and remained significantly lower than 6th class levels into 2nd year ($p < .01$). Change in PAC over time was not significant for males. There was no interaction effect for sex and time on PPA or GSW. There was a significant and large main effect for time on PPA ($F\ (2, 94) = 20.20$, $p < .001$, $\eta^2 = .30$). Pairwise comparisons showed a significant decrease in PPA from 6th class to 1st year for females ($p < .01$) and from 1st year to 2nd year for males ($p < .05$). For both males and females, PPA in 2nd year was significantly lower ($p < .001$) than PPA in 6th class. There was a significant and large main effect for time on GSW ($F\ (2, 96) = 19.34$, $p < .001$, $\eta^2 = .29$). Pairwise comparisons showed a significant decrease in GSW from 6th class to 1st year ($p < .001$) and 1st year to 2nd year ($p < .001$) for females. GSW was significantly lower in 2nd year compared to 6th class for both males ($p < .05$) and females ($p < .001$).

There was no interaction effect for time and sex on VO_{2max}, however there was a significant and large main effect for time on VO_{2max} ($F\ (1.83, 80.59) = 14.89$, $p < .001$, $\eta^2 = .25$). Pairwise comparisons showed that VO_{2max} decreased significantly from 6th class to 1st year ($p < .05$) and from 1st year to 2nd year ($p < .05$) for females. For males VO_{2max} was significantly lower in 2nd year compared to 6th class ($p < .05$). There was a significant medium interaction effect for sex and time on curl-ups ($F\ (1.81, 94.22) = 3.29$, $p < .05$, $\eta^2 = .06$). Pairwise comparisons showed a significant increase ($p < .001$) in the mean number of curl-ups from 6th class to 1st year for both males and females. There were no significant interaction or main effects for push-ups. For HJmax there was a significant medium interaction effect between sex and time ($F\ (2, 96) = 5.78$, $p < .01$, $\eta^2 = .11$). Pairwise comparisons showed that there was no significant change in HJmax from 6th class to 1st year for males or females, or from 1st year to 2nd year for females. There was a significant increase ($p < .05$) in HJmax from 1st year to 2nd year for males. For VJ there was a significant medium interaction effect between sex and time ($F\ (2, 98) = 4.66$, $p < .05$, $\eta^2 = .09$). Pairwise comparisons showed that VJmax did not change significantly over time for males or females but significant differences for sex in mean scores in 1st and 2nd year were found (Table 7.2).

There was no significant interaction effect for time and sex on BMI. There was a significant and large main effect for time on BMI ($F\ (2, 100) = 22.20$, $p < .001$, $\eta^2 = .40$). Pairwise comparisons showed no significant change in BMI from 6th class to 1st year, but a significant increase in BMI from 1st year to 2nd year for both males and females ($p < .01$).

7.6 Discussion

Changes in PA, MC, PC and HRF across the school transition were seen in the current sample. Consistent with previous research (Adamson et al., 2017; Corder et al., 2015), MVPA decreased over time. For females, MVPA decreased at each timepoint, whereas for males there was a sharp decrease in MVPA in the immediate aftermath of the school transition, followed by a slight increase in MVPA into 2nd year, though not returning to pre-transition levels and remaining substantially below the recommended PA guidelines. Similar to the current study, research measuring PA changes directly post-transition found a decrease in MVPA (Jago et al., 2012; Marks et al., 2015), with Jago et al. (2012) also finding a greater decrease in MVPA for males compared to females. Contrary to this trend however is the mean increase in MVPA for males from 1st to 2nd year in the current study. The initial negative impact of the school transition may reduce for males as they continue into secondary school. This is not the case for females in this sample, with a consistent mean decrease in MVPA across the three years. Sociocultural factors may play a role in the relationship between gender/sex and PA (Spencer et al., 2015). Studies show that engagement in PA for females is often at odds with the normative definition of femininity, and that the prevalence of gender stereotyping in sport has a negative impact on young girls' participation (Spencer et al., 2015). In Irish youth, a recent study found that significantly more females than males dropped out of sport over the course of five years, and females were less likely to take up a new sport (Hardie Murphy et al., 2017). Females in the current sample appear to disengage from participating in regular PA during the first two years of secondary school. This extended period of time suggests that females are less likely to change their behaviour in the years to come without a specific intervention in place.

A decrease in self-perceptions in youth, as seen in the current study, may play a role in PA behaviours. Across the three domains of PC, a trend for decreasing PC with age was seen. PAC was the only sub-scale to show a slight recovery following the initial decrease directly post-transition. PAC decreased from 6th class to 1st year in males and females, and then showed a slight increase from 1st to 2nd year, although remaining below 6th class levels. It is not unexpected that PC would decrease with age, especially following the school transition (Arens et al., 2013; Shapka and Keating, 2005). It is interesting to see however that two years post transition, PAC began to increase slightly. The decrease in PAC immediately post transition was much greater for females than for males. Cross-sectionally, a gender difference in PAC is frequently reported, with males having more positive self-perceptions in the PA domain than females (Barnett et al., 2008; Piek et al., 2006; Shapka and Keating, 2005). However, results from this study also show a gender difference for change in PAC. It is unlikely that this is due to less PA participation in females as MVPA decreased in both males and females during this time. The relatively more negative impact that the school transition appears to have on females may relate to sociocultural factors such as the place of females within a male-centred world of sport and PA (Spencer et al., 2015). The school transition has been identified as a time when adolescents' self-perceptions are lowered as they adjust to their new environment and look to figure out their place in it (Anderson et al., 2000). This negative impact has been found to have a greater effect on females (Anderson et al., 2000). Qualitative research has pointed to self-presentation in females at this age as a barrier to engaging in PA in secondary school (Knowles et al., 2011). In the current study, as well as a decrease in PAC across the transition, PPA decreased in males and females from 6th class into 2nd year. At each time-point however, females had poorer perceptions of their physical appearance than males. Lower PPA coupled with the masculine-centred environment established within the PA domain may make PA seem an unviable option for young females (Spencer et al., 2015), particularly in the context of establishing feminine-identity during a time when self-perceptions are already negatively impacted by school transition (Anderson et al., 2000). Therefore, consideration should be given to gender-specific barriers to PA when developing initiatives to promote PA in adolescence.

Males and females did not differ significantly in the way that object-control MC developed over time. A mean increase in object-control proficiency was seen across the transition from 6th class to 1st year. Given most participants did not display full competence in each of the skills assessed in 6th class there is potential for improvement in object-control MC from 6th class, given learning and practice opportunities (Clark, 2007). Exposure to a varied PE curriculum taught by subject-specific teachers in secondary school (National Council for Curriculum and Assessment, 2017), as well as an introduction to a variety of extra-curricular sports, may have allowed for an increase in object-control proficiency. These potential influencing factors were not measured in this research. By contrast, the decrease in accelerometer-measured MVPA would indicate that participants were not engaging in high levels of activity after the transition. However, measuring PA using accelerometers, though valid, is not without its limitations, one of which being the willingness of the participant to wear the device for the required time. Given that this was a longitudinal study requiring three wear periods, the resultant number of participants with valid data was small, which should be noted when interpreting the results.

No significant changes in locomotor MC were seen over the course of three years. However, there was an interaction effect for sex. Males showed a non-significant increase in locomotor skill from 6th class to 1st year, while females showed a steady decrease in locomotor proficiency from 6th class to 2nd year. One possible explanation for this steady decrease seen in female locomotor skill may be linked to changes in PPA and the nature of some of the locomotor tests. For example, both HJ and VJ require participants to swing the arms above the head. Current fashion for girls' sportswear includes cropped tops that, on raising of the arms, expose the stomach. While anecdotal, it was evident numerous times during testing that many of the female participants were uncomfortable moving in this way, and, despite clear demonstrations, were inclined to hold down their clothes while jumping. It is unlikely that females in the current sample reduced their capability to perform locomotor skills with age, given that the success criteria for assessing MC require execution of only the basic movement components which, once learned, are unlikely to be "un-learned". Therefore, it is more likely that other factors such as PC are impacting on the locomotor skill execution during testing in females at this age There may be an unwillingness to correctly perform some skills, such as the HJ and VJ, despite having the physical capabilities to do so. Strategies for promoting female engagement in PE frequently include "girls-only" PE classes (Eime et al., 2010; Knowles et al., 2011; Neumark-Sztainer et al., 2003). While the ideal is to create an environment where females are supported and encouraged to engage in PA with males present (Barr-Anderson et al., 2008), participating with or in front of male peers is evidently a perceived barrier for many young females (Eime et al., 2010). Therefore, in the context of accurate measurement when testing within the PA environment, it may be beneficial to test in small groups of the same sex.

Changes in components of HRF were seen over time. VO_{2max} (CRE) decreased across the transition and into 2nd year for both males and females. A plateau in VO_{2max} levels for females is expected at this age (Janz et al., 2000; Kemper et al., 2013), however, previous research has generally found VO_{2max} continues increasing in males into late adolescence, contrary to what was found in the current sample (Janz et al., 2000; Kemper et al., 2013). A potential reason for the decrease may be the significant reduction in MVPA over the same period, however, as mentioned previously, the ability to obtain a true reflection of PA levels via accelerometry can pose problems in interpreting these results. The greater increase in MS and ME over time in males compared to females was expected due to puberty and physiological changes that accelerate sex differences in HRF around this time (Tomkinson et al., 2018). However, the decrease in MS seen in females was unexpected as previous studies reported increases over time in MS for both males and females (Aires et al., 2010; Janz et al., 2000). That being said, FITNESSGRAM reference norms for MS and ME in females plateau within the age range of 10-12 years (Plowman and Mahar, 2013). These norm-referenced values indicate that large studies have found this plateau in late childhood/early adolescence for females. Similar to locomotor proficiency, the mean decrease in female MS may reflect wider issues related to PC among young girls, and an uncomfortableness in the PA environment (Spencer et al., 2015), rather than purely a decrease in physical capacity over time. In addition, the decreasing PA and MC levels identified in females in the current sample during the early years of secondary school may be associated with decreasing MS, given that without PA and MC it is practically impossible to maintain fitness.

7.7 Conclusion

The aim of this study was to give an overview of how PA, MC, PC and HRF change over the course of the transition from primary to secondary school. Previous longitudinal studies have generally not reported on changes in these variables across a significant transition such as the school transition. Studies which have looked at the transition often measure only one timepoint post transition, which can limit conclusions drawn as to the impact of the transition in the longer term. This study addresses some of these issues. Findings indicate that changes in PA, MC, PC and HRF occur over the transition, but are not linear in all cases. In addition, patterns of change are influenced by sex and gender. Future studies should look to analyse the relationships between these variables, and to identify which variables are predictive of each other across the school transition for males and females.

CHAPTER 8

Discussion and Conclusions

Chapter 8 Discussion and Conclusions

8.1 Thesis General Discussion

The primary objective of this thesis was to evaluate the conceptual model developed by Stodden et al. (2008) across the transition from primary to secondary school. In addition, this research also provided the opportunity to measure and track PA, MC, HRF and PC in Irish adolescents across the school transition.

One of the key gaps identified in the literature review was the scarcity of research on HRF as a mediator in Stodden et al.'s (2008) conceptual model (Robinson et al., 2015). Where studies have considered HRF, they often measure just one component, generally CRE (Barnett et al., 2008; Kriemler et al., 2010), to the exclusion of other components like MS and ME. This is in part due to difficulties in analysing relationships between HRF and other variables while accounting for the multicomponent structure of HRF. To this end, Chapter 4 detailed the development of a statistically and theoretically proofed HRF composite that can be used by researchers to measure HRF. Findings from the study presented in Chapter 4 provide researchers with five tests that have been empirically shown to be representative of HRF in youth, and that are valid, reliable, and easily administered in a field-based setting. Where before, researchers were inclined to choose just one component of HRF, or to simply combine HRF test scores into an equally-weighted mean score, the HRF composite developed in Chapter 4 accounts for the relative importance of each component of HRF within its factor structure, and provides a way to analyse relationships between HRF, as a composite, and other health-related variables.

Following the development of this statistically and theoretically proofed HRF composite, it was possible to address the primary aim of this thesis - to analyse longitudinally the pathways hypothesised in Stodden et al.'s (2008) conceptual model. Firstly, the role of HRF and PC as mediators, and the proposed reciprocity of pathways in the model, were assessed in Chapter 5. Stodden and colleagues (2008) proposed a reciprocal relationship between MC and PA, mediated by HRF and PC. Previous research partially supported this hypothesis, with Barnett et al. (2011) finding a reciprocal relationship between PA and object-control MC, but not locomotor MC. Regarding the mediators, age-related differences in the role of PC as a mediator had been noted (Barnett et al., 2011; Crane et al., 2015; Khodaverdi et al., 2015), while, for HRF, there was limited research on its role as a mediator (Robinson et al., 2015). To fully analyse the role of HRF and PC, and the reciprocal nature of the pathways in the model, a longitudinal analysis of the variables outlined in Stodden et al.'s (2008) conceptual model was conducted in Chapter 5. Findings indicated that there were no direct reciprocal relationships between PA and any component of MC. In other words, MC did not directly predict PA, nor did PA predict MC. Reciprocal relationships between MC and PA existed only when HRF and PC were included to mediate these relationships, supporting the hypothesis made by Stodden et al. (2008). In comparison to Stodden et al.'s (2008) hypothesised pathway, the relationship between MC and PA in our sample was stronger in the direction of PA predicting MC rather than the reverse. This is also consistent with a previous longitudinal study on adolescents (Jaakkola et al., 2018), and suggests that older children and adolescents may not have sufficient MC to engage in adequate levels of PA for health. Another important finding from Chapter 5 was the role of HRF within the model. HRF was stronger as a mediator compared to PC, and HRF was a stronger predictor of both MC and PA, than MC or PA were as predictors of HRF. Thus, HRF appears to be the driving force for the relationships outlined in this model. Without HRF, and to a lesser extent PC, there were no reciprocal pathways between MC and PA. It is essential, therefore, to develop HRF, in conjunction with MC, to promote PA. In the reverse, PA that allows for the development of HRF should in turn promote the development of MC. In sum, HRF, as a composite, is a key player in Stodden et al.'s (2008) conceptual model, and a key driving force for promoting both PA and MC.

Considering the role of HRF as a significant mediator in the MC-PA relationship, coupled with the existence of strong pathways from HRF to both PA and MC, the purpose of Chapter 6 was to build on these findings and determine the relative importance of each variable included in Stodden et al.'s (2008) model for predicting future behaviour across the school transition. Direct reciprocal relationships were also analysed, and a cross-lagged panel design was used to control for baseline levels of each of the variables in predicting future behaviours. The findings from Chapter 6 identified HRF as the strongest predictor of PA post-transition, even when controlling for baseline PA. This is contrary to Stodden et al.'s (2008) model, where MC is hypothesised as the driving force for engaging in PA. Findings also showed that HRF in 6th class positively predicted locomotor MC and PAC in 1st year. Object-control MC was the only other significant predictor of 1st year MVPA, although this pathway was weaker than the HRF to MVPA pathway. These findings question the positioning of HRF as a mediator of PA within Stodden et al.'s (2008) model, rather than as a primary determinant. MC is commonly viewed as one of the primary factors leading to engagement in PA (Barnett et al., 2009; Lloyd et al., 2014; Lopes et al., 2011; Stodden et al., 2008), but the study outlined in Chapter 6 found HRF to be more important than MC in predicting PA across the school transition. A strength of this study is that all the variables included in Stodden et al.'s (2008) model were measured at each time point, which enabled an analysis of the order of importance of each variable in predicting PA. In keeping with previous studies which identified object-control MC, rather than locomotor MC, as a predictor of PA in youth (Barnett et al., 2009, 2011), object-control MC in this study was also found to predict PA, although to a lesser extent than HRF. Overall, findings from Chapter 6 suggests that PA promotion strategies should focus on developing both HRF (focusing on MS and ME, as well as CRE) and object-control MC early in primary school to promote PA in secondary school. Both HRF and object-control MC may be crucial factors in addressing the decrease in PA across the school transition.

Chapters 5 and 6 provided evidence for the importance of HRF and object-control MC in promoting PA across the school transition. However, little is known about how these variables change and develop during this key period. Chapter 7 used data from three timepoints to examine changes in PA, MC, HRF and PC immediately, and one-year post, the school transition. As evidenced in Chapters 5 and 6, HRF is an important factor for PA engagement in youth. Data presented in Chapter 7 show that over the school transition some components of HRF were found to decrease, while others increased or remained stable. Specifically, CRE decreased from 6th class to 1st year, and again from 1st year to 2nd year for both males and females, while MS decreased over time for females. In keeping with trends consistently reported in the literature (Jago et al., 2012; Marks et al., 2015), PA also decreased across the transition for males and females. Considering these results, together with findings from Chapters 5 and 6, it is likely that decreasing CRE, and MS in females, is impacting negatively on both PA and MC over time. In terms of MC, object-control MC increased directly post-transition, but did not change significantly into 2nd year of secondary school. Balance and locomotor skills did not change significantly with time. Despite low levels of MC within this sample, indicating a potential for improvement over time, little development in MC was observed. It is recognised that MC is not innate but must be developed through practice opportunities (Clark, 2007). Considering the decrease in PA, and aspects of HRF, across the transition, it is likely that youth in this study were not engaging in enough PA and as a result were not getting the practice opportunities required for MC development. Combined with changes in MC, PA and HRF, changes in PC were also found across the school transition, with PC decreasing as youth transitioned into secondary school. Changing school environment has been found to impact negatively on

PC in youth (Arens et al., 2013; Shapka and Keating, 2005), and PC has also been reported to be positively associated with PA, although this association is more frequently reported for self-report PA (Kavanaugh et al., 2015). It appears that the school transition may negatively affect PC and, considering the frequently reported association between PA and PC, the decrease in PA across the school transition may also have impacted negatively on PC.

Another key element of this research involved understanding sex and/or gender differences in the variables and pathways depicted in Stodden et al.'s (2008) model. Some of the sex and gender differences of note were discussed in Chapters 6 and 7. In Chapter 6, where the relative importance of each of the variables in predicting behaviour in secondary school was examined, findings indicated that some pathways differed between males and females. For example, PA was much less stable over the school transition for females compared to males. This low stability of PA in females indicates that there are other factors influencing PA during this transition phase causing behaviour change. In addition, PA in 6^{th} class was found to negatively predict MC in 1^{st} year for females, whereas this pathway was positive for males. It is expected that PA should promote MC (Jaakkola et al., 2018; Stodden et al., 2008), but our findings in females show the opposite. The low stability of PA across the transition indicates that PA behaviour for females is changeable during this period, which may account for the negative pathway from PA to MC in females. In Chapter 7, differences between males and females were again noted for changes in many of Stodden et al.'s (2008) variables from primary to secondary school. While a significant mean decrease in PA was seen for males and females immediately post-transition, a mean increase in PA for males into 2^{nd} year of secondary school was seen, while for females, the decline in PA continued into 2^{nd} year. This indicates that the negative effect of the school transition on PA may be greater in females than males. In addition, the continuation of the PA decline into 2^{nd} year for females highlights the need for intervention to address this problem. For HRF there was a trend for increasing MS and ME over time for males, compared to no change, or a decline in MS and ME over time for females. The decrease in specifically MS in females was unexpected, although decreasing PA with time is likely impacting on HRF development. Considering the differences found between males and females for changes in PA, HRF and MC over time, and the differences between males and females in some of the pathways outlined in Stodden et al.'s (2008) model, researchers should tailor PA promotion interventions to be "sex/gender-specific", considering the different factors that are most pertinent to males and females. One of the limitations of Stodden et al.'s (2008) model is that, despite the well-known differences between males and females in many of the variables, the model does not account for sex/gender differences in its hypothesised pathways. Considering the empirical evidence from the current research which identifies gender- and sex-related differences in some of the model's hypothesised pathways, it seems that consideration of these differences should be taken into account within the model, particularly where researchers intend to use Stodden et al.'s (2008) model to guide the development of youth PA promotion interventions. Similar to the way in which developmental age is accounted for within the model (Stodden et al., 2008), it would be beneficial to also account for gender/sex within the model's pathways, with a view to informing interventions which are both age- and gender/sex-specific.

Taken together, the findings from this research suggest that there are potential modifications to the original model that should be further explored. HRF, not MC, was found to be the primary predictor of PA. Therefore, one potential adaptation to Stodden et al.'s (2008) conceptual model is to position HRF as the primary predictor of PA, in place of MC. Object-control skills, as a component of MC, did positively predict PA post school transition, although to a weaker extent than HRF, pointing to a role for MC in PA promotion in youth. Another interesting element that was explored in this research was the difference in pathways in the model between males and females. Stodden and colleagues did not account for sex- or gender-related differences in pathways in the original model. Evidence from the current research suggests however that the associations between the variables in Stodden et al.'s (2008) conceptual model differ based on sex and/or gender. Thus, another potential adaptation to the model that could be further explored is the inclusion of sex/gender-specific pathways, similar to the developmental age pathways included in the original model.

In sum, thesis findings suggest that, in the context of Stodden et al.'s (2008) model, HRF is a primary factor in promoting PA engagement, particularly during the transition from primary to secondary school. The fact that components of HRF were found to decrease over the school transition, suggests interventions that develop HRF early in primary school are needed to buffer against the potential negative effects of school transition. Object-control MC also appears to be an important factor to consider when promoting PA in adolescents, and while object-control MC increased immediately post-transition, no further increase was seen into 2nd year of secondary school. HRF, object-control skills are important in PA promotion, and currently are not developing to the level expected, or to a level that might buffer against the decrease in PA seen with transition into secondary school. Though the role of PC in Stodden et al.'s (2008) model is less clear compared to the roles of both HRF and MC, the fact that PC does mediate some unidirectional relationships between MC and PA suggests that consideration should be taken of PC in youth when designing PA interventions. Specifically, given the decline in PC across the school transition, special care should be taken to develop PC across a range of domains in primary school to positively effect PA in secondary school. Finally, PA promotion strategies should take sex and gender differences into account to ensure that interventions are effective for their intended population.

8.2 Thesis Strengths

Longitudinal design: A major strength of this research is its longitudinal design. This allowed for testing of changes in variables and interpretation of causal pathways which is not possible in cross-sectional designs. In addition, it was possible to truly test the reciprocity of relationships by using longitudinal data.

Consideration of all variables identified in Stodden et al.'s (2008) conceptual model: The inclusion of all of the variables that make up the conceptual model is another major strength of this research. As a result, it was possible to test, in unison, the relevant pathways hypothesised in the model.

Consideration of HRF as a composite: Considering each of the components identified in the definition of HRF, establishing its factor structure, and creating a statistically and theoretically-proofed HRF composite is a strength of this study. It allowed for a comprehensive testing of pathways between HRF and other variables in Stodden et al.'s (2008) conceptual model, without limiting the analysis to a single measure or component of HRF.

Objective measurement of PA: Using accelerometers to objectively measure MVPA, rather than relying on self-report methods of measurement, was a strength of this study.

Sophisticated statistical analysis: The use of confirmatory factor analysis in Chapter 4 revealed the factor structure of HRF in youth, and enabled the creation of a statistically-proofed HRF composite for use in subsequent studies. The use of structural equation modelling, specifically path analysis (Chapters 5) and cross-lagged panel regression (Chapter 6) allowed for detailed examination of predictive pathways, mediated pathways, and reciprocal pathways controlling for baseline values. It also allowed for consideration of measurement invariance over time, and provided methods (e.g. full information maximum likelihood estimation) for analysing data with missing values, both of which are key issues in longitudinal research.

8.3 Study Limitations

Accelerometer compliance: Across each timepoint, the number of participants who failed to wear the accelerometer for the specified wear time was a limitation. Despite using previously recommended strategies to increase compliance, a large amount of PA data was lost due to non-compliance, and this problem was exacerbated with time. The wearing of hip-worn accelerometers is not an appealing or interesting prospect for most adolescents. In addition to being quite cumbersome, accelerometers also have to be removed for many contact-based sports, as well as water-based sports (Warren et al., 2010), reducing the quality of the data collected from them.

Missing data: Missing data across the three years was a limitation of this study, one which is common in longitudinal research. Despite every effort of the lead researcher during recruitment and testing to maximise availability of participants longitudinally, participants within one school were unavailable for tesing in the third year of the study due to adminstrative problems within the school. This greatly reduced the number of participants available for three-year analyses. In addition to this loss of participants for the third year of data collection, missing values across measures at each timepoint were also a limitation. Collection of data on all of the variables occurred over the course of three PE classes. The test set-up was planned to minimise interference of performance on one test with performance on another – for example, the 20metre shuttle run test, which requires participants to run to exhaustion, was scheduled for the first day of testing along with body weight status tests, a balance test, and the handgrip test, as these were deemed to be least affected by a maximal running test. However, when it came to analysing the data and creating composite scores, participants who missed one day of testing may have lost data on every composite measure. Despite these limitiations, statistical methods were chosen which made maximum use of all the available data on each participant.

Sample size: Considering the significant number of pathways to be tested in Stodden et al.'s (2008) conceptual model, the sample size was relatively small, particularly in the third year when participants from one school were unavailable for testing. Analsysis on differences in pathways between BMI category groups was not possible to conduct due to the small number of participants classified as overweight/obese. A larger sample may be less homogenous in terms of body weight status, and could allow for analysis such as this.

8.4 Future Directions

There is a growing body of research highlighting the positive association of MS and ME with health outcomes in youth, therefore measurement of HRF should include these components along with CRE. The five-indicator composite produced in Chapter 4 of this thesis provides researchers with a statistically and theoretically proofed model with which to measure HRF as a composite in field-based research on youth. Future research should use this HRF composite for a more comprehensive and relevant measurement of HRF in youth.

The development of HRF should be one of the primary aims of PA promotion interventions. Compared to MC, PC, and baseline levels of MVPA, HRF was the strongest predictor of MVPA in youth across the transition from primary to secondary school. Interventions that focus on developing HRF in primary schools should avoid overly prescriptive methods of HRF promotion, such as simply mimicking HRF tests, and should develop CRE, MS, and ME in fun and engaging ways.

While it has been previously expected that the MC-PA relationship will be stronger in the direction of MC predicting PA in older childhood and adolescence, this was not the case in the current sample. Lower than expected levels of MC reported in youth in previous studies, and the stronger pathway from PA to MC found in this and other studies, suggest that older children and adolescents are still developing their MC, albeit at an older age than generally expected. Current teachers and practitioners should be aware that many young people have not mastered the basic components of most FMS and should include practice opportunities within to further their MC development.

Accelerometers were used in this research for objective measurement of PA. Despite adopting strategies to promote compliance, a significant number of participants did not provide PA data due to lack of compliance. Future studies, particularly those of a longitudinal nature among adolescents, should investigate alternative options for objective measurement of PA, such as wrist-worn devices, which may increase compliance.

Significant sex and gender differences in many of the variables, and in the nature of changes in these variables, were found in this research, to the detriment of female adolescents. While physiological changes relating to puberty have an effect on absolute scores for HRF, there is no physiological reason that levels of PA, MC and PC should be lower in females compared to males, or should decrease more substantially across the transition from primary to secondary school. Research consistently highlights the gender gap in the physical domain, beyond simply the physiological capacity of males compared to females. The current study suggests however that we are still failing female adolescents when it comes to providing an environment conducive to promoting health-enhancing PA behaviours.

8.5 Concluding the PhD Journey

The primary purpose of this thesis was to evaluate pathways in Stodden et al.'s (2008) conceptual model over the course of the primary to secondary school transition. As well as addressing knowledge gaps in relation to pathways in this model, this research also provides an overview of current levels of PA, MC, HRF and PC in Irish youth, and the nature of changes in these variables during a significant transition period.

Along with addressing the primary research aims of this thesis, the PhD process has provided me with challenges and opportunities, ultimately developing not only my research skills, but also my communication, organisation, and lecturing skills.

I would like to conclude this PhD journey with a quote from 4 Non Blondes which is representative of my time as a postgraduate researcher in DCU, and which became my PhD anthem as I journeyed through bad and good times;

Twenty-five [or nine!] *years and my life is still*
Trying to get up that great big hill of hope
For a destination

...

And I try, oh my God do I try
I try all the time, in this institution

And I pray, oh my God do I pray
I pray every single day
For a revolution

...

What's going on?

8.6 References

ACSM (2014) ACSM's Health-Related Physical Fitness Assessment Manual. 4th ed. Baltiomore: Wolters Kluwer: Lippincott Williams & Wilkins.

Adamson AJ, Farooq MA, Reilly JK, et al. (2017) Timing of the decline in physical activity in childhood and adolescence: Gateshead Millennium Cohort Study. British Journal of Sports Medicine 52(15): 1002–1006. DOI: 10.1136/bjsports-2016-096933.

Ahnert J, Schneider W and Bos K (2009) Developmental changes and individual stability of motor abilities from preschool period to young adulthood. In: Schneider W and Bullock M (eds) Human Development from Early Childhood to Early Adulthood: Evidence from the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC). Mahwah: Erlbaum, pp. 35–62.

Ainsworth BE, Haskell WIL, Whitt MC, et al. (2000) Compendium of physical activities: an update of activity codes and MET intensities. Medicine and Science in Sports and Exercise 32(9 Suppl): S498–S504. DOI: 10.1097/00005768-200009001-00009.

Aires L, Andersen L B, Mendonça D, et al. (2010) A 3-year longitudinal analysis of changes in fitness , physical activity , fatness and screen time.: 140–144. DOI: 10.1111/j.1651-2227.2009.01536.x.

Anderson L, Jacobs J, Schramm S, et al. (2000) School transitions: beginning of the end or a new beginning? International Journal of Educational Research 33: 325–339. DOI: 10.1080/0005772x.1998.11099405.

Anderssen N, Wold B and Torsheim T (2005) Tracking of Physical Activity in Adolescence. Research Quarterly for Exercise and Sport 76(2): 119–129. DOI: 10.1080/02701367.2005.10599274.

Anon, 2016. Schools' Fitness Challenge. Available at: http://www.irishlifehealth.ie/docs/fitness-challenge/sfc_barometer2016_web.pdf [Accessed April 30, 2017].ACSM (2014) ACSM's Health-Related Physical Fitness Assessment Manual. 4th ed. Baltiomore: Wolters Kluwer: Lippincott Williams & Wilkins.

Arbuckle JL (2014) IBM® SPSS® AmosTM 23 User's Guide. DOI: 10.1016/j.enconman.2005.10.016.

Arens AK, Yeung AS, Craven RG, et al. (2013) Does the timing of transition matter? Comparison of German students' self-perceptions before and after transition to secondary school. International Journal of Educational Research 57: 1–11. DOI: 10.1016/j.ijer.2012.11.001.

Artero EG, Espana-Romero V, Castro-Piñero J, et al. (2011) Reliability of Field-Based Fitness Tests in Youth. Int J Sports Med 32: 159–169.

Artero EG, España-Romero V, Ortega FB, et al. (2010) Health-related fitness in adolescents: Underweight, and not only overweight, as an influencing factor. The AVENA study. Scandinavian Journal of Medicine and Science in Sports 20(3): 418–427. DOI: 10.1111/j.1600-0838.2009.00959.x.

Babic MJ, Morgan PJ, Plotnikoff RC, et al. (2014) Physical Activity and Physical Self-Concept in Youth: Systematic Review and Meta-Analysis. Sports Medicine 44(11): 1589–1601. DOI: 10.1007/s40279-014-0229-z.

Bailey DP, Boddy LM, Savory LA, et al. (2012) Associations between cardiorespiratory fitness, physical activity and clustered cardiometabolic risk in children and adolescents: the HAPPY study. European Journal of Pediatrics 171(9): 1317–1323. DOI: 10.1007/s00431-012-1719-3.

Baker BL and Davison KK (2011) I know I can: a longitudinal examination of precursors and outcomes of perceived athletic competence among adolescent girls. Journal of physical activity & health 8(2): 192–199.

Baker JL, Olsen LW, Sørensen TI a. a, et al. (2007) Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. N Engl J Med 357(23): 2329–2337. DOI: 10.1056/NEJMoa072515.Childhood.

Baquet G, Twisk JWR, Kemper HCG, et al. (2006) Longitudinal follow-up of fitness during childhood: Interaction with physical activity. American Journal of Human Biology 18(1): 51–58. DOI: 10.1002/ajhb.20466.

Barker AR, Gracia-Marco L, Ruiz JR, et al. (2018) Physical activity, sedentary time, TV viewing, physical fitness and cardiovascular disease risk in adolescents: The HELENA study. International Journal of Cardiology 254: 303–309. DOI: 10.1016/j.ijcard.2017.11.080.

Barnett L, Hinkley T, Okely AD, et al. (2013) Child, family and environmental correlates of children's motor skill proficiency. Journal of Science and Medicine in Sport 16(4). Sports Medicine Australia: 332–336. DOI: 10.1016/j.jsams.2012.08.011.

Barnett, L., Morgan P, van Beurden E, et al. (2008) Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. The international journal of behavioral nutrition and physical activity 5(1): 40. DOI: 10.1186/1479-5868-5-40.

Barnett L., van BeurdenN E, Morgan PJ, et al. (2008) Does Childhood Motor Skill Proficiency Predict Adolescent Fitness? Medicine & Science in Sports & Exercise 40(12): 2137–2144. DOI: 10.1249/MSS.0b013e31818160d3.

Barnett LM, Henderson. S and Sugden D (2007) Movemement Assessment Battery for Children. 2nd ed.

Barnett LM, Lai SK, Veldman SLC, et al. (2016) Correlates of Gross Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. Sports Medicine. Springer International Publishing. DOI: 10.1007/s40279-016-0495-z.

Barnett LM, Morgan PJ, Van Beurden E, et al. (2011) A reverse pathway? Actual and perceived skill proficiency and physical activity. Medicine and Science in Sports and Exercise 43(5): 898–904. DOI: 10.1249/MSS.0b013e3181fdfadd.

Barnett LM, Ridgers ND and Salmon J (2015) Associations between young children's perceived and actual ball skill competence and physical activity. Journal of Science and Medicine in Sport 18(2). Sports Medicine Australia: 167–171. DOI: 10.1016/j.jsams.2014.03.001.

Barnett LM, van Beurden E, Morgan PJ, et al. (2009) Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity. Journal of Adolescent Health 44(3). Elsevier Ltd: 252–259. DOI: 10.1016/j.jadohealth.2008.07.004.

Barnett LM, van Beurden E, Morgan PJ, et al. (2010) Gender differences in motor skill proficiency from childhood to adolescence: a longitudinal study. Res Q Exerc Sport 81(2): 162–170. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20527301 (accessed 27 July 2016).

Barr-Anderson DJ, Neumark-Sztainer D, Lytle L, et al. (2008) But i like PE: Factors associated with enjoyment of physical education class in middle school girls. Research Quarterly for Exercise and Sport 79(1): 18–27. DOI: 10.1080/02701367.2008.10599456.

Beals K, Crouter SE, Staiano AE, et al. (2016) Results From the United States of America’s 2016 Report Card on Physical Activity for Children and Youth. Journal of Physical Activity and Health 13(11 Suppl 2): S307–S313. DOI: 10.1123/jpah.2016-0321.

Belton S, Issartel J, McGrane B, et al. (2018) The Y-PATH programme: A consideration for physical literacy in Irish youth, and implications for physical education in a changing landscape. Irish Educational Studies. DOI: 10.1080/03323315.2018.1552604.

Belton S, O’ Brien W, Meegan S, et al. (2014) Youth-Physical Activity Towards Health: evidence and background to the development of the Y-PATH physical activity intervention for adolescents. BMC public health 14(1): 122. DOI: 10.1186/1471-2458-14-122.

Belton S, O’ Brien W, Wickel EE, et al. (2013) Patterns of noncompliance in adolescent field-based accelerometer research. Journal of Physical Activity & Health 10(8): 1181–5.

Belton S, O’Brien W, McGann J, et al. (2018) Bright spots, physical activity investments that work: Workplace Challenge. British Journal of Sports Medicine 0(0): 1026–1028. DOI: 10.1136/bjsports-2017-097716.

Benson AC, Torode ME and Singh MAF (2006) Muscular strength and cardiorespiratory fitness is associated with higher insulin sensitivity in children and adolescents. International journal of pediatric obesity : IJPO : an official journal of the International Association for the Study of Obesity 1(4): 222–231. DOI: 10.1080/17477160600962864.

Borraccino A, Lemma P, Iannotti RJ, et al. (2009) Socioeconomic effects on meeting physical activity guidelines: Comparisons among 32 countries. Medicine and Science in Sports and Exercise 41(4): 749–756. DOI: 10.1249/MSS.0b013e3181917722.

Breslin G, Murphy M, McKee D, et al. (2012) The effect of teachers trained in a fundamental movement skills programme on children’s self-perceptions and motor competence. European Physical Education Review 18(1): 114–126. DOI: 10.1177/1356336X11430657.

Britton Ú, Issartel J and Belton S (2019) Small Fish, Big Pond: the role of health-related fitness and perceived athletic competence in mediating the physical activity-motor competence relationship during the transition from primary to secondary school (Accepted Paper). Journal of Sport Sciences.

Britton U, Issartel J, Fahey G, et al. (2018) What is Health-Related Fitness? Investigating the underlying factor structure of fitness in youth. In: 23rd Annual Congress of the European College of Sport Science, 2018.

Bronikowski M and Bronikowska M (2011) Will they stay fit and healthy? A three-year follow-up evaluation of a physical activity and health intervention in Polish youth. Scandinavian Journal of Public Health 39(August): 704–713. DOI: 10.1177/1403494811421059.

Brown T and Lalor A (2009) The Movement Assessment Battery for Children - Second Edition (MABC-2): A Review and Critique. Physical & Occupational Therapy in Pediatrics. DOI: 10.1080/01942630802574908.

Brown TA (2006) Confirmatory Factor Analysis for Applied Research. New York, NY, US: Guilford Press.

Brunet M, Chaput JP and Tremblay A (2007) The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: The 'Qu??bec en Forme' Project. International Journal of Obesity 31(4): 637–643. DOI: 10.1038/sj.ijo.0803448.

Burgi F, Meyer U, Granacher U, et al. (2011) Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina). Int J Obes (Lond) 35(7): 937–944. DOI: 10.1038/ijo.2011.54.

Byrne B (2010) Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming. 3rd ed. New York: Routledge.

Cairney J, Kwan MY, Velduizen S, et al. (2012) Gender, perceived competence and the enjoyment of physical education in children: a longitudinal examination. International Journal of Behavioral Nutrition and Physical Activity 9(1). BioMed Central Ltd: 26. DOI: 10.1186/1479-5868-9-26.

Cameron N, Jones LL, Griffiths PL, et al. (2009) How well do waist circumference and body mass index reflect body composition in pre-pubertal children? European journal of clinical nutrition 63(9): 1065–1070. DOI: 10.1038/ejcn.2009.26.

Canadian Institutes of Health Research (2018) How to integrate sex and gender into research. Available at: http://www.cihr-irsc.gc.ca/e/50836.html.

Cantell Marja, Crawford SG and Doyle-Baker PK (2008) Physical fitness and health indices in children, adolescents and adults with high or low motor competence. Human movement science 27(2): 344–62. DOI: 10.1016/j.humov.2008.02.007.

Cantell MH, Smyth MM and Ahonen TP (2003) Two distinct pathways for developmental coordination disorder: Persistence and resolution. Human Movement Science 22(4–5): 413–431. DOI: 10.1016/j.humov.2003.09.002.

Carraro A, Scarpa S and Ventura L (2010) RELATIONSHIPS BETWEEN PHYSICAL SELF-CONCEPT AND PHYSICAL FITNESS IN ITALIAN ADOLESCENTS 1. Perceptual and Motor Skills 110(2): 522–530. DOI: 10.2466/pms.110.2.522-530.

Casonatto J, Fernandes RA, Batista MB, et al. (2016) Association between health-related physical fitness and body mass index status in children. Journal of Child Health Care 20(3): 294–303. DOI: 10.1177/1367493515598645.

Caspersen CJ, Powell KE and Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public health reports (Washington, D.C. : 1974) 100(2): 126–31. DOI: 10.2307/20056429.

Castro-Piñero J, Girela-Rejón MJ, González-Montesinos JL, et al. (2013) Percentile values for flexibility tests in youths aged 6 to 17 years: Influence of weight status. European Journal of Sport Science 13(2): 139–148. DOI: 10.1080/17461391.2011.606833.

Cattuzzo MT, Dos Santos Henrique R, Ré AHN, et al. (2014) Motor competence and health related physical fitness in youth: A systematic review. Journal of science and medicine in sport / Sports Medicine Australia (JANUARY). Sports Medicine Australia. DOI: 10.1016/j.jsams.2014.12.004.

Cattuzzo MT, dos Santos Henrique R, Ré AHN, et al. (2016) Motor competence and health related physical fitness in youth: A systematic review. Journal of Science and Medicine in Sport. DOI: 10.1016/j.jsams.2014.12.004.

Chen KY and Bassett DR (2005) The Technology of Accelerometry-Based Activity Monitors: Current and Future. Medicine and Science in Sports & Exercise (December). DOI: 10.1249/01.mss.0000185571.49104.82.

Clark J and Metcalfe J (2002) The mountain of motor development: A metaphor. In: Clark JE and Humphrey J (eds) Motor Development: Research and Reviews. Reston, V.A.: NASPE Publications, pp. 163–190. DOI: 10.4081/ejh.2015.2477.

Clark JE (2007) On the Problem of Motor Skill Development. Journal of Physical Education, Recreation & Dance 78(5): 39–44. DOI: 10.1080/07303084.2007.10598023.

Clayton JA and Tannenbaum C (2016) Reporting sex, gender, or both in clinical research? JAMA - Journal of the American Medical Association. DOI: 10.1001/jama.2016.16405.

Cohen J (1988) Statistical Power Analysis for the Behavioral Sciences. 2nd Ed. Lawrence Erlbaum Associates: New Jersey.

Cohen J (1992) A Power Primer. Psychological Bulletin [PsycARTICLES 112(1). Available at: http://www2.psych.ubc.ca/~schaller/528Readings/Cohen1992.pdf (accessed 18 April 2018).

Cohen KE, Morgan PJ, Plotnikoff RC, et al. (2015) Improvements in fundamental movement skill competency mediate the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children. Journal of Sports Sciences 33(18): 1908–1918. DOI: 10.1080/02640414.2015.1017734.

Coker CA (2018) Improving Functional Movement Proficiency in Middle School Physical Education. Research Quarterly for Exercise and Sport 89(3): 367–372. DOI: 10.1080/02701367.2018.1484066.

Cook S, Auinger P and Huang TT-K (2009) Growth curves for cardio-metabolic risk factors in children and adolescents. The Journal of pediatrics 155(3): S6.e15-26. DOI: 10.1016/j.jpeds.2009.04.051.

Cools W, De Martelaer K, Samaey C, et al. (2009) Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. ©Journal of Sports Science and Medicine 8: 154–168. Available at: http://www.jssm.org (accessed 4 May 2016).

Cooper AR, Goodman A, Page AS, et al. (2015) Objectively measured physical activity and sedentary time in youth: the International children's accelerometry database (ICAD). DOI: 10.1186/s12966-015-0274-5.

Corbin C, Welk G, Richardson C, et al. (2014) Youth Physical Fitness: Ten Key Concepts. Journal of Physical Education, Recreation & Dance (JOPERD) 85(2): 24–31.

Corder K, Sharp SJ, Atkin AJ, et al. (2015) Change in objectively measured physical activity during the transition to adolescence. British journal of sports medicine 49(11): 730–6. DOI: 10.1136/bjsports-2013-093190.

Council of Europe (1983) Testing Physical Fitness: Eurofit.: 1–18.

Council Of Europe (1983) Testing Physical Fitness: Eurofit.: 1–18. Available at: http://www.bitworks-engineering.co.uk/linked/eurofit provisional handbook leger beep test 1983.pdf (accessed 3 April 2017).

Crane JR, Naylor PJ, Cook R, et al. (2015) Do Perceptions of Competence Mediate The Relationship Between Fundamental Motor Skill Proficiency and Physical Activity Levels of Children in Kindergarten? Journal of physical activity & health 12(7): 954–61. DOI: 10.1123/jpah.2013-0398.

Crocker PRE, Eklund RC and Kowalski KC (2000) Children ' s physical activity and physical self-perceptions. Journal of Sport Sciences (March 2012): 37–41.

D'Hondt E, Deforche B, Gentier I, et al. (2013) A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. International Journal of Obesity 37(November 2011): 61–67. DOI: 10.1038/ijo.2012.55.

D'Hondt E, Deforche B, Gentier I, et al. (2014) A longitudinal study of gross motor coordination and weight status in children. Obesity 22(6): 1505–1511. DOI: 10.1002/oby.20723.

Dalla Pozza R, Ehringer-Schetitska D, Fritsch P, et al. (2015) Intima media thickness measurement in children: A statement from the Association for European Paediatric Cardiology (AEPC) Working Group on Cardiovascular Prevention endorsed by the Association for European Paediatric Cardiology. Atherosclerosis 238(2). Elsevier Ltd: 380–387. DOI: 10.1016/j.atherosclerosis.2014.12.029.

Davison KK, Downs DS and Birch LL (2006) Pathways Linking Perceived Athletic Competence and Parental Support at Age 9 Years to Girls' Physical Activity at Age 11 Years. Research quarterly for exercise and sport 77(1): 23–31. DOI: 10.5641/027013606X13080769703722.

Davison KK, Schmalz DL and Downs DS (2010) Hop, skip... no! Explaining adolescent girls' disinclination for physical activity. Annals of behavioral medicine : a publication of the Society of Behavioral Medicine 39: 290–302. DOI: 10.1007/s12160-010-9180-x.

De Meester A, Maes J, Stodden D, et al. (2016) Identifying profiles of actual and perceived motor competence among adolescents: associations with motivation, physical activity, and sports participation. Journal of Sports Sciences 34(21): 2027–2037. DOI: 10.1080/02640414.2016.1149608.

De Meester A, Stodden D, Brian A, et al. (2016) Associations among Elementary School Children's Actual Motor Competence, Perceived Motor Competence, Physical Activity and BMI: A Cross-Sectional Study. Plos One 11(10): e0164600. DOI: 10.1371/journal.pone.0164600.

De Meester A, Stodden D, Goodway J, et al. (2018) Identifying a motor proficiency barrier for meeting physical activity guidelines in children. In: Journal of Science and Medicine in Sport, 2018, pp. 58–62. DOI: 10.1016/j.jsams.2017.05.007.

De Meester F, De Bourdeaudhuij I, Deforche B, et al. (2011) Measuring physical activity using accelerometry in 13-15-year-old adolescents: the importance of including non-wear activities. Public health nutrition 14(12): 2124–33. DOI: 10.1017/S1368980011001868.

De Meester F, Van Dyck D, De Bourdeaudhuij I, et al. (2014) Changes in physical activity during the transition from primary to secondary school in Belgian children: what is the role of the school environment? BMC public health 14(1). BMC Public Health: 261. DOI: 10.1186/1471-2458-14-261.

de Onis M and Lobstein T (2010) Defining obesity risk status in the general childhood population: Which cut-offs should we use? International Journal of Pediatric Obesity 5(6): 458–460. DOI: 10.3109/17477161003615583.

de Onis M, Onyango AW, Borghi E, et al. (2007) Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization 85(9): 660–7. DOI: 10.2471/BLT.07.043497.

Deci EL and Ryan RM (2000) The " What " and " Why " of Goal Pursuits: Human Needs and the Self-Determination of Behavior. Psychological Inquiry 11(4): 227–268. DOI: 10.1207/S15327965PLI1104_01.

Department of Health and Children: Health Service Executive (2009) The National Guidelines on Physical Activity for Ireland. Available at: http://www.getirelandactive.ie/Resources/Nat guidelines/GuidelinesPhysicalActivity.pdf (accessed 24 April 2017).

Department of Health Physical Activity Health Improvement and Protection (2011) Start Active , Stay Active. Report: 62. DOI: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216370/dh_128210.pdf.

Després JP (2012) Body fat distribution and risk of cardiovascular disease: An update. Circulation 126(10): 1301–1313. DOI: 10.1161/CIRCULATIONAHA.111.067264.

Dossegger A, Ruch N, Jimmy G, et al. (2014) Reactivity to accelerometer measurement of children and adolescents. Medicine and Science in Sports and Exercise 46(6): 1140–1146. DOI: 10.1249/MSS.0000000000000215.

Dumith SC, Gigante DP, Domingues MR, et al. (2012) A longitudinal evaluation of physical activity in Brazilian adolescents: tracking, change and predictors. Pediatric exercise science 24(1). Europe PMC Funders: 58–71. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22433265 (accessed 19 March 2019).

Dunton GF, Schneider M, Graham DJ, et al. (2006) Physical activity, fitness, and physical self-concept in adolescent females. Pediatric Exercise Science 18(11): 240–251.

Eime RM, Payne WR, Casey MM, et al. (2010) Transition in participation in sport and unstructured physical activity for rural living adolescent girls. Health Education Research 25(2): 282–293. DOI: 10.1093/her/cyn060.

Ekelund U, Luan J, Sherar LB, et al. (2012) Moderate to Vigorous Physical Activity and Sedentary Time and Cardiometabolic Risk Factors in Children and Adolescents. Journal of the American Medical Association 307(7): 704–712. DOI: 10.1016/j.yspm.2012.03.030.

Enders CK, Bandalos DL and Enders CK (2001) The Relative Performance of Full Information Maximum Likelihood Estimation for Missing Data in Structural Equation Models. Educational Psychology Papers and Publications 64. DOI: 10.1207/S15328007SEM0803.

Erwin H and Castelli D (2008) National physical education stan dards: a summary of student performance and its correlates. Research Quarterly for Exercise and Sport 79(4): 495–505.

Esliger DW, Copeland JL, Barnes JD, et al. (2005) Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. Journal of Physical Activity and Health 2(3): 366–383. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Standardizing+and+Optimizing+the+Use+of+Accelerometer+Data+for+Free-Living+Physical+Activity+Monitoring#0.

Evans D, Borriello GA and Field AP (2018) A review of the academic and psychological impact of the transition to secondary education. Frontiers in Psychology 9(AUG). DOI: 10.3389/fpsyg.2018.01482.

Farmer O, Belton S and O'Brien W (2017) The Relationship between Actual Fundamental Motor Skill Proficiency, Perceived Motor Skill Confidence and Competence, and Physical Activity in 8–12-Year-Old Irish Female Youth. Sports 5(4): 74. DOI: 10.3390/sports5040074.

Feltz DL (1978) Athletics in the status system of female adolescents. Review of Sport and Leisure 3.

Feltz DL (1988) Self-confidence and sports performance. Exercise and sport sciences reviews 16: 423–57. Available at: http://www.ncbi.nlm.nih.gov/pubmed/3292264.

Field AP (2013) Discovering Statistics Using SPSS: And Sex and Drugs and Rock 'n' Roll. 4th ed. London: Sage Publications Ltd.

Fisher A, Reilly JJ, Kelly LA, et al. (2005) Fundamental movement skills and habitual physical activity in young children. Medicine and Science in Sports and Exercise 37(4): 684–688. DOI: 10.1249/01.MSS.0000159138.48107.7D.

Fleishman EA (1964) What Do Physical Fitness Test Measure? A Review of Previous Research. Englewood Cliffs N.J., Prentice-Hall.

Foweather L, McWhannell N, Henaghan J, et al. (2008) Effect of a 9-Wk. after-School Multiskills Club on Fundamental Movement Skill Proficiency in 8- to 9-Yr.-Old Children: An Exploratory Trial. Perceptual and Motor Skills 106(3): 745–754. DOI: 10.2466/pms.106.3.745-754.

Fox KR and Corbin CB (1990) The Physical Self-Perception Profile Manual. Fox KR (ed.). Northern Illinois: DeKalb, IL: : University Office for Health Promotion.

Fox R (2010) Confirmatory Factor Analysis. Encyclopedia of Research Design: 181–186. DOI: 10.4135/9781412961288.

Francis CE, Longmuir PE, Boyer C, et al. (2016) The Canadian Assessment of Physical Literacy: Development of a Model of Children's Capacity for a Healthy, Active Lifestyle through a Delphi Process. Journal of Physical Activity and Health 13(2): 214–222. DOI: 10.1123/jpah.2014-0597.

Freedman DS, Serdula MK, Srinivasan SR, et al. (1999) Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: The Bogalusa Heart Study. American Journal of Clinical Nutrition 69(2): 308–317.

Fu Y, Gao Z, Hannon J, et al. (2013) Influence of a health-related physical fitness model on students physical activity, perceived competence, and enjoyment. Available at: http://www.amsciepub.com/doi/pdf/10.2466/10.06.PMS.117x32z0 (accessed 26 November 2015).

Gallahue D and Ozmun J (2012) Understanding Motor Development: Infants, Children, Adolescents, Adults.

Gavin A, Keane E, Callaghan M, et al. (2014) The Irish Health Behaviour in School-Aged Children (HBSC) Study 2014. Children. DOI: 10.1037/e531492013-001.

Gísladóttir O, Haga M and Sigmundsson H (2014) Motor competence and physical fitness in adolescents. Pediatric Physical Therapy 26(1): 69–74. DOI: 10.1097/PEP.0000000000000006.

Grant S, Corbett K, Amjad AM, et al. (1995) A comparison of methods of predicting maximum oxygen uptake. British journal of sports medicine 29: 147–152.

Green D, Lingam R, Mattocks C, et al. (2011) The risk of reduced physical activity in children with probable Developmental Coordination Disorder: A prospective longitudinal study. Research in Developmental Disabilities 32(4): 1332–1342. DOI: 10.1016/j.ridd.2011.01.040.

Griffiths A, Toovey R, Morgan PE, et al. (2018) Psychometric properties of gross motor assessment tools for children: a systematic review. BMJ open 8(10): e021734. DOI: 10.1136/bmjopen-2018-021734.

Grimminger E (2013) Sport motor competencies and the experience of social recognition among peers in physical education - a video-based study. Physical Education and Sport Pedagogy 18(5): 506–519. DOI: 10.1080/17408989.2012.690387.

Grøntved A, Ried-Larsen M, Møller NC, et al. (2015a) Muscle strength in youth and cardiovascular risk in young adulthood (the European Youth Heart Study). British journal of sports medicine 49(February 2016): 90–94. DOI: 10.1136/bjsports-2012-091907.

Grydeland M, Hansen BH, Ried-Larsen M, et al. (2014) Comparison of three generations of ActiGraph activity monitors under free-living conditions: do they provide comparable assessments of overall physical activity in 9-year old children? BMC public health 6(26): 1–8. DOI: 10.1186/2052-1847-6-26.

Gupta N, Balasekaran G, Victor Govindaswamy V, et al. (2011) Comparison of body composition with bioelectric impedance (BIA) and dual energy X-ray absorptiometry (DEXA) among Singapore Chinese. Journal of Science and Medicine in Sport 14(1): 33–35. DOI: 10.1016/j.jsams.2010.04.005.

Haerens L, Stodden D, De Meester A, et al. (2016) Associations among Elementary School Children's Actual Motor Competence, Perceived Motor Competence, Physical Activity and BMI: A Cross-Sectional Study. Pappalardo F (ed.) PLOS ONE 11(10): e0164600. DOI: 10.1371/journal.pone.0164600.

Haga M, Gisladottir T and Sigmundsson H (2015) The relationship between motor competence and physical fitness is weaker in the 15-16yr. adolescent age group than in younger age groups (4-5yr.

and 11-12yr.). Perceptual and Motor Skills: Physical Development and Measurement 121(3): 900–912.

Hallal PC, Andersen LB, Bull FC, et al. (2012) Physical activity levels of the world ' s population Surveillance progress , gaps and prospects. The Lancet 380: 247–257.

Hands B, Larkin D, Parker H, et al. (2009) The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. Scandinavian Journal of Medicine and Science in Sports 19: 655–663. DOI: 10.1111/j.1600-0838.2008.00847.x.

Hardie Murphy M, Rowe DA and Woods CB (2017) Impact of physical activity domains on subsequent physical activity in youth: a 5-year longitudinal study. Journal of Sports Sciences 35(3). Routledge: 262–268. DOI: 10.1080/02640414.2016.1161219.

Hardy LL, King L, Farrell L, et al. (2010) Fundamental movement skills among Australian preschool children. Journal of Science and Medicine in Sport 13(5): 503–508. DOI: 10.1016/j.jsams.2009.05.010.

Harju LK, Hakanen JJ and Schaufeli WB (2016) Can job crafting reduce job boredom and increase work engagement? A three-year cross-lagged panel study. Journal of Vocational Behavior 95–96. Elsevier Inc.: 11–20. DOI: 10.1016/j.jvb.2016.07.001.

Harrington D, Belton S, Woods C, et al. (2014) Ireland's Report Card on Physical Activity in Children and Youth. Available at: https://www.dcu.ie/sites/default/files/shhp/docs/ReportCardIreland2014_ShortForm_Final.pdf (accessed 27 April 2017).

Harrington DM, Murphy M, Carlin A, et al. (2016) Results From Ireland North and South's 2016 Report Card on Physical Activity for Children and Youth. Journal of Physical Activity and Health 13(11 Suppl 2): S183–S188. DOI: 10.1123/jpah.2016-0334.

Harter S (1978) Effectance Motivation Reconsidered. Toward a Developmental Model. Human Development 21(1): 34–64.

Harter S (1982a) The Perceived Competence Scale for Children. Child Development 53(1): 87. DOI: 10.2307/1129640.

Harter S (2012) The Self-Perception Profile for Adolescents: Manual and Questionaires.: 47.

Harter S and Pike R (1984) The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children. Child Development 55(6): 1969–1982.

Hassan N, Kamal H and Hussein Z (2016) Relation between body mass index percentile and muscle strength and endurance. Egyptian Journal of Medical Human Genetics 17(4). Ain Shams University: 367–372. DOI: 10.1016/j.ejmhg.2016.01.002.

Haubenstricker J and Seefeldt V (1986) Acquisition of motor skills during childhood. In: Seefeldt V (ed.) Physical Activity and Wellbeing. Waldorf, M.D.: AAHPERD, pp. 41–102.

Haugen T, Ommundsen Y and Seiler S (2013) The Relationship Between Physical Activity and Physical Self-Esteem in Adolescents: The Role of Physical Fitness Indices. Pediatric Exercise Science 25(1): 138–153. Available at:

http://ezproxy.library.yorku.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=sph&AN=85827942&site=ehost-live.

Health Service Executive (2012) Training Programme for Public Health Nurses and Doctors Growth Monitoring Module - updated October 2012. Health Service Executive (October). Available at: http://www.hse.ie/eng/services/Publications/Children/Training_Programme_for_Nurses_and_Doctors_in_Child_Health_Screening,_Surveillance_and_Health_Promotion.html (accessed 5 January 2017).
Health Service Executive (2012) Training Programme for Public Health Nurses and Doctors Growth Monitoring Module - updated October 2012. Health Service Executive (October). Available at: http://www.hse.ie/eng/services/Publications/Children/Training_Programme_for_Nurses_and_Doctors_in_Child_Health_Screening,_Surveillance_and_Health_Promotion.html (accessed 5 January 2017).
Heidari S, Babor TF, De Castro P, et al. (2016) Sex and Gender Equity in Research: rationalae for the SAGER guidelines and recommended use. Research Integrity and Peer Review 1(2). DOI: 10.1186/s41073-016-0007-6.

Heinen M, Murrin C, Daly L, et al. (2014) The Childhood Obesity Surveillance Initiative (COSI) in the Republic of Ireland : Findings from 2008 , 2010 and 2012. Health Service Executive. Available at: http://www.ucd.ie/t4cms/COSI report (2014).pdf (accessed 1 June 2017).

Helmerhorst HJF, Brage S, Warren J, et al. (2012) A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. International Journal of Behavioral Nutrition and Physical Activity. DOI: 10.1186/1479-5868-9-103.

Henderson S, Sugden D and Barnett L (2007) Movement Assessment Battery for Children-2: Movement ABC-2: Examiner’s Manual. Pearson.

Henrique RS, Bustamante A V, Freitas DL, et al. (2018) Tracking of gross motor coordination in Portuguese children. Journal of Sports Sciences 36(2): 220–228. DOI: 10.1080/02640414.2017.1297534.

Heyward VH (1998) The Physical Fitness Specialist Certification Manual, The Cooper Institute for Aerobics Research. In: Advance Fitness Assessment & Exercise Prescription. 3rd ed.

Hidding LM, M Chinapaw MJ, M van Poppel MN, et al. (2018) An Updated Systematic Review of Childhood Physical Activity Questionnaires. Sports Medicine 48: 2797–2842. DOI: 10.1007/s40279-018-0987-0.

Hills AP, Andersen LB and Byrne NM (2011) Physical activity and obesity in children. British journal of sports medicine 45(11): 866–870. DOI: 10.1136/bjsports-2011-090199 [doi].

Holfelder B and Schott N (2014) Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. Psychol Sport Exerc 15(4): 382–391. DOI: 10.1016/j.psychsport.2014.03.005.

Hu L and Bentler P (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal 6(1): 1–55.

Hutchens MJ (2017) Nested Model Comparison. The International Encyclopedia of Communication Research Methods: 1–2. DOI: 10.1002/9781118901731.iecrm0166.

Ihmels M, Welk GJ and McClain JJ (2004) The Reliability and Convergent Validity of Field Tests of Body Composition in Adolescents. Medicine & Science in Sports & Exercise 36(Supplement): S73. DOI: 10.1097/00005768-200405001-00347.

Inchley J, Kirby J and Currie C (2008) Physical Activity Among Adolescents in Scotland: Final Report of the PASS Study. Edinburgh: Child and Adolescent Health Research Unit (CAHRU), The University of Edinburgh. Available at: http://www.healthscotland.com/uploads/documents/8099-PASS_Final_Report 2008.pdf (accessed 19 December 2018).

Irish Life Schools Fitness Challenge (2016) Irish Life Schools' Fitness Challenge. Available at: http://www.irishlifehealth.ie/docs/fitness-challenge/sfc_barometer2016_web.pdf (accessed 30 April 2017).

Issartel J, McGrane B, Fletcher R, et al. (2017) A cross-validation study of the TGMD-2: The case of an adolescent population. Journal of Science and Medicine in Sport 20(5): 475–479. DOI: 10.1016/j.jsams.2016.09.013.

Jaakkola T and Washington T (2012) The relationship between fundamental movement skills and self-reported physical activity during Finnish junior high school. Physical Education & Sport Pedagogy 18(January 2013): 1–14. DOI: 10.1080/17408989.2012.690386.

Jaakkola T, Hakonen H, Kankaanpää A, et al. (2018) Longitudinal associations of fundamental movement skills with objectively measured physical activity and sedentariness during school transition from primary to lower secondary school. Journal of Science and Medicine in Sport. DOI: 10.1016/j.jsams.2018.07.012.

Jaakkola T, Huhtiniemi M, Salin K, et al. (2019) Motor competence, perceived physical competence, physical fitness, and physical activity within Finnish children. Scandinavian Journal of Medicine & Science in Sports: 0–3. DOI: 10.1111/sms.13412.

Jaakkola T, Yli-Piipari S, Huotari P, et al. (2016) Fundamental movement skills and physical fitness as predictors of physical activity: A 6-year follow-up study. Scandinavian Journal of Medicine and Science in Sports 26(1): 74–81. DOI: 10.1111/sms.12407.

Jago R, Page AS and Cooper AR (2012) Friends and physical activity during the transition from primary to secondary school. Medicine and Science in Sports and Exercise 44(1): 111–117. DOI: 10.1249/MSS.0b013e318229df6e.

Janz KF, Dawson JD and Mahoney LT (2000) Tracking physical fitness and physical activity from childhood to adolescence: the Muscatine study. Medicine & Science in Sports & Exercise 32(7): 1250–1257. DOI: 10.1097/00005768-200007000-00011.

Janz KF, Dawson JD and Mahoney LT (2002) Increases in physical fitness during childhood improve cardiovascular health during adolescence: the Muscatine Study. International journal of sports medicine 23 Suppl 1: S15–S21. DOI: 10.1055/s-2002-28456.

Jetté M, Sidney K and Blumchen G (1990) Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clinical Cardiology 13(8): 555–565. DOI: 10.1002/clc.4960130809.

Kaminsky L and Ozemek C (2012) A comparison of the Actigraphh GT1M and GT3X accelerometers under standardized and free-living conditions. Physiol. Meas 33. Available at: http://iopscience.iop.org/0967-3334/33/11/1869 (accessed 4 June 2017).

Kavanaugh K, Moore JB, Hibbett LJ, et al. (2015) Correlates of subjectively and objectively measured physical activity in young adolescents. Journal of Sport & Health Science 4: 222–227. DOI: 10.1016/j.jshs.2014.03.015.

Kavey REW, Daniels SR, Lauer RM, et al. (2003) American Heart Association guidelines for primary prevention of atherosclerotic cardiovascular disease beginning in childhood. Circulation 107(11): 1562–1566. DOI: 10.1161/01.CIR.0000061521.15730.6E.

Keane E, Kearney PM, Perry IJ, et al. (2014) Trends and prevalence of overweight and obesity in primary school aged children in the Republic of Ireland from 2002-2012: a systematic review. BMC public health 14(1): 974. DOI: 10.1186/1471-2458-14-974.

Kelloway K (1998) Using LISREL for Structural Equation Modeling; A Researcher’s Guide. London: Sage Publications Ltd.

Kelly L, O’connor S, Harrison AJ, et al. (2018) Does fundamental movement skill proficiency vary by sex, class group or weight status? Evidence from an Irish primary school setting. DOI: 10.1080/02640414.2018.1543833.

Kelly LA, Reilly JJ, Jackson DM, et al. (2007) Tracking physical activity and sedentary behavior in young children. Pediatric exercise science 19(1): 51–60. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17554157.

Kemper HCG, Twisk JWR and van Mechelen W (2013) Changes in aerobic fitness in boys and girls over a period of 25 years: data from the Amsterdam Growth And Health Longitudinal Study revisited and extended. Pediatric exercise science 25: 524–35. DOI: 10.1123/pes.25.4.524.

Khodaverdi Z, Bahram A, Stodden D, et al. (2015) The relationship between actual motor competence and physical activity in children: mediating roles of perceived motor competence and health-related physical fitness. DOI: 10.1080/02640414.2015.1122202.

King KM, Littlefield AK, McCabe CJ, et al. (2018) Longitudinal modeling in developmental neuroimaging research: Common challenges, and solutions from developmental psychology. Developmental Cognitive Neuroscience. DOI: 10.1016/j.dcn.2017.11.009.

Kiphard EJ and Schilling F (2007) Körperkoordinationstest Für Kinder. 2 (Überarbeitete Undergänzte Auflage). Weinheim: Beltz Test GmbH.

Klein S, Allison DB, Heymsfield SB, et al. (2007) Waist circumference and cardiometabolic risk: A consensus statement from Shaping America’s Health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Associat. Diabetes Care 30(6): 1647–1652. DOI: 10.2337/dc07-9921.

Kline R (2015) Principles and Practice of Structural Equation Modeling. 4th ed. London: Sage Publications Ltd.

Knowles A-M, Niven A and Fawkner S (2011) A qualitative examination of factors related to the decrease in physical activity behavior in adolescent girls during the transition from primary to secondary school. Journal of physical activity & health 8(8): 1084–91. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22039126.

Kriemler S, Zahner L, Schindler C, et al. (2010) Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: cluster randomised controlled trial. BMJ (Clinical research ed.) 340: c785. DOI: 10.1136/bmj.c785.

Lai SK, Costigan SA, Morgan PJ, et al. (2014) Do School-Based Interventions Focusing on Physical Activity, Fitness, or Fundamental Movement Skill Competency Produce a Sustained Impact in These Outcomes in Children and Adolescents? A Systematic Review of Follow-Up Studies. Sports Medicine 44(1): 67–79. DOI: 10.1007/s40279-013-0099-9.

Lämmle L, Tittlbach S, Oberger J, et al. (2010) A Two-level Model of Motor Performance Ability. Journal of Exercise Science and Fitness 8(1): 41–49. DOI: 10.1016/S1728-869X(10)60006-8.

Larsen LR, Kristensen PL, Junge T, et al. (2015) Motor Performance as Predictor of Physical Activity in Children: The CHAMPS Study-DK. Medicine and Science in Sports and Exercise 47(9): 1849–1856. DOI: 10.1249/MSS.0000000000000604.

Lau EY, Dowda M, McIver KL, et al. (2017) Changes in Physical Activity in the School , Afterschool , and Evening Periods During. Journal of School Health 87(7): 531–537. DOI: 10.1111/josh.12523.

Léger L a, Mercier D, Gadoury C, et al. (1988) The multistage 20 metre shuttle run test for aerobic fitness. Journal of sports sciences 6(2): 93–101. DOI: 10.1080/02640418808729800.

Li AM, Yin J, Yu CCW, et al. (2005) The six-minute walk test in healthy children: Reliability and validity. European Respiratory Journal 25(6): 1057–1060. DOI: 10.1183/09031936.05.00134904.

Lima RA, Pfeiffer K, Larsen LR, et al. (2017) Physical Activity and Motor Competence Present a Positive Reciprocal Longitudinal Relationship Across Childhood and Early Adolescence. Journal of Physical Activity and Health 14(6): 440–447. DOI: 10.1123/jpah.2016-0473.

Lima RA, Pfeiffer KA, Bugge A, et al. (2017) Motor competence and cardiorespiratory fitness have greater influence on body fatness than physical activity across time. Scandinavian Journal of Medicine and Science in Sports (January): 1–10. DOI: 10.1111/sms.12850.

Livesey D, Lum Mow M, Toshack T, et al. (2011) The relationship between motor performance and peer relations in 9- to 12-year-old children. Child: Care, Health and Development 37(4): 581–588. DOI: 10.1111/j.1365-2214.2010.01183.x.

Lloyd M, Colley RC and Tremblay MS (2010) Advancing the debate on ‘fitness testing’ for children: Perhaps we’re riding the wrong animal. Pediatric exercise science 22(18): 176–182. DOI: 10.1123/pes.22.2.176.

Lloyd M, Saunders TJ, Bremer E, et al. (2014) Long-term importance of fundamental motor skills: A 20-year follow-up study. Adapted Physical Activity Quarterly 31(1): 67–78. DOI: 10.1123/apaq.2013-0048.

Loenneke JP, Barnes JT, Wilson JM, et al. (2013) Reliability of field methods for estimating body fat. Clinical Physiology and Functional Imaging 33(5): 405–408. DOI: 10.1111/cpf.12045.

Logan SW, Barnett LM, Goodway JD, et al. (2016) Comparison of performance on process- and product-oriented assessments of fundamental motor skills across childhood. Journal of sports sciences 0414(May): 1–8. DOI: 10.1080/02640414.2016.1183803.

Logan SW, Kipling Webster E, Getchell N, et al. (2015) Relationship Between Fundamental Motor Skill Competence and Physical Activity During Childhood and Adolescence: A Systematic Review. Kinesiology Review 4(4): 416–426. DOI: 10.1123/kr.2013-0012.

Lopes VP, Rodrigues LP, Maia JAR, et al. (2011) Motor coordination as predictor of physical activity in childhood. Scandinavian Journal of Medicine and Science in Sports 21(5): 663–669. DOI: 10.1111/j.1600-0838.2009.01027.x.

Lubans D, Morgan P, Cliff D, et al. (2010) Fundamental movement skills in children and adolescents: review of associated health benefits. Sports medicine 40(12): 1019–1035. DOI: 10.2165/11536850-000000000-00000.

Malina RM (2001) Tracking of physical activity across the lifespan. President's Council on Physical Fitness and Sports Research Digest 3: 3–10. DOI: 10.1080/02701367.1996.10608853.

Marks J, Barnett LM, Strugnell C, et al. (2015) Changing from primary to secondary school highlights opportunities for school environment interventions aiming to increase physical activity and reduce sedentary behaviour: a longitudinal cohort study. International Journal of Behavioral Nutrition and Physical Activity 12(1). ??? 59. DOI: 10.1186/s12966-015-0218-0.

Marsh HW (1993) The Multidimensional Structure of Physical Fitness: Invariance Over Gender and Age. American Educational Research Journal 30(4): 841–860. DOI: 10.3102/00028312030004841.

Masci I, Schmidt M, Marchetti R, et al. (2017) When Children's Perceived and Actual Motor Competence Mismatch: Sport Participation and Gender Differences. Journal of Motor Learning and Development: 1–33. DOI: 10.1123/jmld.2016-0081.

May AL, Kuklina E V. and Yoon PW (2012) Prevalence of Cardiovascular Disease Risk Factors Among US Adolescents, 1999-2008. Pediatrics 129: 1035–1041. DOI: 10.1542/peds.2011-1082.

McClenahan C, Irwing P, Stringer M, et al. (2003) Educational differences in self-perceptions of adolescents in Northern Ireland. International Journal of Behavioral Development 27(6): 513–518. DOI: 10.1080/01650250344000136.

McGrane B, Belton S, Powell D, et al. (2016) The relationship between fundamental movement skill proficiency and physical self-confidence among adolescents. Journal of Sports Sciences 00(00). Routledge: 1–6. DOI: 10.1080/02640414.2016.1235280.

McIntyre F, Chivers P, Larkin D, et al. (2014) Exercise can improve physical self perceptions in adolescents with low motor competence. Human movement science 42. Elsevier B.V.: 333–343. DOI: 10.1016/j.humov.2014.12.003.

McKenzie T, Sallis J, Broyles S, et al. (2002) Childhood movement skills: Predictors of physical activity in Anglo American and Mexican American Adolescents? Research Quarterly for Exercise and Sport Sep 73(3).

McMurray RG, Harrell JS, Bangdiwala SI, et al. (2003) Tracking of Physical Activity and Aerobic Power from Childhood through Adolescence. Medicine and Science in Sports and Exercise 35(11): 1914–1922. DOI: 10.1249/01.MSS.0000093612.59984.0E.

Mcswegin PJ, Plowman SA, Wolff GM, et al. (1998) The Validity of a One-Mile Walk Test for High School Age Individuals. Measurement in Physical Education and Exercise Science 2(1): 47–63. DOI: 10.1207/s15327841mpee0201_4.

Melo X, Santa-Clara H, Pimenta NM, et al. (2014) Intima-Media Thickness in 11-13 Years-Old Children: Variation Attributed to Sedentary Behavior, Physical Activity, Cardiorespiratory Fitness and Waist Circumference. Journal of physical activity & health (October): 610–617. DOI: 10.1123/jpah.2013-0501.

Meyer AA, Kundt G, Lenschow U, et al. (2006) Improvement of Early Vascular Changes and Cardiovascular Risk Factors in Obese Children After a Six-Month Exercise Program. Journal of the American College of Cardiology 48(9): 1865–1870. DOI: 10.1016/j.jacc.2006.07.035.

Miller J, Vine K and Larkin D (2007) The relationship of process and product performance of the two-handed sidearm strike. Physical Education & Sport Pedagogy 12(January 2015): 61–76. DOI: 10.1080/17408980601060291.

Milton K, Bull FC and Bauman A (2011) Reliability and validity testing of a single-item physical activity measure. British Journal of Sports Medicine 45(3): 203–208. DOI: 10.1136/bjsm.2009.068395.

Minck MR, Ruiter LM, Van Mechelen W, et al. (2000) Physical fitness, body fatness, and physical activity: The Amsterdam Growth and Health Study. American Journal of Human Biology 12(March 1999): 593–599. DOI: 10.1002/1520-6300(200009/10)12:5<593::aid-ajhb3>3.0.co;2-u.

Mitchell B, McLennan S, Latimer K, et al. (2013) Improvement of fundamental movement skills through support and mentorship of class room teachers. Obesity Research and Clinical Practice 7(3): 230–234. DOI: 10.1016/j.orcp.2011.11.002.

Mitchell NG, Moore JB, Bibeau WS, et al. (2012) Cardiovascular fitness moderates the relations between estimates of obesity and physical self-perceptions in rural elementary school students. Journal of physical activity & health 9(2): 288–94. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22368227.

Moliner-Urdiales D, Ruiz JR, Vicente-Rodriguez G, et al. (2011) Associations of muscular and cardiorespiratory fitness with total and central body fat in adolescents: the HELENA study. British journal of sports medicine 45(2): 101–108. DOI: 10.1136/bjsm.2009.062430.

Morina B, Hadžić R, Vehapi S, et al. (2015) RELIABILITY OF EUROFIT TEST BATTERY WITH PUPILS FROM KOSOVO battery.

Morrow JR, Martin SB and Jackson AW (2010) Reliability and validity of the FITNESSGRAM®: Quality of teacher-collected health-related fitness surveillance data. Research Quarterly for Exercise and Sport 81. Payne & Morrow: S24–S30. DOI: 10.1080/02701367.2010.10599691.

Muldoon OT (2000) Social group membership and self-perceptions in Northern Irish children: A longitudinal study. British Journal of Developmental Psychology 18(1): 65–80.

Murphy MH, Rowe DA and Woods CB (2016) Sports Participation in Youth as a Predictor of Physical Activity: A 5-Year Longitudinal Study. Journal of Physical Activity and Health 13(7): 704–711. DOI: 10.1123/jpah.2015-0526.

Nader PR, Bradley RH, Houts RM, et al. (2008) Moderate-to Vigorous Physical Activity From Ages 9 to 15 Years. American Medical Association 300(3): 295–305.

NCCA (National Council for Curriculum and Assessment) (2017) Junior Cycle Wellbeing Guidelines. Guidelines for Wellbeing in Junior Cycle 2017. Dublin. Available at: https://www.ncca.ie/media/2487/wellbeingguidelines_forjunior_cycle.pdf (accessed 16 May 2019).

Nemet D, Barkan S, Epstein Y, et al. (2005) Short- and long-term beneficial effects of a combined dietary-behavioral-physical activity intervention for the treatment of childhood obesity. Pediatrics 115(4): e443–e449. DOI: 10.1542/peds.2004-2172.

Neumark-Sztainer D, Story M, Hannan PJ, et al. (2003) New moves: a school-based obesity prevention program for adolescent girls. Preventive Medicine 37(1): 41–51. DOI: 10.1016/S0091-7435(03)00057-4.

Ng M, Fleming T, Robinson M, et al. (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the Global Burden of Disease Study 2013. The Lancet 384(9945): 766–781. DOI: 10.1016/S0140-6736(14)60460-8.

Nikolaïdis PT (2011) Association between submaximal and maximal measures of aerobic power in female adolescents. Biomedical Human Kinetics 3: 106–110. DOI: 10.2478/v10101-011-0023-4.

NSW Department of Education and Training (2000) GET SKILLED : GET ACTIVE A K-6 resource to support the teaching.: 16–17. Available at: https://www.healthykids.nsw.gov.au/downloads/file/teacherschildcare/Get_skilled_get_active_booklet.pdf (accessed 25 May 2017).

O' Brien W, Belton S and Issartel J (2015a) Fundamental movement skill proficiency amongst adolescent youth. Physical Education and Sport Pedagogy (March 2015): 1–15. DOI: 10.1080/17408989.2015.1017451.

O' Brien W, Belton S and Issartel J (2015b) The relationship between adolescents' physical activity, fundamental movement skills and weight status. Journal of sports sciences 0414(October): 1–9. DOI: 10.1080/02640414.2015.1096017.

O' Brien W, Issartel J and Belton S (2013) Evidence for the efficacy of the Youth-Physical Activity Towards Health (Y-PATH) intervention. Advances in Physical Education 03(04): 145–153. DOI: 10.4236/ape.2013.34024.

O'Brien W, Duncan MJ, Farmer O, et al. (2018) Title Do Irish adolescents have adequate functional movement skill and confidence? Journal of Motor Learning and Development. DOI: 10.1123/jmld.2016.

O'Connor S, Whyte EF, Gibbons B, et al. (2018) Fundamental movement skill proficiency in juvenile Gaelic games. Sport Sciences for Health 14(1): 161–172. DOI: 10.1007/s11332-017-0421-2.

O'Keeffe SL, Harrison AJ and Smyth PJ (2007) Transfer or specificity? An applied investigation into the relationship between fundamental overarm throwing and related sport skills. Physical Education and Sport Pedagogy 12(2): 89–102. DOI: 10.1080/17408980701281995.

Ogden CL, Carroll MD, Fryar CD, et al. (2015) Prevalence of Obesity Among Adults and Youth: United States, 2011 - 2014. Available at: http://c.ymcdn.com/sites/www.acutept.org/resource/resmgr/Critical_EdgEmail/0216-prevalence-of-obesity.pdf (accessed 2 May 2017).

Okely AD and Booth ML (2000) The development and validation of an instrument to assess children's fundamental movement skill ability. In: In 2000 Pre-Olympic Congress Book of Abstracts, 2000; 245, 2000.

Okely AD and Booth ML (2004) Mastery of fundamental movement skills among children in New South Wales: Prevalence and sociodemographic distribution. Journal of Science and Medicine in Sport 7(3): 358–372. DOI: 10.1016/S1440-2440(04)80031-8.

Okely AD, Booth ML and Patterson JW (2001) Relationship of physical activity to fundamental movement skills among adolescents. Medicine & Science in Sports & Exercise (19): 1899–1904.

Ortega F, Artero E, Ruiz J, et al. (2008) Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. International Journal of Obesity 32(10). DOI: 10.1038/ijo.2008.183.

Ortega F., Ruiz JR, Castillo MJ, et al. (2008) Physical fitness in childhood and adolescence: a powerful marker of health. International Journal of Obesity 32(1): 1–11. DOI: 10.1038/sj.ijo.0803774.

Ortega FB, Ruiz JR, Castillo MJ, et al. (2005) Low Level of Physical Fitness in Spanish Adolescents. Relevance for Future Cardiovascular Health (AVENA Study) O R I G I N A L A RT I C L E S. Rev Esp Cardiol 58(8): 898–909.

Ortega Francisco B, Ortega F B, Artero EG, et al. (2011) Physical fitness levels among European adolescents: the HELENA study. Br J Sports Med 45: 20–29. DOI: 10.1136/bjsm.2009.062679.

Pate R, Oria M and Pillsbury L (2012) Fitness Measures and Health Outcomes in Youth. National Academies Press 11. DOI: 10.17226/13483.

Pate R, Oria M, Pillsbury L, et al. (2012) Fitness Measures and Health Outcomes in Youth. The Psysician and Sports Medicine. DOI: 10.17226/13483.

Pate RR (1988) The evolving definition of physical fitness. Quest 40(3): 174–179. DOI: 10.1080/00336297.1988.10483898.

Pate RR, Pratt M, Blair SN, et al. (1995) Public Health and Prevention and the American College of Sports Medicine. Journal of the American Medical 273(5).

Pate RR, Wang C, Dowda M, et al. (2006) Cardiorespiratory Fitness Levels Among US Youth 12 to 19 Years of Age. Arch Pediatr Adolesc Med 160: 1005–1012. DOI: 10.1001/archpedi.160.10.1005.

Payne G and Isaacs L (2016) Human Motor Development: A Lifespan Approach. 9th ed. Routledge.

Piek JP, Baynam GB and Barrett NC (2006) The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. Human Movement Science 25(1): 65–75. DOI: 10.1016/j.humov.2005.10.011.

Plowman SA and Mahar MT (2013) FITNESSGRAM /ACTIVITYGRAM Reference Guide (4th Edition). The Cooper Institute, Dallas, TX. The Cooper Institute. DOI: 10.1055/s-0033-1334967.

Powell C, Carson BP, Dowd KP, et al. (2016) Simultaneous validation of five activity monitors for use in adult populations. Scandinavian Journal of Medicine and Science in Sports (November): 1–12. DOI: 10.1111/sms.12813.

Prochaska JJ, Sallis JF and Long B (2001) A physical activity screening measure for use with adolescents in primary care. Archives of pediatrics & adolescent medicine 155(May): 554–559. DOI: 10.1001/archpedi.155.5.554.

Raitakari OT, Juonala M, Kähö Nen M, et al. (2003) Cardiovascular risk factors in childhood and carotid artery intima-media thickness in adulthood. The Cardiovascular Risk in Young Finns Study. JAMA 290(17): 2277–2283. DOI: 10.1001/jama.290.17.2277.

Ramsbottom R, Brewer J and Williams C (1988) A progressive shuttle run test to estimate maximal oxygen uptake. British Journal of Sports Medicine 22(4): 141–144. DOI: 10.1136/bjsm.22.4.141.

Raudsepp L, Liblik R and Hannus A (2002) Children’s and Adolescents’ Physical Self-Perceptions as Related to Moderate to Vigorous Physical Activity and Physical Fitness. Pediatric Exercise Science 14: 97–106.

Ré AHN, Cattuzzo MT, Ré AHN, et al. (2016) Physical characteristics that predict involvement with the ball in recreational youth soccer. Journal of Sport Sciences (February). DOI: 10.1080/02640414.2015.1136067.

Rich C, Geraci M, Griffiths L, et al. (2013) Quality Control Methods in Accelerometer Data Processing: Defining Minimum Wear Time. PLoS ONE 8(6): 1–8. DOI: 10.1371/journal.pone.0067206.

Riddiford-Harland DL, Steele JR and Baur LA (2006) Upper and lower limb functionality: Are these compromised in obese children? International Journal of Pediatric Obesity 1(1): 42–49. DOI: 10.1080/17477160600586606.

Ridley K, Ainsworth BE and Olds TS (2008) Development of a compendium of energy expenditures for youth. The international journal of behavioral nutrition and physical activity 5: 45. DOI: 10.1186/1479-5868-5-45.

Robinson LE, Stodden DF, Barnett LM, et al. (2015) Motor Competence and its Effect on Positive Developmental Trajectories of Health. Sports Medicine 45(9). Springer International Publishing: 1273–1284. DOI: 10.1007/s40279-015-0351-6.

Rodgers WM, Markland D, Selzler AM, et al. (2014) Distinguishing perceived competence and self-efficacy: an example from exercise. Research Quarterly for Exercise and Sport 85(4): 527–539. DOI: 10.1080/02701367.2014.961050.

Rodrigues Luis P, Stodden DF and Lopes VP (2016) Developmental pathways of change in fitness and motor competence are related to overweight and obesity status at the end of primary school.

Journal of science and medicine in sport / Sports Medicine Australia 19(1): 87–92. DOI: 10.1016/j.jsams.2015.01.002.

Rowland TW (2005) Children's Exercise Physiology. Champaign, IL: Human Kinetics.

Ruiz JR, Castro-Piñero J, Artero EG, et al. (2009) Predictive validity of health-related fitness in youth: a systematic review. British journal of sports medicine 43(12): 909–923. DOI: 10.1136/bjsm.2008.056499.

Ruiz JR, Castro-Piñero J, España-Romero V, et al. (2011) Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. British journal of sports medicine 45(6): 518–24. DOI: 10.1136/bjsm.2010.075341.

Ruiz JR, Ortega FB, Gutierrez A, et al. (2006) Health-related fitness assessment in childhood and adolescence: A European approach based on the AVENA, EYHS and HELENA studies. In: Journal of Public Health, 2006, pp. 269–277. DOI: 10.1007/s10389-006-0059-z.

Sallis JF and Saelens BE (2000) Assessment of Physical Activity by Self-Report : Status, Limitations, and Future Directions. Research Quarterly for Exercise and Sport 71(2). DOI: 10.1080/02701367.2000.11082780.

Santos R, Mota J, Santos DA, et al. (2014) Physical fitness percentiles for Portuguese children and adolescents aged 10-18 years. Journal of sports sciences (May 2014): 1–9. DOI: 10.1080/02640414.2014.906046.

Saraiva L, Rodrigues P and Cordovil R (2013) Influence of age , sex and somatic variables on the motor performance of pre-school children. 4460: 1–7. DOI: 10.3109/03014460.2013.802012.

Savva S, Tornaritis M, Savva M, et al. (2000) Waist circumference and waist-to-hip ratio are better predictors of cardiovascular disease risk factors in children than body mass index. International Journal of Obesity 24: 1453–1458.

Schumacker ER and Lomax GR (1996) A Beginner's Guide to Structural Equation Modeling. New Jersey: Erlbaum.

Shapka JD and Keating DP (2005) Structure and change in self-concept during adolescence. Canadian Journal of Behavioural Science 37(2): 83–96. DOI: 10.1037/h0087247.

Shavelson RJ, Hubner JJ and Stanton GC (1976) Self-Concept: Validation of Construct Interpretations. Review of Educational Research 46(3): 407–441. DOI: 10.3102/00346543046003407.

Shen W, Punyanitya M, Chen J, et al. (2006) Waist circumference correlates with metabolic syndrome indicators better than percentage fat. Obesity (Silver Spring, Md.) 14(4): 727–736. DOI: 10.1038/oby.2006.83.

Shin T, Davison M and Long J (2016) Maximum Likelihood Versus Multiple Imputation for Missing Data in Data in Small Longitudinal Samples With Nonnormality. Psychological Methods: American Psychological Association: 211–232. DOI: 10.1007/s11336-008-9088-6.

Silva LR, Cavaglieri C, Lopes WA, et al. (2014) Endothelial wall thickness, cardiorespiratory fitness and inflammatory markers in obese and non-obese adolescents. Brazilian Journal of Physical Therapy 18(1): 47–55. DOI: 10.1590/S1413-35552012005000133.

Smith JJ, Eather N, Morgan PJ, et al. (2014) The Health Benefits of Muscular Fitness for Children and Adolescents: A Systematic Review and Meta-Analysis. Sports Medicine 44(9): 1209–1223. DOI: 10.1007/s40279-014-0196-4.

Spencer RA, Rehman L and Kirk SF (2015) Understanding gender norms, nutrition, and physical activity in adolescent girls: a scoping review. International Journal of Behavioral Nutrition and Physical Activity 12: 1–11. DOI: 10.1186/s12966-015-0166-8.

Spessato BC, Gabbard C, Robinson L, et al. (2013) Body mass index, perceived and actual physical competence: The relationship among young children. Child: Care, Health and Development 39(6): 845–850. DOI: 10.1111/cch.12014.

Stodden D (2014) Current evidence on the associations between motor competence and aspects of health in youth: What do we know? Science & Sports 29: S6–S6. DOI: 10.1016/j.scispo.2014.08.004.

Stodden D, Langendorfer S and Roberton MA (2009) The association between motor skill competence and physical fitness in young adults. Research quarterly for exercise and sport 80(June): 223–9. DOI: 10.5641/027013609X13087704028318.

Stodden D, Sacko R and Nesbitt D (2015) A Review of the Promotion of Fitness Measures and Health Outcomes in Youth. XX(X): 1–11. DOI: 10.1177/1559827615619577.

Stodden DF, Gao Z, Goodway JD, et al. (2014) Dynamic Relationships Between Motor Skill Competence and Health-Related Fitness in Youth. Pediatric Exercise Science 26(August): 231–241. DOI: 10.1123/pes.2013-0027.

Stodden DF, Goodway JD, Langendorfer SJ, et al. (2008) A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. Quest 60(2): 290–306. DOI: 10.1080/00336297.2008.10483582.

Stodden DF, True LK, Langendorfer SJ, et al. (2013) Associations Among Selected Motor Skills and Health-Related Fitness: Indirect Evidence for Seefeldt's Proficiency Barrier in Young Adults? Research Quarterly for Exercise and Sport 84(3): 397–403. DOI: 10.1080/02701367.2013.814910.

Symonds JE and Galton M (2014) Moving to the next school at age 10-14 years: an international review of psychological development at school transition. Review of Education 2(1): 28–30. DOI: 10.1002/rev3.3022.

Tabachnick BG and Fidell LS (2007) Using Multivariate Statistics. 5th ed. New York: Allyn and Bacon.

Talma H, Chinapaw MJM, Bakker B, et al. (2013) Bioelectrical impedance analysis to estimate body composition in children and adolescents: A systematic review and evidence appraisal of validity, responsiveness, reliability and measurement error. Obesity Reviews 14(11): 895–905. DOI: 10.1111/obr.12061.

Taymoori P, Berry TR and Lubans DR (2011) Tracking of physical activity during middle school transition in Iranian adolescents. Health Education Journal. DOI: 10.1177/0017896911419341.

The Cooper Institute (2001) Muscular strength, endurance and flexibility assessments. Fitnessgram/Activitygram Reference Guide: 129–168.

Timo J, Sami YP, Anthony W, et al. (2016) Perceived physical competence towards physical activity, and motivation and enjoyment in physical education as longitudinal predictors of adolescents' self-reported physical activity. Journal of Science and Medicine in Sport 19(9): 750–754. DOI: 10.1016/j.jsams.2015.11.003.

Toftager M, Kristensen PL, Oliver M, et al. (2013) Accelerometer data reduction in adolescents: effects on sample retention and bias. The International Journal of Behavioral Nutrition and Physical Activity 10: 140. DOI: 10.1186/1479-5868-10-140.

Tomkinson GR, Carver KD, Atkinson F, et al. (2018) European normative values for physical fitness in children and adolescents aged 9-17 years: Results from 2 779 165 Eurofit performances representing 30 countries. British Journal of Sports Medicine 52(22): 1445–1456. DOI: 10.1136/bjsports-2017-098253.

Trost SG, Loprinzi PD, Moore R, et al. (2011) Comparison of accelerometer cut points for predicting activity intensity in youth. Medicine and Science in Sports and Exercise 43(7): 1360–1368. DOI: 10.1249/MSS.0b013e318206476e.

True L, Brian A, Goodway J, et al. (2017) Relationships Between Product- and Process-Oriented Measures of Motor Competence and Perceived Competence. Journal of Motor Learning and Development 5(2): 319–335. DOI: 10.1123/jmld.2016-0042.

U.S. Department of Health and Human Services (2008) 2008 Physical Activity Guidelines for Americans THE SECRETARY OF HEALTH AND HUMAN SERVICES. Available at: www.health.gov/paguidelines (accessed 24 April 2017).

Ulrich D (2000) Test of Gross Motor Development: Examiner's Manual. 2nd ed. Austin, Texas: Pro-Ed.

Ulrich D (2016) Test of Gross Motor Development-3. 3rd ed. Pro-Ed (ed.). Austin, Texas: Pro-Ed.

Utesch T, Bardid F, Busch D, et al. (2019) The relationship between motor competence and physical fitness from early 2 childhood to early adulthood: A meta-analysis. Sports Medicine: 1–29.

Van Beurden E, Barnett LM, Zask A, et al. (2003) Can we skill and activate children through primary school physical education lessons? 'Move it Groove it' - A collaborative health promotion intervention. Preventive Medicine 36(4): 493–501. DOI: 10.1016/S0091-7435(02)00044-0.

Vandendriessche JB, Vandorpe BFR, Vaeyens R, et al. (2012) Variation in sport participation, fitness and motor coordination with socioeconomic status among Flemish children. Pediatric exercise science 24(1): 113–28. Available at: https://biblio.ugent.be/publication/2320175/file/6773598.pdf (accessed 29 April 2017).

Vandorpe B, Vandendriessche J, Lefevre J, et al. (2011) The KorperkoordinationsTest fur Kinder: Reference values and suitability for 6-12-year-old children in Flanders. Scandinavian Journal of Medicine and Science in Sports 21(3): 378–388. DOI: 10.1111/j.1600-0838.2009.01067.x.

Vandorpe B, Vandendriessche J, Vaeyens R, et al. (2012) Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach. Journal of Science and Medicine in Sport 15: 220–225. DOI: 10.1016/j.jsams.2011.09.006.

Vedul-Kjelsås V, Sigmundsson H, Stensdotter a. K, et al. (2012a) The relationship between motor competence, physical fitness and self-perception in children. Child: Care, Health and Development 38: 394–402. DOI: 10.1111/j.1365-2214.2011.01275.x.

Venetsanou F and Kambas A (2011) The effect of age and gender on balance skills in preschool children. Physical Education and Sport 9(1): 81–90. Available at: http://facta.junis.ni.ac.rs/pe/pe201101/pe201101-08.pdf (accessed 29 April 2017).

Victoria Department of Education V (1996) Fundamental Motor Skills. A Manual for Classroom Teachers. Department of Education, Victoria: 52. Available at: https://www.eduweb.vic.gov.au/edulibrary/public/teachlearn/student/fmsteachermanual09.pdf (accessed 5 April 2017).

Warburton DER, Nicol CW and Bredin SSD (2006) Health benefits of physical activity: the evidence. CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne 174(6): 801–9. DOI: 10.1503/cmaj.051351.

Warren JM, Ekelund U, Besson H, et al. (2010) Assessment of physical activity - a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. European Journal of Cardiovascular Prevention and Rehabilitation 17(2): 127–139. DOI: 10.1097/HJR.0b013e32832ed875.

Welk GJ (1999) The Youth Physical Activity Promotion Model: A Conceptual Bridge Between Theory and Practice. Quest 51(1): 5–23. DOI: 10.1080/00336297.1999.10484297.

Welk GJ, Going SB, Morrow JR, et al. (2011) Development of new criterion-referenced fitness standards in the FITNESSGRAM ?? program: Rationale and conceptual overview. American Journal of Preventive Medicine. DOI: 10.1016/j.amepre.2011.07.012.

Weston A, Petosa R and Pate R (1997) Validation of an instrument for measurement of physical activity in youth. Medicine & Science in Sports & Exercise 29(1): 138–143.

White RW (1959) Motivation reconsidered: the concept of competence. Psychological review 66(S): 297–333. DOI: 10.1037/h0040934.

Whitehead JR (1995) A study of children's physical self-perceptions using an adapted physical self-perception profile questionnaire. Pediatr Exerc Sci 7: 132–151.

WHO (2009) Global Health Risks: Mortality and burden of disease attributable to selected major risks. Bulletin of the World Health Organization 87: 646–646. DOI: 10.2471/BLT.09.070565.

WHO (2013) The World Health Report 2013. Available at: www.who.int/about/licensing/copyright_form/en/index.html (accessed 9 June 2019).

WHO (2018a) Obesity and Overweight.

WHO (2018b) Physical Activity.

Williams HG, Pfeiffer KA, O'Neill JR, et al. (2008) Motor skill performance and physical activity in preschool children. Obesity (Silver Spring, Md.) 16(6): 1421–6. DOI: 10.1038/oby.2008.214.

Williams JM and White KA (1983) Adolescent status systems for males and females at three age levels. Adolescence 2: 381–9.

Wilson BN, Kaplan BJ, Crawford SG, et al. (2000) Reliability and validity of a parent questionnaire on childhood motor skills. American Journal of Occupational Therapy 54(5): 484–493. DOI: 10.5014/ajot.54.5.484.

Woods CB, Tannehill D, Quinlan A, et al. (2010) The Children's Sport Participation and Physical Activity Study (CSPPA). Research Report No 1. School of Health and Human Performance, Dublin City University and The Irish Sports Council, Dublin, Ireland.

World Health Organization (2010) Global recommendations on physical activity for health. Geneva: World Health Organization: 60. DOI: 10.1080/11026480410034349.

Yee Allison Wong K and Yin Cheung S (2010) Confirmatory Factor Analysis of the Test of Gross Motor Development-2 Confirmatory Factor Analysis of the Test of Gross Motor Development-2. Measurement in Physical Education and Exercise Science 143(14): 202–209. DOI: 10.1080/10913671003726968.

Zhang T, Thomas K and Weiller K (2015) Predicting Physical Activity in 10-12 Year Old Children: A Social Ecological Approach. JOURNAL OF TEACHING IN PHYSICAL EDUCATION 34(3): 517–536. DOI: 10.1123/jtpe.2013-0195.

Appendix A

Informed Consent Form - Principal/Teacher

Informed Consent Form - Principal or PE teacher

I. Research Study Title:"Youth Physical Activity Towards Health (Y-PATH):Building the Bridge"

II. Clarification of the purpose of the research

Physical activity has been shown to be extremely beneficial to youth; however the majority of young people in Ireland are not participating in enough physical activity to benefit their health. Y-PATH: Building the Bridge aims to improve physical activity levels among youth by identifying pertinent factors relating to physical activity levels in children and adolescents during the transition from primary to second level school.

The current recommendation in Ireland for children and young people (2-18 yrs) is at least 60 minutes of moderate to vigorous physical activity everyday (Department of Health and Children, 2009). At present the gap between the recommended time children should spend being physically active and the reality is causing increasing problems in children's and adolescent's health.

The purpose of this research is to gather information on physical activity levels, health-related fitness, motor competence, perceived competence, and neurocognitive function, as children transition from primary to second level school. Participants will be measured on these variables at three time points during the research; 6th class of primary school, 1st year, and 2nd year of second level school. This information will be used to develop strategies that may be used in the school to increase the opportunities for physical activity, and to ultimately improve the physical activity levels of the students in the school.

III. Confirmation of particular requirements as highlighted in Plain Language Statement

Participating School: please complete the following (Circle Yes or No for each question)

Have you read or had read to you the Plain Language Statement	*Yes/No*
Do you understand the information provided?	*Yes/No*
Do you understand you must make student grades available to the research team?	*Yes/No*
Have you had an opportunity to ask questions and discuss this study?	*Yes/No*
Have you received satisfactory answers to all your questions?	*Yes/No*

Involvement in the research is completely voluntary. Participants may choose to withdraw from the study at anytime. There shall be no penalty for withdrawing before all stages of the research project have been completed**.** Confidentiality is an important issue during data collection. Participants' identity, or other personal information, will not be revealed or published. Participants will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. The investigators alone will have access to the data. Confidentiality of information provided can only be protected within the limitations of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent for my school to take part in this research project

Teacher/Principal's Signature: ______________________________

Name in Block Capitals: ______________________________

Witness: ______________________________

Date: ______________________________

Appendix B

Parent/Guardian Informed Consent Form

Informed Consent Form – Parent/Guardian of U16s

Dear Parent/Guardian,

Please find overleaf an informed consent form for your child's participation in a physical activity study titled "Youth Physical Activity Towards Health (Y-PATH): Building the Bridge". This study is being carried out by Dublin City University in your child's school. The study aims to gather information on the physical activity levels of students in the school as well as information on other factors such as perceived self-competence, body composition measurements, neuro-cognitive functioning and physical fitness levels. As part of this we will be looking at students grades in English, Irish and Maths, to consider whether changes in physical activity levels result in changes in academic performance. All of these measures will be taken in 6th class of primary school, and again in both 1st and 2nd year of second level school.

There is increasing evidence to show that physical inactivity in childhood leads to health problems later in adolescence and adulthood. By tracking changes in various factors relating to your child's overall health and wellbeing, we will be able to better understand how to promote physical activity, physical fitness, and health and wellbeing among Irish youth. This will lead to better informed physical activity programmes that will improve the health of all children and adolescents.

Information gathered on your child will not be shown individually to anyone - it will be combined with information from lots of other students and as such no-one will have access to an individual child's information. Information gathered on the group of students involved in the study will be made available to parents through the school once the study has been completed.
In order for your child to participate in this study, please read the attached form. If you wish your child to be involved please sign and return Option 1 at the bottom of the form. If you <u>DO NOT</u> wish your child to participate in the study you need take no further action.

Thank you for your time.

Yours sincerely,

Úna Britton

Ms. Úna Britton Dr. Sarahjane Belton Dr. Johann Issartel

Informed Consent Form Under 16's

Project Title: "Youth Physical Activity Towards Health (Y-PATH): Building the Bridge"

Investigators: Dr. Sarahjane Belton, Dr. Johann Issartel, Ms Úna Britton.

Introduction to the study:
Physical activity has been shown to be extremely beneficial to youth. However the majority of young people in Ireland are not participating in enough physical activity to benefit their health. Y-PATH: Building the Bridge aims to track changes in physical activity levels of youth, as well as other factors such as physical fitness levels, perceived physical self-competence, body composition, fundamental movement skills and neurocognitive functioning. The purpose of this study is to monitor changes in physical activity and related factors, including academic performance, over time.

This is what will happen during the research project:

Before any testing commences you will fill out a Physical Activity Readiness Questionnaire for your child to determine if they are able to participate.

- Your child will complete a perceived physical competence questionnaire. This questionnaire will be filled out in class with the help of the class teacher and a researcher.This questionnaire aims to determine your child's perceptions of their athletic capabilities, physical appearance, and general self-worth.
- Your child will have their height, weight hip/waist circumference, and percentage body fat measured.
- Your child will take part in a 20 minute shuttle run test.
- Your child will be recorded using a video camera in PE class measuring how well they can:
    - Run
    - Horizontal jump
    - Two-board balance
    - Walking toe-heel backwards
    - Zig-zag hopping
    - Kick
    - Overhand throw
    - One-hand strike
    - Two-hand strike
    - Skip
    - Catch
    - Push-up
    - Sit-up
    - Sit-and-reach
    - Grip strength
    - Vertical jump

  Your child will be asked to wear a small device (accelerometer) around their waist to measure how much they move in a specific length of time (9 days). Your child will receive an automated text message on their mobile phone each morning and afternoon from the research team reminding them to put on their accelerometer (if you wish to provide your phone number to the researcher team).

  Your child will undergo a series of neuro-cognitive function tests to assess areas such as attention and memory.

  Your child's year-head/principal will make your child's grades in English, Irish and Maths available to the research team.

All information gathered will be treated in the strictest of confidence. To ensure this, your child's name will be removed from all data and replaced with an ID number. Only the researcher will know your child's ID number, and only the researchers will have access to the information.

Please read Option 1 and Option 2 below and complete as appropriate.

Option 1: Child to be included in the study

I have read and understood the information in this form. I have read and explained the information in the form to my child. The researchers have answered my questions and concerns, and I have a copy of this consent form. I understand that all students, including my child, are included in this study.

ACTION: To advise the research team of your decision to include your child in the study please sign and return this form to your child's PE teacher for attention of Ms Úna Britton.

Parent/Guardian Signature:___________________________________

Name in Block Capitals: ___________________________________

Child's Name in Block Capitals: _______________________________

Option 2 Child to be removed from the study

I have read and understood the information in this form. I have read and explained the information in the form to my child. The researchers have answered my questions and concerns, and I have a copy of this consent form. I request that my child is not included in the study. I understand that my child will not be penalised in any way for doing this.

ACTION: No further action necessary. Please file this consent form for future reference.

Appendix C

Participant Assent Form

ASSENT FORM FOR PARTICIPANTS

Study Title:Youth Physical Activity Towards Health (Y-PATH): Building the Bridge

My parent/guardian has talked to me about being part of a research study.
It has been explained to me that I will be asked to participate in activities to do with the study in 1st year and 2nd year of second level school. At each of these times, the study will involve me:

i. Completing a physical activity questionnaire.
ii. Completing a mental health and wellbeing questionnaire.
iii. Having my height, weight, and body fat percentage measured.
iv. Taking part in a 20m shuttle run test.
v. Wearing a device to measure how quickly and how often I move.
vi. Completing a cognitive functioning assessment to see how well my brain works.
vii. Being video recorded doing the following activities in PE class;
Running, jumping, balancing on two boards, walking toe-heel backwards, zig-zag hopping, kicking, throwing, striking, skipping, catching, push-ups, sit-ups, sit-and-reach, and grip strength.
viii. Having my year head/principal give my English, Irish and Maths grades to the researcher.

1. I know that I am free to decide not to take part in this study if I wish.
2. I can change my mind and not take part if I wish.

SIGNED: ____ DATE: __________
(Participant's name)

Participant's Phone Number (Reminder Text): ______________________________

SIGNED: ____ DATE: __________
(Witness' name)

Appendix D

Physical Activity Readiness Questionnaire - Children

Physical Activity Readiness Questionnaire – Children
PRE-TEST QUESTIONNAIRE
Completed by a Parent/Guardian of Child

NAME OF CHILD ……………………………………………………………………………….

CHILD DATE OF BIRTH …………………………… CHILD'S AGE: ………………

As your child is to be a participant in this project, would you please complete the following physical activity readiness questionnaire for your child.

Please tick appropriate box

	YES	NO
Has the test procedure(s) that your child will participate in been fully explained to you?	☐	☐

Any information contained herein will be treated as confidential

	YES	NO
(1) Has your doctor ever said that your child has a heart condition and that your child should only do physical activity recommended by a doctor?	☐	☐
(2) Does your child ever experience chest pain during physical activity?	☐	☐
(3) Does your child ever lose balance because of dizziness or do they ever lose consciousness?	☐	☐
(4) Does your child have a bone or joint problem that could be made worse by a change in their physical activity participation?	☐	☐
(5) Does your child have uncontrolled asthma (i.e. asthma that is not easily controlled by an inhaler?	☐	☐
(6) Is your doctor currently prescribing any medication for your child's blood pressure or a heart condition?	☐	☐
(7) Do you know of any other reasons why your child should not undergo physical activity? This might include diabetes, a recent injury, or serious illness.	☐	☐

If you have answered **NO** to <u>all</u> questions then you can be reasonably sure that your child can take part in the physical activity requirement of this project.

I ………………………………. declare that the above information is correct at the time of completing this questionnaire on date ……/……/…….

Please note: If your child’s health changes so that you can answer YES to any of the above questions, notify the investigators and consult with your doctor regarding the level of physical activity that your child can participate in.

If you answered YES to one or more questions:

Talk to your doctor in person discussing with him/her those questions you answered yes.

Ask your doctor if your child is able to participate in the physical activity requirements of the project.

Doctor’s Name…. ………………………………. Date …………………………..

Doctor’s Signature ……………………………….

Signature of Investigator ………………………… Date …………………………..