Assessment of physical activity in adolescents: protocols, compliance and participants' perceptions

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Statement of Originality

This thesis contains no material which has been accepted for the award of any other degree of diploma in any university or other tertiary institution. To the authors' knowledge it contains no material previously published or written by any other person, except where due reference has been made within the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968.

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Statement of Authorship

I hereby certify that this thesis is submitted in the form of a series of published papers of which I am a joint author. I have included as part of the thesis a written statement from each co-author; and endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications. I warrant that I have obtained, where necessary, permission from the copyright owners to use any third-party copyright material reproduced in the thesis (e.g. questionnaires, artwork, unpublished letters), or to use any of my own published work (e.g. journal articles) in which the copyright is held by another party (e.g. publisher, co-author)

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Publications arising from this thesis

This thesis presents a series of five papers. I am the lead author in four papers and I am the co-author of one paper. At the time of submission, five of these papers were published. I have presented results arising from this thesis at the University of Newcastle (Faculty of Education and the PRCPAN conferences) and also at two international conferences (detailed below).

Manuscripts published in peer-reviewed journals:

1. Lubans, D. R., Plotnikoff, R. C., Miller, A., **Scott, J. J.**, Thompson, D., & Tudor-Locke, C. (2014). Using pedometers for measuring and increasing physical activity in children and adolescents: the next step. *American Journal of Lifestyle Medicine*. doi: 10.1177/1559827614537774

2. **Scott, J.J.,** Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R., (2015). Reliability and validity of a single-item physical activity measure for adolescents. *Journal of Paediatric Child Health*, 2015. **51**(8): p. 787-93.

3. **Scott, J. J.**, Morgan, P. J., Plotnikoff, R. C., Trost, S. G., & Lubans, D. R. (2013). Adolescent pedometer protocols: examining reactivity, tampering and participants' perceptions. *Journal of Sports Sciences*, *32*(2), 183-190

4. **Scott, J. J.,** Rowlands, A. V., Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R (2017). Comparability and feasibility of wrist- and hip-worn accelerometers in free-living adolescents, *Journal of Science and Medicine in Sport*, doi: 10.1016/j.jsams.2017.04.017

5. **Scott, J. J.**, Hansen, V. Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R (2017). Young Peoples' Perceptions of the Objective Physical Activity Monitoring Process: A Qualitative Exploration, *Health Education Journal,* doi: 10.1177/0017896917734576

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2. **Scott, J. J.**, Hansen, V. Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R (2015). Adolescents' Perceptions of the Objective Physical Activity Monitoring Process: A Qualitative Exploration, *International Congress of Diet and Physical Activity Measurement.* Brisbane, 1 - 3 Sept, 2015. Symposium presentation.

Statement of contribution of others

I attest that Research Higher Degree candidate Mr Joseph J Scott contributed to the publication for which I am a co-author. For all publications, where applicable, Joseph has:

- Contributed to the development of research questions
- Contributed to research design and methodology
- Contributed to the development and modification of data collection tools
- Contributed to study design
- Managed data collection procedures
- Cleaned the data
- Led all data analysis
- Led the writing of each manuscript

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Table of contents

List of tables

List of Figures

Thesis abstract

Background

The identification of appropriate and accurate tools for measuring physical activity is an international research priority. There is now a plethora of existing physical activity questionnaires that have been designed to assess activity patterns; few, however, are both valid and reliable. Existing questionnaires vary extensively in length and complexity with some requiring high level cognitive recall, rendering them unsuitable for some population groups. In particular, adolescents represent a problematic and complex sub-population in which to measure physical activity, due to incomplete or inaccurate reporting. There is thus a need for simplified and validated physical activity questionnaires designed specifically for use with adolescents.

Objective monitoring devices such as pedometers and accelerometers have acceptable feasibility, validity and reliability. In addition, as both motion sensors share similar technical and adherence issues. There is, however, a lack consensus regarding the optimal monitoring protocols. Poor adherence to objective monitoring protocols is a common reason why assessing activity patterns of adolescents remains complex. This may explain why adolescents are one of the least studied sub-population groups in physical activity research. As physical activity levels decline through adolescence, it is important that we improve our understanding of physical activity assessment in this target population.

Pedometers are now commonly used to measure physical activity in different age groups (that is, children, adolescents, adults and older adults); however, little is known about the influence of different pedometer protocols on the accuracy of physical activity measurement. Previous studies in children and adults have investigated reactivity and tampering with pedometer monitoring, however the research in the adolescent domain remains relatively sparse. Furthermore, no studies have explored adolescents’ perceptions of the pedometer monitoring process to gain insight into how and why they do not comply with monitoring protocols.

To date, accelerometers have predominantly been worn on the hip. However, in an attempt to increase participant compliance, researchers have more recently trialled the use of wrist-worn accelerometers in various populations. Currently, no studies have investigated the comparability and feasibility of hip- and wrist-worn accelerometers in adolescents. Given the importance of accurate physical activity measurement, there is a clear need for standardised physical activity monitoring protocols.

Aims

This thesis-by-publication presents a series of studies that were conducted to address the gap in the evidence base surrounding physical activity assessment in adolescents. The overarching aim of this thesis was to investigate current physical activity measurement protocols to assess physical activity levels in this sub-population. This thesis presents a series of studies that investigated six key study objectives, which are described briefly below. As these studies provide important context for the overall aim, the thesis is presented in the following order:

Study objective 1: assess the test–retest reliability of a single-item physical activity questionnaire for adolescents.

Study objective 2: determine the concurrent validity of a single-item physical activity measure for adolescents compared to accelerometry.

Considering the large number of existing physical activity measures available, the wide-ranging variability in their format; length and complexity and their limitations in accuracy, there is a need for more direct comparisons of questionnaires to improve our understanding of the most appropriate physical activity measures. The aim of this study was to investigate the test–retest reliability and validity of a single-item questionnaire in free-living adolescents (n = 123) by testing it against a more extensive existing physical activity questionnaire (The Oxford Physical Activity Questionnaire [OPAQ]) and accelerometer output. The single-item (intra-class correlation coefficient [ICC] = 0.75, 95% confidence interval [CI] = 0.64 - 0.83, $p < 0.001$) and the OPAQ (ICC = 0.79, 95% CI = 0.69 - 0.86, $p < 0.001$) were both found to have moderate-to-strong reliability. Correlations between self-reported and objectively-measured moderate-to-vigorous physical activity (MVPA) were similar for the single-item measure ($r = 0.44$, 95% CI = 0.24 - 0.63, $p < 0.001$) and the OPAQ ($r = 0.50$, 95% CI = 0.30 - 0.65, $p < 0.001$). The single-item questionnaire compared well to both the OPAQ and accelerometer derived activity counts. Study findings suggest the single-item measure can provide a reliable and valid assessment of adolescent physical activity. The single-item measure is easy to administer and may have utility for screening purposes and for use in population surveys.

Study objective 3: explore the impact of different pedometer monitoring protocols on compliance, reactivity and tampering in a sample of adolescents.

The aim of this study was to investigate adolescents' potential reactivity and tampering while wearing pedometers. In this study, adolescents were randomised to one of three pedometer monitoring protocols: (i) daily sealed pedometer group, (ii) unsealed pedometer group or (iii) weekly sealed pedometer group. Participants wore pedometers (Yamax Digi-Walker CW700, Yamax Corporation, Kumamoto City, Japan) and accelerometers (ActiGraph GT3X+, Pensacola, USA) simultaneously for seven days and completed a pedometry behaviour questionnaire. Repeated measures analysis of variance was used to examine potential reactivity. Bivariate correlations between step counts and accelerometer output were calculated to explore potential tampering. The correlation between accelerometer output and pedometer steps/day was strongest among participants in the weekly sealed group ($r = 0.82$, $p \leq 0.001$), compared with the unsealed ($r = 0.63$, $p \leq 0.001$) and daily sealed ($r = 0.16$, $p > 0.05$) groups. The daily sealed ($p \leq 0.001$) and unsealed ($p \leq 0.001$) groups, but not the weekly sealed ($p = 0.886$) group, showed evidence of reactivity. Responses from the questionnaire indicated that almost half the participants reported shaking their pedometers to increase their step count, 40% reported that they did not like wearing pedometers, 81% found wearing a pedometer uncomfortable, and 69% reported that they found wearing a pedometer 'embarrassing at times'. Contrary to previous research, the study findings suggest that the protocol selected for pedometer monitoring impacts behaviour and compliance. A seven-day monitoring protocol using sealed pedometers capable of storing at least seven days of step count data in their internal memory is recommended to limit reactivity and tampering in adolescents.

Study objective 4: explore adolescents' perceptions of wearing pedometers and investigate behaviours exhibited while wearing pedometers.

The aim of this study was to explore adolescents' perceptions of pedometer monitoring and investigate the physical activity behaviours exhibited whilst wearing the devices. Six focus groups (3 boys' groups and 3 girls' groups), each involving four participants, were completed. The focus group participants were selected from the larger group of students participating in the monitoring protocol study; that is, from the 123 participants who wore pedometers (Yamax CW700) and accelerometers (ActiGraph GT3X+) simultaneously for seven days. Students were then grouped based on their daily accelerometer-determined MVPA level: i) low active: < 30 minutes/day in MVPA, ii) medium active 30 - 60 minutes/day in MVPA and iii) high active ≥ 60 minutes/day in MVPA over their monitoring period).

Participants were questioned on the behaviours exhibited while they were wearing activity monitors and their perceptions of the monitoring process. A large proportion of the participants (approximately 60%) reported purposely changing their levels of physical activity during the monitoring process, and 21 of the 24 focus group participants reported shaking their pedometers to increase their step counts. More participants in the medium and high active groups reported changing their activity patterns than in the low active groups. The study findings suggest that the reasons for non-adherence to pedometer protocol were not related to sex or physical activity level. The high amount of reported reactivity indicates that pedometers are still a useful tool to promote physical activity in adolescents, but are less useful, however, when attempting to obtain habitual activity patterns.

Study objective 5: test the comparability and feasibility of the wrist- and hip-worn accelerometers in the free-living adolescent population.

Study objective 6: compare wear-time, missing data and participant perceptions regarding wrist- and hip-worn accelerometers.

The aim of this study was to determine the comparability and feasibility of wrist- and hip-worn accelerometers among free-living adolescents. In addition, the study focused on participants' perceptions of wrist- and hip-worn accelerometers to assist in determining the superior site placement for accelerometers when assessing adolescents in free-living conditions. The sample included 89 adolescents (age = 13 - 14 years) from eight secondary schools in New South Wales (NSW), Australia. Participants wore wrist-worn GENEActiv and hip-worn ActiGraph (GT3X+) accelerometers simultaneously for seven days and completed an accelerometry behaviour questionnaire. Bivariate correlations between the wrist- and hip-worn output were used to determine concurrent validity. Paired samples t-test were used to compare minutes per day in MVPA. Group means and paired sample t-tests were used to analyse participants' perceptions of the wrist- and hip-worn monitoring protocols to determine feasibility.

Wrist-worn accelerometers compared favourably with hip-worn in average activity (r = 0.88, $p < 0.001$) and MVPA (r = 0.84 $p < 0.001$, mean difference = 3.54 mins/day, SD = 12.37). The wrist-worn accelerometer had 50% fewer non-valid days (75 days, 12%) than the hip-worn accelerometer (n = 152, 24.4%). Participants reported they preferred to wear the device on the wrist ($p < 0.001$), and that it was less uncomfortable ($p = 0.023$) and less embarrassing to wear on the wrist ($p < 0.001$). Furthermore, they reported they would be more willing to wear the device on the wrist than on the hip ($p < 0.001$). Study findings revealed a strong linear relationship between wrist- and hip-worn accelerometer output among adolescents in free-living conditions. Compliance was significantly higher for wrist placement, with participants reporting that it was more comfortable and less embarrassing to wear and, importantly, they would be more willing to wear it again on the wrist than on the hip.

Summary

This thesis reviews the existing literature surrounding existing pedometer protocols among adolescents to investigate gaps in the research. The single item physical activity questionnaire designed specifically for adolescents compared well to an existing physical activity

questionnaire. As such, this measure may utility for determining whether or not adolescents are meeting physical activity guidelines. In addition, this thesis presents findings that support that reactivity and tampering are inherent risks to validity when assessing adolescents' physical activity with pedometers. Strategies to limit reactivity and tampering should be considered by researchers during studies when attempting to accurately assess adolescents' physical activity patterns. In an attempt to increase compliance with monitoring protocols in the adolescent population, it is recommended that future research utilise wrist-worn accelerometers. The original contribution of this thesis is the collection of data using both quantitative and qualitative methods to improve our understanding of adolescents' compliance to physical activity monitoring protocols. The evidence collected in this thesis may assist in the development of pedometer and accelerometer measurement protocols designed for adolescents.

Contribution statement

- This thesis includes five peer-reviewed journal publications.
- I was the sole PhD student for this study and was involved in all aspects of the study design, implementation, data collection and interpretation, reporting writing and manuscript preparation through to submission. A summary of the contributions that I made to this study is provided below:

Study design

- With the assistance of my supervisors, I was involved in study conception and design. This involved a number of joint decisions that would allow us to test various existing physical activity measures, including self-report measures, pedometer and accelerometer protocols.
- With the assistance of my supervisors, I led the completion of the ethics applications for both university and other educational (secondary school) institutions.
- With the assistance of my principal supervisor, I completed seed funding grant funding application.

Data collection and management

- In collaboration with my supervisors, I led the development of the measurement protocol resources, consent letters, physical activity questionnaire and focus group questions.
- I was personally responsible for recruiting the study principals, schools, and students.
- I ran workshops for the teachers involved in study 1 at the three different schools to assist with data collection. I then coordinated data collection timeframes with principals, head teachers and involved teachers.
- I was responsible for the distribution and collection of physical activity questionnaires, pedometers and accelerometers. I conducted the focus groups with students and handled recording and arranged transcription of data.

- I was responsible for the self-report questionnaire data entry. I also pre-set and initialised pedometers and accelerometers prior to monitoring, and, on completion of monitoring, downloaded, entered and cleaned all of the data.
- The data used in Chapter 6 was collected research assistants as part of the existing Switch-off 4 Healthy Minds (S4HM) cluster randomised controlled trial [1]. I designed the accelerometer monitoring protocol, trained the involved research assistants prior to data collection and developed the accelerometer behaviour questionnaire. I was responsible for the accelerometer data entry, cleaning, interpretation and analysis of the data so that it could later be reported.
- With the assistance of my supervisors, I completed the statistical analysis on four of the five papers presented in this thesis.

Reporting and presentation of results

- With the assistance of my supervisors, I was responsible for reporting the findings of the project and drafting manuscripts for submission to peer-reviewed journals.
- Throughout my candidature, I presented two peer-reviewed paper presentations at international conferences.

Operational definitions

Child: Individuals 5 - 12 years of age [2].

Youth: Individuals 12 - 24 years of age [3].

Adolescent: Individuals 10 - 19 years of age [4].

Adult: Individuals ≥ 18 years of age [5].

MET: Metabolic equivalent count is the ratio of a person's working metabolic rate relative to their resting metabolic rate. Metabolic equivalents are used to express activity intensity [6].

Physical activity: Any bodily movement produced by skeletal muscles that requires energy expenditure [5].

Moderate-to-vigorous physical activity (MVPA): Physical activity with a MET count of > three [7].

Pedometer: A small device, most commonly worn on the hip or the wrist, used to measure step counts [8].

Accelerometer: A small electromechanical device, commonly worn on the hip or the wrist, used to measure acceleration forces, which can be converted into activity estimates [8].

Reactivity: Defined as a change in normal activity pattern when participants are aware that they are being monitored [9].

Tampering: The term used for shaking a pedometer to inflate/increase an individual's step counts [10].

Thesis structure

This thesis presents a series of five papers, four of which are published, and one is under peer-review. The thesis structure is presented below.

Chapter 1: Introduction

The first chapter presents an overview of physical activity benefits, recommendations and trends. It also reviews the literature in relation to physical activity measurement and highlights current issues regarding the assessment of physical activity in adolescents.

Chapter 2: Using pedometers for measuring and increasing physical activity in children and adolescents: the next step

Chapter 2 examines the current pedometer protocols for children and adolescents within the literature and provides future recommendations for objective monitoring protocols. *(Overall aim)*

Previously published as:

Lubans, D. R., Plotnikoff, R. C., Miller, A., **Scott, J. J**., Thompson, D., & Tudor-Locke, C. (2014). Using pedometers for measuring and increasing physical activity in children and adolescents: the next step. *American Journal of Lifestyle Medicine*. doi: 10.1177/1559827614537774

Chapter 3: Reliability and validity of a single-item physical activity measure for adolescents
Chapter 3 reports the test-retest reliability and concurrent validity of a single-item measure designed for adolescents. *(Overall aim and study objectives 1 and 2)*

Previously published as:

Scott, J. J, Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R. (2015). Reliability and validity of a single item measure for adolescents. *Journal of Paediatrics and Child Health, 51*(8), 787-793. doi: 10.1111/jpc.12836

Chapter 4: Adolescent pedometer protocols: examining reactivity, tampering and participants' perceptions

Chapter 4 investigates the effect of pedometer protocols on level of reactivity and tampering in a sample of adolescents. *(Overall aim and study objectives 3 and 4)*

Previously published as:

Scott, J. J., Morgan, P. J., Plotnikoff, R. C., Trost, S. G., & Lubans, D. R. (2014). Adolescent pedometer protocols: examining reactivity, tampering and participants' perceptions. *Journal of Sports Sciences, 32*(2), 183-190. doi: 10.1080/02640414.2013.815361

Chapter 5: Young Peoples' perceptions of the objective physical activity monitoring process: a qualitative exploration

Chapter 5 uses focus group data to explore participants' perceptions of pedometers and reports reasons why adolescent may change their habitual activity pattern during objective monitoring. (*Overall aim and study objective 4)*

Previously published as:

Scott, J. J., Hansen, V. Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R (2017). Young Peoples' perceptions of the objective physical activity monitoring process: A qualitative exploration, *Health Education Journal*, doi: 10.1177/0017896917734576

Chapter 6: Comparability and feasibility of wrist- and hip-worn accelerometers in free-living adolescents

Chapter 6 examines the comparability and feasibility of the wrist- and hip-worn accelerometers in a free-living adolescent population. *(Overall aim and study objectives 5 and 6)*

Previously published as:

Scott, J. J., Rowlands, A. V., Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R (2016). Comparability and feasibility of wrist- and hip-worn accelerometers in free-living adolescents, *Journal of Science and Medicine in Sport*, doi: 10.1016/j.jsams.2017.04.017 (Article in press, accepted 16 April 2017.)

Chapter 7: Discussion and conclusion

Chapter 7 includes a synthesis of study findings, chapter highlights, strengths, weaknesses and recommendation for future research.

1 CHAPTER 1: INTRODUCTION

1.1 Background

The accurate assessment of physical activity is essential for a number of reasons including: i) determining population physical activity levels; ii) identifying mechanisms of physical activity behaviour change; iii) determining dose-response relationships between physical activity and health outcomes; iv) identifying individuals at risk of physical inactivity and v) evaluating the effectiveness of physical activity interventions [11].

Identification of appropriate and accurate assessment tools is therefore a key priority in physical activity research [12]. Although self-report measures have been commonly used in physical activity studies to date [13-15], over the last ten years there has been a proliferation in the use of objective monitoring devices such as pedometers and accelerometers [11, 14, 16, 17]. Due to the considerable variability in objective physical activity monitoring protocols, and in the treatment and analysis of data, however, it is difficult to compare findings across studies [16]. There is a clear need to improve our understanding of objective monitoring protocols by examining both existing technical problems (e.g., monitor selection, site placement, minimum number or required days and data reduction techniques) and issues related to participant behaviour (e.g., non-compliance with monitoring protocols and reactivity) while being measured.

The literature review in this chapter provides a summary of the following:

i) benefits of physical activity

ii) current physical activity recommendations and guidelines for youth

iii) physical activity prevalence and patterns among adolescents

iv) existing measurement protocols for adolescents

v) current issues surrounding physical activity measurement in adolescents, both technical and behavioural.

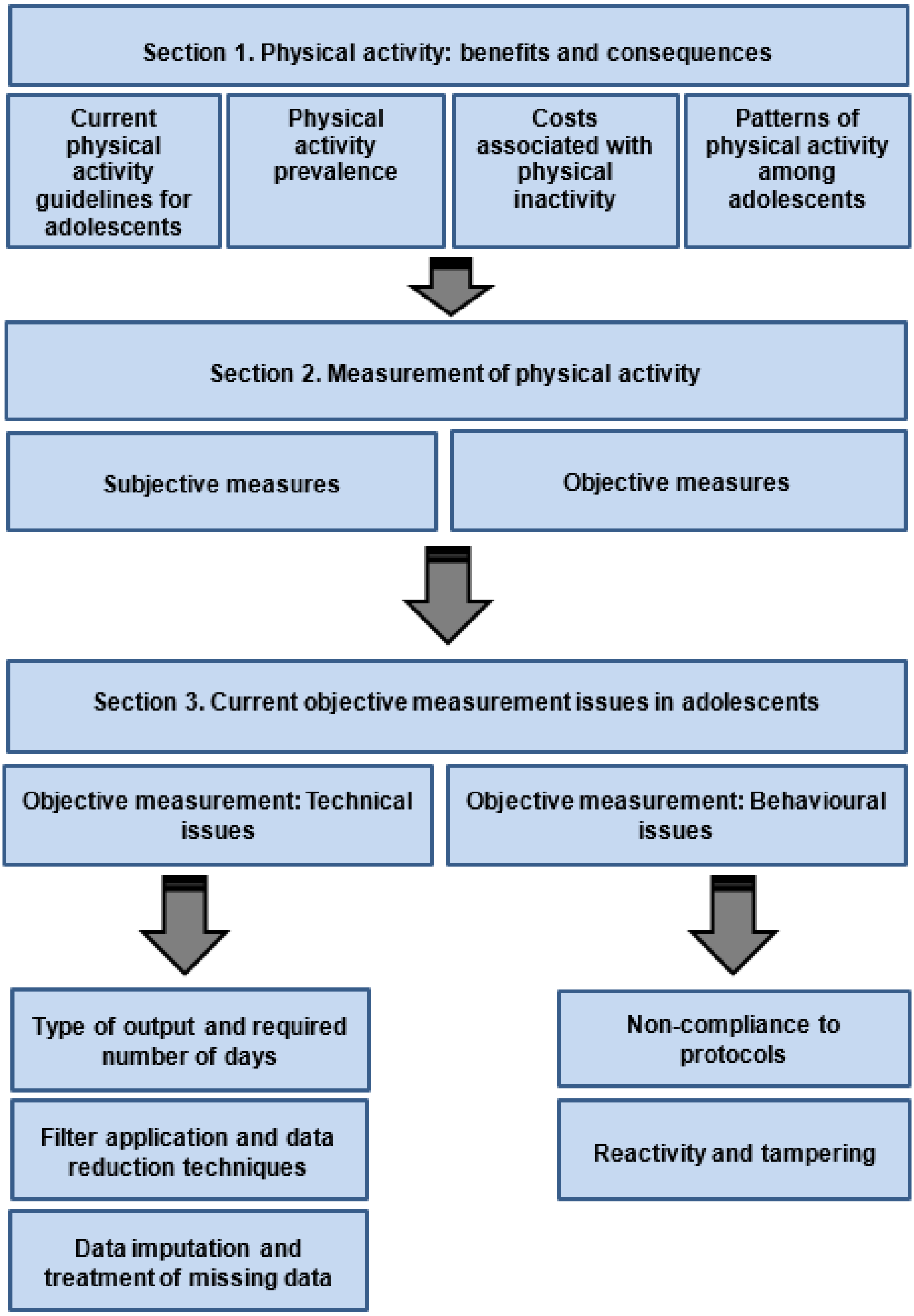

Figure 1.1. Schematic diagram of Chapter 1

1.2 Physical activity: benefits, recommendations and trends

Extensive research has clearly demonstrated the benefits of physical activity for health [5]. Compelling findings from a large number of studies have demonstrated the relationship between higher levels of physical activity and lower morbidity and mortality rates [18-20]. More specifically, it has been shown that regular physical activity can reduce the risk of cardiovascular disease, osteoporosis, diabetes and obesity, and promote psychological well-being [18]. A 2010, systematic review of 86 studies focusing on the health benefits of physical activity in children and adolescents concluded that increased physical activity is positively associated with better respiratory and cardiovascular health, musculoskeletal improvements and higher bone density, as well as reduced adiposity and improved mental health [21, 22]. In addition, a more recent review of the benefits of physical activity examined 15 longitudinal studies with at least a 5-year follow up and a total of 288,724 subjects (aged 18-85). The review concluded that there is a longitudinal relationship between higher levels of physical activity and lower incidence of non-communicable disease and health problems [23].

1.2.1 Current physical activity guidelines for adolescents

The World Health Organisation [24] outlined the following physical activity recommendations for young people:

- Children and youth aged 5 - 17 years should accumulate at least 60 minutes of moderate-to vigorous-intensity physical activity (MVPA) daily.
- Amounts of physical activity greater than 60 minutes provide additional health benefits.
- Most of the daily physical activity should be aerobic. Vigorous-intensity activities should be incorporated, including those that strengthen muscle and bone, at least three times per week.

Table 1.1 shows variations in the minimum international physical activity guidelines compared with World Health Organisation recommendations.

Table 1.1. International physical activity guidelines for young people (5 - 17 years)

Country	Quantity and Intensity		Type of Activity	
	Total PA	Vigorous PA	Aerobic PA	MBSPA
Australia [25]	≥ 60 mins/day MVPA (up to several hours)	Include daily	Include variety daily	≥ 3 days/week
USA [26]	≥ 60 mins/day MVPA	≥ 3 days/week	Most of total activity should be MVPA	≥ 3 days/week (as part of total MVPA)
Canada [27]	≥ 60 mins/day MVPA	≥ 3 days/week	-	≥ 3 days/week
UK [28]	≥ 60 mins/day MVPA (up to several hours)	≥ 3 days/week	-	Include as part of vigorous PA
WHO [24]	≥ 60 mins/day MVPA	≥ 3 days/week	Most of total activity should be MVPA	Include as part of vigorous PA

Abbreviations: MBSPA: Muscle and bone strengthening physical activity; MVPA: moderate-to-vigorous physical activity; PA: physical activity; UK: United Kingdom; USA: United States of America; WHO: World Health Organisation.

1.1.2. Physical activity prevalence

In 2009, physical inactivity was identified as the fourth leading risk factor for non-communicable diseases and was estimated to have caused more than three million preventable deaths globally [22]. Physical 'inactivity' is defined to be an activity level insufficient to meet current recommendations or guidelines [29]. In 2012, *The Lancet* published a series of papers that reviewed global inactivity, physical activity trends and evidence-based strategies to improve physical activity. The review concluded that physical activity was an important modifiable risk factor for chronic disease and highlighted the need for further global intervention [22, 30-33]. In 2016, The Lancet published a second series of papers, reporting the largest harmonised meta-analysis on the joint health effects of sedentary behaviour and physical activity. This series highlighted the need for policy change at both national and international levels to address the physical inactivity pandemic [34-37].

In 2012, the data collected from up to 122 countries revealed that, worldwide, 31.1% of adults are physically inactive [22]. This shows an increase in inactivity globally; prior research by the World Health Organisation in 2010 estimated that 23% of adults are inactive [19]. In Australia, an estimated 62% of adults fail to meet minimum physical activity guidelines [38]. Despite the health benefits associated with an active lifestyle, many children and adolescents also fail to meet the minimum physical activity guidelines [39]. The 2012 series of articles in *The Lancet* also provided data from 105 countries on adolescents aged 13-15 and concluded that 80.1% failed to meet the minimum international physical activity guidelines of 60 minutes of MVPA per day.

1.2.3 National and global costs associated with physical inactivity

The 2012 *Lancet* series on physical activity indicated that analysis of the global economic burden of inactivity was required to properly understand the pandemic of physical inactivity [33]. Consequently, the 2016 *Lancet* series completed an in-depth analysis of the burden of physical inactivity, and concluded that the estimated cost to health-care systems globally was

$53.8 billion in 2013. This consisted of $31.2 billion paid by the public sector, $12.9 billion paid by the private sector and $9.7 billion paid by households [37]. Moreover, decades of epidemiological research and recent health reports have illustrated the worldwide negative public health impact and global financial burden of physical inactivity [5, 18, 19, 37, 40]. The associated health-care system burden in Australia is exponentially growing from year to year, and was estimated at $1.5 billion in 2008 [41]. Both nationally and globally, these findings clearly highlight the need to prioritise resources to implement strategies that promote physical activity, to reduce the economic burden associated with physical inactivity.

1.2.4 Patterns of physical activity among adolescents

Existing cross-sectional and longitudinal studies have reported that physical activity steeply declines through adolescence [42-44]. For example, one recent longitudinal study using Norwegian adolescents (1,945 9-year-olds and 1,759 15-year-olds) reported that, from ages 9-15, both girls and boys reduced light physical activity, by an average of ≥ 106.7 min/day ($p < 0.001$), and MVPA, by ≥ 20.8 min/day ($p < 0.001$) [43]. These findings were supported by a further longitudinal descriptive analyses study that used 1032 subjects in the 1991-2007 National Institute of Child Health and Human Development Study of Early Child Care and Youth Development birth cohort found that between the ages of 9 and 15, weekday MVPA decreased by 38 minutes, and weekend day MVPA by 41minutes [45]. In addition, National longitudinal and cross-sectional studies have revealed that as few as 15 - 19.7% of Australian adolescents achieve the recommended amount of daily physical activity [46, 47]. A recent systematic review focusing on the impact of physical activity interventions in youth examined 10 studies and concluded that further research is required to clarify the relationship between interventions and long-term impact on physical activity level, self-efficacy and weight management [48]. Further research is warranted to determine if physical activity interventions can ameliorate the decline of activity typically observed during adolescence. Consequently, adolescents are now an important target population for physical activity interventions.

1.3 Measurement of physical activity

1.3.1 Assessing physical activity

There is a plethora of existing assessment instruments used to measure physical activity, and researchers are commonly faced with the issue of selecting the most appropriate measurement approach [49]. Measure appropriateness is dependent on purpose of study (e.g. intervention, clinical research, descriptive assessment/cohort studies or population surveys); sample size; age group(s); respondent burden; method/delivery mode; assessment timeframe; type of physical activity information required; data management; budget and other study limitations [50]. In addition, selection may be dependent on whether the researcher is attempting to obtain physiological response to activity (e.g. energy expenditure (EE)) or movement response to activity (e.g. mode, frequency, intensity) [51]. Physical activity measurement instruments are typically categorised into two sub-groups: ‘subjective’ and ‘objective’ [52].

Subjective measures include physical activity questionnaires, diaries, and log books. Questionnaires are typically used for large-scale population survey or studies as they have the ability to collect large amounts of data, are relatively inexpensive and are less burdensome for the participant than other measures [53]. Logbooks and diaries require participants to record their activity patterns over a period of time, typically one week [13, 15]. Objective measures include direct observation, heart rate monitors, pedometers and accelerometers [50]. The flowchart in Figure 1.2, which is modified from a review of physical activity measurement approaches [50], provides an overview of how physical activity measurement instruments are commonly categorised.

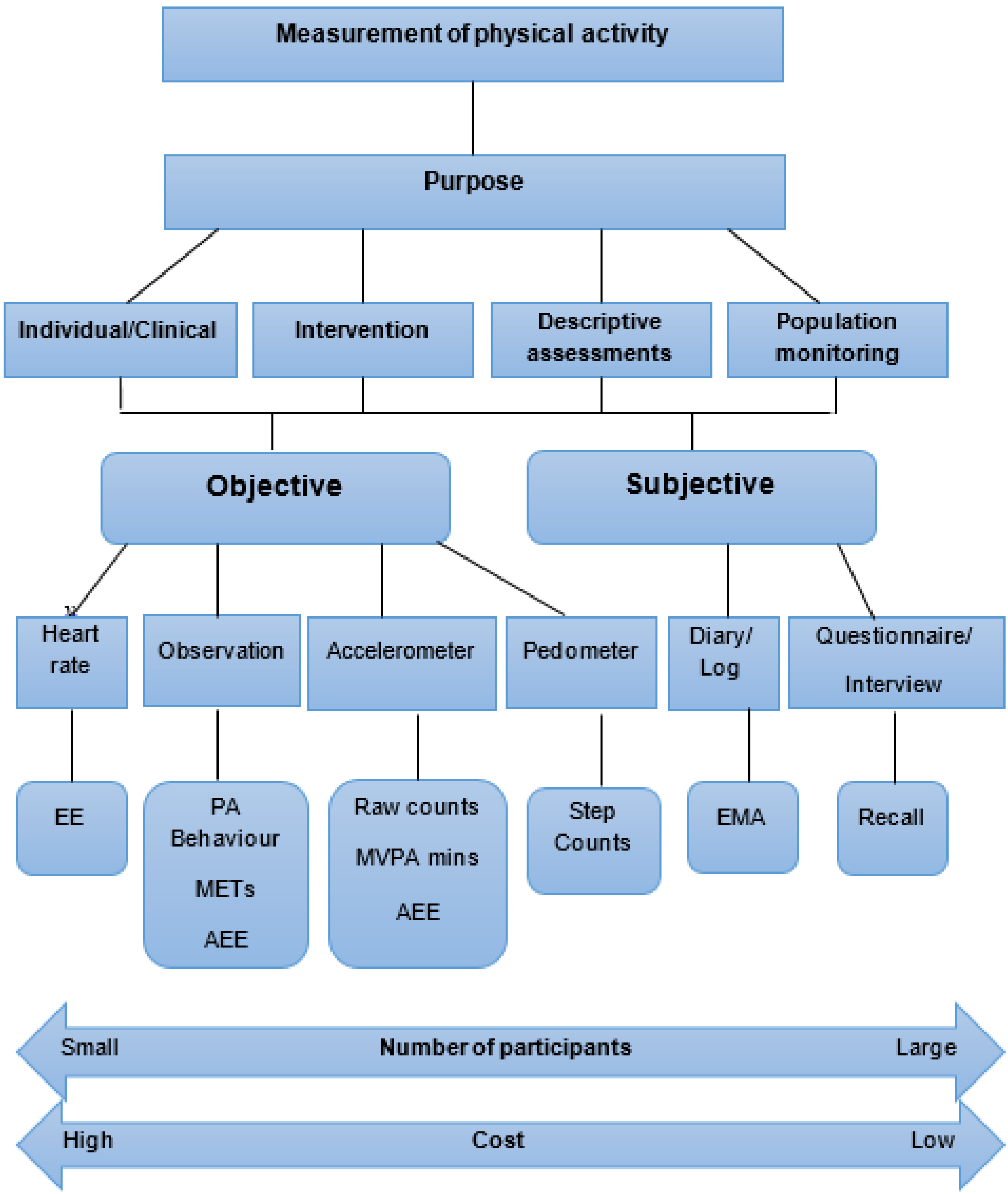

Figure 1.2 Categorisation of physical activity measurement

Abbreviations: HR: heart rate; EE: energy expenditure; AEE: activity energy expenditure; MVPA: moderate-to-vigorous-intensity physical activity; EMA: ecological momentary assessment.

1.3.2 Subjective measures of physical activity

1.3.3 Self-report measures

Physical activity self-report measures require participants to recall and report their participation in physical activity over a specified period of time. The aim of questionnaires in general is to obtain an estimate of an individual's frequency, duration and distribution of physical activity [14]. This information can be used to assess prevalence of population groups meeting physical activity guidelines; to make cross-sectional comparisons and to evaluate interventions [54]. As the most commonly used subjective method for physical activity assessment in adolescents is self-report questionnaires [15], this thesis only investigated this form of subjective measure. There are four categories of physical activity subjective measures generally used [55]:

i) Self-report (self-completed) questionnaires

ii) Diaries and logs (recording all activities)

iii) Interviewer administered (e.g., face-to-face, telephone and focus groups)

iv) Proxy reports of physical activity completed by parents, carers or teachers.

1.3.4 Strengths and limitations of self-report measures

Self-report measures are still used extensively as they are non-invasive and relatively easy to administer [12, 13]. Questionnaires are perhaps the most feasible method of assessing physical activity in large-scale epidemiological and surveillance studies as they are logistically easier, have low participant burdens and are relatively inexpensive [56-58].

Self-report data can be collected in a variety of ways. Diaries and logs are simple tools that allow participants to record their activity at regular intervals, thus reducing extended recall times and increasing the likelihood of accurate recall [59]. Individual and focus group interviews provide rich qualitative data in relation to the type, timing, frequency and intensity of physical activity, which allows researchers to gain a deeper understanding of habitual activity patterns [60, 61]. To collect data on younger children (usually < 10 years of age), parent/carer proxy reporting is commonly used in physical activity intervention studies and large-scale population studies [62, 63]. Due to their low cost, low participant burden and general acceptability, physical activity self-report measures have been, and continue to be, designed to gain insight into target population level and type of activity [64].

The major limitation of self-report measures is that they are characterised by respondent bias [65]. Recalling physical activity is a complex cognitive task, and children and adolescents are less likely to provide accurate recall than adults [15]. Prince and colleagues systematically reviewed 83 physical activity measurement studies, and found that 72% of children and youth significantly over reported their physical activity levels [64]. More active youth were more likely to ‘under report’ their physical activity level, whereas the least active youth were more likely to ‘over report’ [64]. A large study of 2,761 adolescents, which compared self-reporting measures to accelerometer-determined physical activity levels, found that 65.4% of participants over reported their time spent in MVPA by at least 5 minutes per day, 20% under reported their MVPA, and only 14.6% accurately reported their MVPA level [66]. It was reported that this was a result of skewed perception of time and intensity and issues inherent with recall [67].

In contrast to children and adolescents, the literature suggests that adults are more accurate in self-reporting their physical activity; perhaps due to their greater ability to think abstractly and perform more detailed recall [14]. Although not surprising, a further study that focused on young people found that adolescents were more accurate in recalling their physical activity than were children [66]. The literature is inconsistent regarding sex differences in misreporting in youth [66, 68]. One study indicated that adolescent boys over report activity levels more than adolescent girls [69], while another found the opposite to be true [70]. The research available suggests that race and age are not associated with over reporting in adolescents [64, 66].

Consistent with previous reviews [13, 71], a recent systematic review of 96 physical activity questionnaires designed for youth and adults reported that very few questionnaires demonstrated acceptable reliability and validity [14]. The modified version of the International Physical Activity Questionnaire designed specifically for adolescents (IPAQ-A) was designed to capture health-enhancing activity levels globally, and is still commonly used in this population. However, when validated against accelerometer output, the IPAQ-A was shown to have only acceptable validity in older adolescents aged 15–17 years, and poor validity in younger adolescents (< 14 years) [72].

The increasing interest in physical activity research has led to the development of a plethora of questionnaires designed to assess physical activity behaviours and patterns. Given the vast differences in the types of instruments available, comparing results across studies is difficult [73]. For this reason, it is challenging for researchers to identify the most appropriate instrument to address their study aims [13, 15]. A 2008, systematic review of 89 youth physical activity measures identified the Physical Activity Questionnaire for Adolescents (PAQ-A) [74], the Youth Risk Behaviour Surveillance Survey (YRBS) [75], and the Teen Health Survey [76] as the most suitable and useful tools for population surveillance, based on their validity and reliability [73]. The World Health Organisation also designed the Health Behaviours in School Children (HSBC) cross-national survey that was administered in 43 countries with 11-15year olds revealed the magnitudes of international differences in physical activity [77]. Some of the physical activity items in the HSBC survey were later adapted for use in the Australian Health Survey (2011-2013) [78].

A recent systematic review of adolescent physical activity self-report measures [15] concluded that the Oxford Physical Activity Questionnaire (OPAQ) was one of the most reliable instruments assessing adolescent physical activity (ICC = 0.89 for boys and 0.78 for girls) although it was considered to hold only acceptable validity [79]. The OPAQ is a time-based seven-day recall questionnaire for which participants are asked to report their time spent in MVPA [15]. This questionnaire was developed for adolescents, and respondents are required to report the last seven days of physical activity, including type, frequency and duration [79]., Further research is required to determine the strengths and limitations of the OPAQ in terms of its validity, however. Further research into the specificity of items and the effect this has on reliability and validity will inform future work in the field of valid and reliable physical activity measures.

To reduce participant burden, researchers have experimented with shorter and less detailed questionnaires [13]. It has been suggested that shorter questionnaires may result in fewer outliers, less participant fatigue, fewer inaccuracies and less missing data, particularly among adolescents who have shorter attention spans [80, 81]. A recent study evaluated the validity and reliability of a single-item measure of physical activity for adults, and concluded that it compared well with other existing physical activity questionnaires [12]. Currently, no such instrument exists for adolescents. As inaccuracies with self-reporting continue to be an inherent threat to the validity in adolescents, researchers have been encouraged to further refine self-report measures and validate questionnaires against objective measures, such as accelerometers [14, 15].

In summary, considering the large number of existing physical activity measures available, the wide-ranging variability in their format, length and complexity, and their limitations in accuracy [13, 15], there is a need for more direct comparisons of questionnaires to improve our understanding of the most appropriate physical activity measures. The in-depth detail of most existing physical activity questionnaires and high participant burden [14, 15] highlights the need for shorter, more simplified physical activity questionnaires tailored to adolescents. There appears to be no existing single-item physical activity measures designed specifically for use in free-living adolescents. Furthermore, no previous study has examined the validity and reliability of a single-item measure by comparing it with both an existing physical activity questionnaire and accelerometer output.

1.3.5 Objective measures of physical activity

This section discusses the strengths and limitations of the following objective measures: direct observation, pedometers and accelerometers. There is some interchange in the discussion of these pedometers and accelerometers devices as they are compared and contrasted below.

1.3.6 Direct observation

Systematic (direct) observation of physical activity is a data collection procedure that involves observing an individual (or group of individuals) using an instrument to code the activity, which may result in identification of the type of activity, the intensity of activity and the place it occurs [82]. Activities are coded on time-sampled intervals; normally between five seconds and one minute [65]. Researchers then collate the data to give a representation of activity patterns based on what has been observed.

1.3.6.1 Strengths and limitations of direct observation

Direct observation has typically been used to measure activity within a specific context (such as a school or park setting) [83]. It can provide contextually-rich data on the environment, such as where the activity is being completed; who the activity is completed with (social interaction); type of activity and so on [82]. This has become particularly important when exploring the environmental and psychosocial factors that influence physical activity levels. Direct observation has been considered an appropriate criterion measure for physical activity in adolescents [84]. The major strength of direct observation is it can provide a contextually rich and comprehensive assessment of an individual's physical activity. It is particularly useful when researchers are interested in the influence that setting (e.g., parks and schools) has on the individual or group level of activity The flexible nature of the direct observation procedures also allows researchers to collect data on other factors that might influence physical activity levels, such as environmental conditions, availability of equipment, access to facilities and family or peer involvement [65].

However, direct observation can be burdensome and expensive due to the time taken to train research staff, the length of observation time, and the time spent completing coding and data imputation. It may be less suitable, therefore, for studies that are concerned with assessing habitual physical activity in large samples [65, 85]. As direct observation involves actually witnessing the activity and also recording it, it is therefore less suitable for longer-term or daily or weekly data collection. Furthermore, direct observation is not suitable for assessing physical activity in ‘free-living’ participants unless they are in a confined space such as a school, gym facility or recreational area. Therefore, data collection timeframes are normally short and only provide a ‘snapshot’ of an individual activity pattern within a certain context [49].

In summary, direct observation has been considered a criterion measure for physical activity in youth [52]. Although somewhat limited in terms of its broader use, it remains an important tool to assist researchers to better understand the social and environmental factors that may influence adolescents’ physical activity levels. [49]. Greater understanding of these environmental and social factors will assist researchers in designing and implementing physical activity behaviour change interventions.

1.3.7 Pedometers

Pedometers provide an accurate and feasible method for measuring adolescents’ physical activity levels [15, 58, 86-88]. Studies have also shown that pedometer step counts are moderately associated with doubly labelled water, heart rate and VO_2, and strongly associated with accelerometer output [89-92]. There is now consensus that measurement of cumulative steps over the course of a 24-hour period is a suitable and effective measure of physical activity level in adolescents [65]. While pedometers can be worn on various parts of the body (upper arm, wrist, thigh, ankle etc.), they have are most commonly worn at the hip [93]. Pedometers do not measure acceleration, but work by detecting vertical motion. When there is a change in vertical motion, a horizontal arm bounces up and down inside the unit and records the step. More recently, piezoelectric pedometers have been developed. In these pedometers, the internal mechanism is a suspended beam and piezoelectric crystal that measure horizontal movement past the in-built threshold. The movement is displayed on a digital screen and stored into the device’s internal memory [94]. The step counts can then be recorded by the individual or by the researcher periodically during data collection, or once the data collection period has been completed, if the device has the ability to store data over a series of days.

1.3.7.1 Strengths and limitations of pedometers

Pedometers provide a valid, reliable [95, 96] and cost-effective way to collect physical activity in free-living youth [94, 97]. They are easy to use and normally do not require initialisation prior to use or downloading of data after use. They offer an easily-understood measure in a standard metric (most commonly steps/day) [96]. Some pedometers, such as the Yamax Digi-Walker CW700 (Yamax Corporation, Kumamoto City, Japan), possess the ability to store data over a seven-day period and therefore do not require daily resets. This is an important advantage when measuring youth as it removes the cognitive requirement for participants to self-report/log their step count, and reduces the chance of over/under estimating and risk of accidental resets.

While pedometers are commonly used as an objective way to assess habitual activity in young people, there are some limitations that should be noted. It has been reported that: i) wearing them can be considered invasive [98]; ii) they are insensitive to non-ambulatory movements and are normally not waterproof; hence they have to be removed for water activities [99]; iii) they are prone to data loss due to accidental resets, iv) they are subject to potential participant tampering (i.e., shaking) [58, 99]; v) they do not provide intensity or any contextual information of the activity completed [15, 93]; and vi) they normally require either the participant, teacher or parent to log the daily step count, which can lead to inaccuracies with reporting [88]. Finally, as the participant wearing the device may see the step count, there is the potential for them to increase their physical activity in response to the feedback provided by the pedometer [100].

In summary, many studies have now used pedometers to successfully collect physical activity in free-living adolescent populations [93, 101, 102]. Pedometers provide a widely and easily understood step count, which allows for simple analysis of data and comparison across studies [103]. There are, however, no standardised protocols for the use of pedometers in adolescent populations; in addition, there is limited research investigating how these protocols may influence participant behaviour while wearing the pedometers.

1.3.8 Accelerometers

Accelerometers are small devices most commonly worn at the hip and, more recently, at the wrist [104]. The monitor measures the magnitude or acceleration of movements, which can be categorised into different intensities using cut-points [49]. The majority of accelerometers use a piezoelectric sensor to detect accelerations on one to three planes (anteroposterior, mediolateral, and vertical). The accelerations are stored in the internal memory of the device and later downloaded to a computer software program for analysis [105].

Some of the accelerometers used in physical activity research such as the activPAL™ (Pal Technologies Ltd, Scotland, United Kingdom), ActiGraph GT3X+ (ActiGraph, Pensacola, United States of America (USA)) and StepWatch™ (Modus Health IIc Washington, USA) include an inclinometer feature. By assessing the tilt angle across two or more planes (forwards/backwards as well as sideways), the inclinometer provides output to estimate anatomical position in space (i.e., not wearing the monitor, lying supine, sitting, standing) [106, 107]. A recent study, using the inclinometer feature in the commonly used ActiGraph and StepWatch accelerometers, found that the inclinometer correctly identified anatomical position two thirds of the time during sedentary behaviour, and was even more accurate (71.8-85.1%) during light intensity activity; however, it was highlighted that the device had limitations when discriminating between different intensities [108]. While inclinometers have merit for assessing general behaviour pattern, their lack of sensitivity in identifying activity intensity is a noted weakness [108]. It has been hypothesised that multi-unit accelerometers that contain features such as inclinometers and physiological sensors may be the future of physical activity measurement [109]. These devices remain relatively under researched in free-living populations; thus, further research is warranted.

There is now an extensive range of commercial accelerometers designed for measuring physical activity (e.g., Fitbit® (Fitbit Inc, San Francisco, USA), Misfit© (Misfit, Burlingame, USA), Archos Activity Tracker® (Archos S.A, Igny, France), Vivofit® (Garmin Ltd, Schaffhausen, Switzerland), Jawbone® (Jawbone Co., San Francisco, USA). As each accelerometer brand varies slightly, comparability between accelerometer brands remains problematic and has introduced new challenges in interpretation of data [110]. A recent systematic review of consumer-wearable activity trackers analysed 22 studies and found that Fitbit monitors showed high inter-device reliability for steps, distance, energy expenditure and sleep. However, the authors concluded that further research is needed examining the measurement properties of each device as they are released into the market [17]. While many of the devices have novel features, research into comparability across brands is sparse [111]. In addition, there is limited research into the reliability and validity of the monitors [112], clearly highlighting the need for further research into consumer-wearable monitoring devices and their use in data collection for physical activity research.

1.3.8.1 Strengths and limitations of accelerometers

Reviews of physical activity assessment methods have concluded that accelerometers are an accurate, reliable and practical objective measure of physical activity among adolescents [49, 95, 113, 114]. Survey and intervention research has shown that they are currently one of the most effective ways to assess free-living adolescents' physical activity levels [115, 116]. The biggest advantage of accelerometers is that they can capture duration, timing and intensity of physical activity [15]. Consequently, we have seen an increase in the use of accelerometers in adolescent studies [114].

Accelerometers are suitable for well-funded large population studies, and provide an accurate way to collect objective measures of physical activity. They have been used for wide-scale surveillance studies (for example, National Health and Nutrition Examination Survey [NHANES] [115]), validation studies and adolescent physical activity interventions [50]. A further benefit is that they capture activity in 'real-time', allowing categorisation of activity over different periods of the day/monitoring period [50]. As adolescents remain a difficult population to measure, due to non-adherence to monitoring protocols (discussed in more detail in Section 1.5.7), the robust waterproof nature, large storage capacity and widely-recognised reliability of accelerometers make them appealing to researchers attempting to improve adherence levels and accurately quantify activity in adolescents [115].

Some recognised limitations of accelerometers have been noted in the literature. For example: i) they require pre-set initialisation/time stamping, application of filters and charging prior to use [117]; ii) they can be burdensome on the participant [61]; iii) they may be subject to reactivity [118] and iv) require downloading after use; and iv) the output can vary, requiring time-consuming complex cleaning and analysis of data [49, 65]. In addition, accelerometers are typically more expensive than heart-rate monitors and pedometers [50].

In summary, accelerometers are a valid and reliable way to objectively assess activity in adolescent populations [114]. However, the inconsistencies with treatment of missing data, application of cut-points, choice of output, highlight the need for standardised accelerometer protocols in adolescents [114, 119, 120].

1.4 Summary of physical activity assessment methods

Quantifying physical activity in adolescents is a challenging endeavour [65]. Surveys, logs and self-report questionnaires can provide units of time spent in activity (in minutes/hours), contextual information, estimated intensity level (sedentary, low, moderate, high), and activity type (which can be converted to a metabolic equivalent [MET] count). As they are subject to respondent bias, however, the accuracy in the use of self-report measures varies regardless of the output chosen [15]. The assessment of physiological markers (e.g., heart rate monitoring, doubly labelled water and direct calorimetry) offers a potential advantage over self-reporting measures in reducing bias, though it provides complex output and requires tedious analysis by trained researchers. Objective measures such as pedometers and accelerometers have emerged as a feasible and accurate way to assess physical activity in free-living adolescents [114].

The validity and reliability of various physical activity measures have been studied extensively; however, very little is known about adolescents' perceptions of the monitoring process and why compliance is consistently low in this population group [60]. Previous studies have reported that adolescents' views of the objective monitoring process are mixed (both positive and negative) and dependent on the design of the protocols and the incentives that are provided [60, 61, 100]. Further refinement of objective monitoring protocols and in-depth qualitative research is warranted to advance the field. This will lead to a better understanding of participants' perceptions of the monitoring process and assist with implementation of strategies to maximise retention and adherence to monitoring protocols. Table 1.2 shows the strengths and limitations for existing measures used in both child and adolescent physical activity research, some of which are discussed above (Section 1.3). The table illustrates the importance of selecting the right measurement tool for the study aims, budget, number and age of participants.

Table 1.2. Summary of key attributes for current methods used to measure physical activity in children and adolescents; adapted from Trost and colleagues [65].

Method	Valid	Affordability	Objective	Ease of administration	Ease to complete	Measures patterns of activity	Non-reactive	Feasibility in large studies	Suitable for age <10yrs	Suitable for age >10yrs
Questionnaires	✓	✓✓✓	✗	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✗	✓✓
Diaries/logs	✓	✓✓✓	✗	✓✓	✗	✓✓✓	✓	✓	✗	✓
Interviews	✓✓	✓	✗	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓	✓✓
Proxy reports	✓	✓✓✓	✗	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓
Observation	✓✓✓	✗	✓✓	✓	✓✓✓	✓✓	✓	✓	✓✓✓	✓✓
Pedometers	✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✗	✓	✓✓	✓✓✓	✓✓✓
Inclinometer	✓✓	✓✓	✓✓✓	✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
Accelerometers	✓✓	✓	✓✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓

✗ Poor or inappropriate; ✓ Acceptable; ✓✓ Good; ✓✓✓ Excellent
* Does not induce changes in physical activity behaviour as a result of being measured.

1.5 Specific objective physical activity measurement issues in adolescent populations

1.5.1 Introduction

This section focuses on the challenges researchers face with objective physical activity assessment in adolescent populations. As both pedometers and accelerometers are types of motions sensors they share some common issues related to adherence and analysis, there is some interchange in the following discussion. The current technical challenges for researchers include: i) device selection and comparability; ii) outputs application filters and cut-points; iii) data reduction techniques; and iv) treatment of missing data. Adolescents are a particularly difficult population to objectively measure [115], due to behavioural challenges such as non-compliance with monitoring protocols, reactivity to activity monitors and device tampering.

1.5.2 Objective measurement: technical issues

1.5.3 Selection of device and comparability

There is a wide array of existing movement detection instruments that provide varying types of output, making it difficult for researchers to select the most suitable instrument [94]. Over the past two decades, there has been a public health shift from ‘exercise to develop fitness’ to a focus on moderate intensity lifestyle physical activity intended to improve overall health [93]. This has led to the development of numerous studies focusing on intensities of activity and relationship to health outcomes.

A study that investigated interchangeability of pedometer brands found that there was good accuracy across brands with walking speed; however, as speed increased > 3.2kms/hour the degree of error also increased [121]. Further inconsistencies have been shown with distance travelled, as the estimates are dependent on participants’ stride length and frequency [122, 123]. As a result, researchers have recommended that pedometer output should be expressed as steps/day without further estimation of distance or energy expenditure, as the level of inconsistencies may be unacceptably high for comparative purposes [95]. Studies have shown strong correlations between step counts derived from pedometers and accelerometers [124].

Accelerometers quantify a further dimension of movement by capturing velocity in relation to time; that is, acceleration. In many studies, acceleration is expressed as an ‘activity count’, which is an arbitrary value and not normally comparable across brands [113]. Each brand of device has its own proprietary algorithm used to process, filter and scale the raw data [104]. This leads to further issues when attempting to translate various types of output into intensity levels, highlighting the need for consistent thresholds or cut-points [95]. The lack of equivalency of devices has resulted in low comparability of measurement approaches across studies. More recently, there has been the development of tri-axial accelerometers such as the ActiGraph GT3X+/GTX9 and GENEActiv. These have the ability to collect raw unfiltered accelerations, which can be subjected to data processing procedures to allow accurate comparison of output from different devices [110].

1.5.4 Use of epochs and cut-points

Accelerometers possess a time sampling mechanism that allow researchers to quantify the intensity, frequency and duration of activity [125]. This interval is normally termed an ‘epoch’, which summarises activity into a count that is stored, to maximise battery life. Although 60-second epochs are considered appropriate for adults [126], children and adolescents are involved in more sporadic bouts of physical activity, and shorter epoch lengths are recommended [127, 128]. Indeed, researchers have found young people’s activity is highly intermittent, with the majority of activity bouts lasting 3 - 22 seconds [129, 130]. The application of epoch length can therefore be important when attempting to accurately quantify intensity of daily physical activity levels and adherence to physical activity guidelines. One recent study containing 268 participants aged 7 - 11years, examined effect that epoch length (1-, 5-, 10-, 15-, 30- and 60-seconds) has on estimation of daily activity and concluded that the application of epoch length can substantially affect the estimation of daily activity and time spent in various intensities of activity [131].

A study using 534 youth aged 7-16 years, tested the effect of epoch length on physical activity intensity and recommended that a 30 - 60 second epoch be used when assessing adolescents activity [132]. In addition, a recent review of 183 studies reported that epochs ranged from 5 - 60 seconds in adolescents (63.2% of these studies used a 60 second epoch) [114]. Best practice recommendations for children, adolescents and adults are to use shorter time sampling intervals (epoch lengths) for example 10-, 15- or 30seconds rather than longer epochs to capture more sporadic movements [133]. In the last decade, calibration studies have attempted to find the most accurate way of converting accelerometer output (i.e., counts per epoch) into time spent in different physical activity intensities, by creating and applying cut-point thresholds [134]. There are now a range of age-specific cut-points that have been introduced for various monitors [134]. A recent systematic review, of existing cut-points specifically designed for youth, concluded that there are no widely agreed upon cut-points to classify MVPA in adolescents [134]. Further studies have shown that moderate-to-vigorous thresholds derived for young people range from 615 - 3200 counts/minute even with the same accelerometer model [135-138].

A review of 11 calibration studies concluded that there was no consensus on ‘the best’ cut-point to use in adolescents for MVPA, and recommended further research in the area [134]. Trost and colleagues evaluated five different ActiGraph cut-points, and recommended that the ‘Evenson cut-points’ should be applied when estimating sedentary, light, moderate and vigorous activity in children and adolescents [139]. However, a more recent review on accelerometer protocols highlighted the need for calibration studies to focus on a wider age-range and various epoch lengths and cut-points to determine a definitive protocol [114].

Due to the complexity of issues surrounding epoch length, activity ‘counts’, and cut-points, there has been an increase in the use of unfiltered raw acceleration to compare different monitor brands (i.e., for validation studies) [111]. This has negated the need for epochs and cut-points, although currently only a limited number of devices have the ability to capture unfiltered raw accelerations.

1.5.5 Treatment of missing data and data imputation

Poor adherence to objective monitoring protocols [10, 100, 115] results in large amounts of missing data, making it difficult to obtain an estimate of normal activity patterns [140]. It has been suggested that the minimum number of days required to gain a valid physical activity representation is dependent on population size and age of participants [87]. Ozdoba and colleagues found that, in children, four days of measurement was enough to get an ICC of 0.90 [58]. Further research on children found that three to four days was sufficient to obtain an ICC value of (0.70) and five days was sufficient for a value of (0.80) [119, 141]. Trost and colleagues concluded that seven days of monitoring is needed to provide a reliable estimate of usual physical activity in adolescents and account for the differences in weekday and weekend expenditure [119]. To have a single reliable timeframe for this age group would require continual large data sets containing multiple days of pedometer monitoring [87].

Procedures for managing missing data is another important issue to consider when assessing physical activity objectively [142]. Some research suggests that participants should be excluded from the analysis if there is an incomplete day of data collection; this is most commonly due to accidental resets [58] or extended periods of non–wear time [16]. As some pedometers are not waterproof, they are removed for showering and water activities such as swimming. Non-ambulatory activities such as cycling and swimming are not accurately recorded by pedometers and accelerometers, as there is little vertical movement at the hip [99]. Therefore, when completing non-ambulatory activities, participants must estimate their step count or time spent being physically active via self-report, which, as previously reported, can result in bias.

The relative contribution of ambulatory and non-ambulatory movement to adolescents' physical activity has not been tested extensively. The most basic way to estimate non-ambulatory movement (and convert into step counts) is called the Simple Conversion Method (SCM). With this approach, every minute of non-ambulatory movement is converted to 100 pedometer-based steps. The same research team developed the 'intermediate' and 'complex' conversion methods (ICM and CCM). More complex conversions are used as they can gain activity counts per minute, instead of a simple step count [143]. These approaches use more complex mathematical calculations and may not be suitable for all studies, as they require more expert researchers to complete the conversions.

Rowe and colleagues proposed that, to be considered a valid estimate of activity pattern, daily step counts must fall between 1,000 and 30,000/day; they suggested that values < 1,000 and > 30,000 are implausible and should be removed [144]. It is not yet clear whether this approach is appropriate [87], nor is there a set of common protocols to follow in the treatment of pedometer-based data. Physical activity studies show much variation in the way missing values and outliers are addressed, and the way data is transformed and analysed [88]. Standardised pedometer protocols and data reduction techniques are required to facilitate accurate physical activity data collection [16].

Recent accelerometer studies have also confirmed that non-adherence to accelerometer monitoring protocols is common in adolescent populations [115, 140]. In 2005, Ward and colleagues reviewed the existing accelerometers protocols and made future recommendations for researchers to address gaps in the literature. The researchers highlighted the need for consistent methodological approaches in monitor use protocols, analysis of accelerometer data, monitor selection and integration with other data sources [145]. A decade later, there remain several unresolved methodological issues, particularly regarding treatment of missing data [146].

To address the issue of non-adherence and missing data, researchers have proposed an analytical approach, whereby collected data (recorded while monitor was worn) is used to predict segments of data where the monitor was removed; known as ‘data imputation’ [147]. It has been proposed that the use of data imputation software provides more accurate and less biased assessments of activity patterns [147]. Reviews of the literature suggest, however, that most studies discard incomplete or invalid days from the analysis [146, 148]. Although there is growing recognition for the use of invalid days and data imputation methods to increase the accuracy of objectively assessing activity patterns, no standardised method exists for the adolescent population. Non-wear time is classified by pre-programming the accelerometer to detect that there is no movement (i.e., the accelerometer has been removed); this can be set in consecutive strings of zeros for an amount of time (e.g., 20 minutes, 30 minutes, 40 minutes, and so on).

Currently there is no standard recommendation for the classification of non-wear time for accelerometers [148] with existing studies in youth ranging from 10 - 180 minutes [114, 149-151]. In addition, there are no widespread recommendations for minimum wear-time per day, and days per week to collect a valid estimation of normal activity patterns. As a result of widespread low adherence to accelerometer protocols [140], more flexible inclusion criteria have emerged for adolescent populations. A recent review of accelerometer methods in youth found that the most commonly used wear-time inclusion criteria were a minimum of 8 - 10 hours of wear-time/day, worn on at least 3 - 4 days, with a non-wear time classification of 20 minutes non-wear [114].

1.5.6 Objective measures: behavioural issues

1.5.7 Reasons for non-compliance with protocols

Few studies have investigated why adherence to objective monitoring is so poor in adolescent populations [100]. A small number of qualitative studies have examined the complex issues that might influence adolescents' perceptions of the objective monitoring process [61, 100]. Kirby and colleagues used five focus groups to explore the views of young people aged 7 - 18 on objective monitoring [61]. The reasons for poor compliance reported included size and comfort, unwanted attention and increased risk of being bullied, and feelings of embarrassment. This differed from adults, who reported adult-specific issues such as occupational factors; for example, discomfort when driving [61, 152]. An additional study conducted with young people found that girls were more concerned about the look of the device than boys and recommended that compliance could be increased with use of a two-part reward (before and after monitoring) [60]. In order to understand this complex phenomenon and increase adolescent compliance with monitoring protocols, further qualitative research is warranted.

1.5.8 Device placement and compliance

Researchers have experimented with device placement in an attempt to improve compliance with objective monitoring protocols. Pedometers are most commonly worn on the hip [93], but have also been placed on the wrist and lower back. For example, Oliver and colleagues studied children in free play wearing pedometers on their backs, and concluded that pedometers worn on the back were less accurate than those worn at the left or right hip [11]. Researchers now acknowledge that waistband tilt due to torso body fat may also diminish the accuracy of pedometers [153]. One study revealed that the effect of pedometer tilt can be minimised by placing the device level laterally at the participant's hip, rather than on the anterior or posterior of the waist [154].

Similar to pedometers, accelerometers have been trialled in different placement sites on the body [155]. The ActiGraph accelerometer is the most common objective monitoring device used in the adolescent domain. The ActiGraph has traditionally been worn at the hip and secured firmly with an elastic waist belt; however, there is growing support for its comparative accuracy when worn on the wrist [115]. In addition, there has been the development of tri-axial accelerometers that can be worn on other parts of the body, such as the GENEActiv (ActivInsights, Cambridgeshire, UK). Studies in adults and children have shown higher accelerometer compliance when the monitor was worn on the wrist than when it was worn at the hip [156, 157]. It is not currently known whether accelerometer monitoring compliance can be improved in adolescent populations if monitors are worn on the wrist instead of at the hip.

1.5.9 Reactivity

Reactivity is a potential threat to the accurate assessment of physical activity, and can be defined as a change in normal activity pattern when participants are aware that they are being monitored [141]. Although many studies have explored participant reactivity to wearing pedometers, the findings have been mixed [11, 58, 86, 141, 158-160]. If reactivity exists, it is expected that participants will exhibit an increase in activity at the start of the monitoring period and then return to a more stable pattern once they become accustomed to wearing the devices

[86]. A common method for minimising reactivity is by ‘sealing’ the pedometer using ‘zip ties’ or ‘stickers’ [141, 160].

Some studies have proposed that sealing of pedometers can sufficiently reduce reactivity [141]. For this reason, researchers have investigated reactivity in children and adults with using sealed and unsealed pedometers in their studies [11, 141, 159, 161]. A study focusing on children concluded that, if the pedometers are sealed (thus ruling out feedback), reactivity does not occur [141]. Ozdoba and colleagues used sealed and unsealed pedometers on 45 children over a 14-day period and determined that reactivity was not present. In addition, they concluded that the sealing of pedometers also greatly reduced accidental resets, which is a common problem in pedometer studies [58].

The evidence for reactivity for pedometer monitoring in adults is mixed. Clemes and colleagues examined reactivity in adults. They concluded that the reactivity was greatest when unsealed pedometers were used [161], and also that reactivity may only last a few days [159]. A further study exploring reactivity with young adults found no evidence of change in daily activity, nor evidence of a feedback effect [86].

Most accelerometers used for research purposes do not provide real-time feedback to participants; therefore, there is less risk of reactivity. However, it has also been noted in the literature that reactivity may be caused by a participant reacting to the attention from the researchers and the excitement and novelty of being measured, which might influence their behaviour, regardless of whether or not they receive feedback from the device [118]. Behrens and Dinger studied reactivity to accelerometers in adults and found that it was not present [86]. A more recent study involving adolescents found evidence of reactivity, noting that it was more likely to occur on the first day of monitoring [118]. As the literature in this area is limited, further research into the extent of reactivity with accelerometers and the effect it has on validity is needed.

1.5.10 Tampering

Device tampering is an additional threat to the accuracy of physical activity assessment. It involves the participant purposely attempting to increase their activity counts by manually shaking the device and/or putting the device on someone or something else (e.g., pets, cars or machines) to increase activity counts [100]. Although tampering may occur with both accelerometers and pedometers, previous research has focused on tampering with pedometers.

One study that reviewed pedometer use in children and adolescents reported that, even if researchers implement safeguards (such as sealing), some participants will still shake their pedometers [162]. A later study examining adolescent adherence to a pedometer protocol found that 30 of the 43 participants self-reported tampering with their pedometers [100]. Surprisingly, no other studies have explored pedometer tampering among adolescents and the potential threat to validity.

As noted previously, adolescents are a difficult group to measure, due to their poor compliance with monitoring protocols [115]. Further understanding of their behaviours while being monitored and their perceptions of the monitoring process is needed to improve existing objective monitoring protocols.

1.6 Chapter summary

Large-scale physical activity research has demonstrated that many adolescents fail to meet the minimum recommended daily guidelines. This chapter highlighted the current behavioural and technical issues that researchers face when attempting to measure physical activity in adolescents. Furthermore, it reinforced the need for valid, accurate and reliable measurement protocols for adolescents. To date, no previous study has examined the validity and reliability of a single-item measure in adolescents by comparing it to both an existing physical activity questionnaire and accelerometer output. Currently there are no globally accepted protocols for the objective measurement of habitual activity in adolescents. This thesis addresses this gap in research by testing the existing research tools for collecting physical activity levels including self-report measures, pedometers and accelerometers.

1.7 Research aim and study objectives

1.7.1 Primary aim

The overall aim of this thesis was to investigate current physical activity measurement protocols to assess physical activity levels in adolescents.

1.7.2 Study objectives

The study objectives of this thesis were to:

1. Assess the test-retest reliability of a single-item physical activity questionnaire for adolescents;

2. Determine the concurrent validity of a single-item physical activity measure for adolescents, by testing it against accelerometer output;

3. Explore the impact of different pedometer monitoring protocols on compliance, reactivity and tampering in a sample of adolescents;

4. Explore adolescents' perceptions of wearing pedometers and investigate behaviours exhibited by participants while wearing pedometers;

5. Test the comparability of hip- and wrist-worn accelerometers in the free-living adolescent population; and

6. Compare wear-time, missing data and participant perceptions of hip- and wrist-worn accelerometers in the adolescent domain.

CHAPTER 2: USING PEDOMETERS FOR MEASURING AND INCREASING PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS: THE NEXT STEP

Preface: This chapter presents an overview of the current pedometer protocols for measuring physical activity in children and adolescents. The objective of this review was to evaluate the current evidence and identify future research directions.

Citation:

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2 Using pedometers for measuring and increasing physical activity in children and adolescents: the next step

2.1 Abstract

The science and practice of step counting in children (typically 6 to 11 years) and adolescents (typically 12 to 19 years) has evolved rapidly over a relatively brief period of time with the commercial availability of research-grade pedometers and accelerometers. Recent reviews have summarized considerations for assessing physical activity using pedometers in young people (both children and adolescents), but three areas have received little attention: pedometer monitoring protocols, minimal (as opposed to optimal) step counts necessary for maintaining basal levels of health, and appropriate pedometer-based interventions for young people. Therefore, the objective of this review was to evaluate the current evidence and identify future research directions in these areas. The challenges of objective monitoring of physical activity in children and adolescents reinforce the importance of using protocols that minimize participant burden and the potential for tampering/reactivity. Evidence for a sedentary lifestyle cut-point is limited, researchers are therefore encouraged to investigate several cut-points (i.e., < 5000, < 6000, < 7000 steps/day) in children and adolescents to identify the health consequences of very low levels of ambulatory activity. Personalized messages may be necessary for health behaviour change in pedometer-based interventions, but there is a need for more high-quality studies.

2.2 Introduction

The science and practice of step counting in children (typically 6 to 11 years) and adolescents (typically 12 to 19 years) has evolved rapidly over a relatively brief period of time with the ever-increasing commercial availability of research-grade pedometers and accelerometers. Unlike accelerometers, which are more expensive and generally require specialized software to interpret data, pedometers provide a cost-effective and feasible approach for measuring ambulatory physical activity in young people (both children and adolescents) [102]. In 1997, Rowlands, Eston, and Ingledew [163] wrote a seminal article presenting the potential for using pedometry to study children's free-living physical activity and subsequently followed up with the first publication of expected values for steps/day in 8 to 10 year old children [164].

Today, a simple PubMed search (3rd December 2013) using the keywords "children" and "pedomet*" yields over 300 articles. Among these include two methods-based papers, [88, 98] a systematic review of pedometer-based intervention in young people (i.e., children and adolescents), [93] and a review article [102] compiling expected values for children's and adolescents' steps/day on weekdays vs. weekend days, and steps accumulated during school, recess, physical education (PE) classes, and after school. An international effort has produced a researchers' consensus statement addressing the question of "how many steps/day are enough?" in terms of children's and adolescents' health [165]. Steps/day are also now routinely collected as an outcome of interest in large accelerometer-based studies, [166] and recently the protocol of accelerometer-determined peak cadence (steps/min) indicators (a measure of the best daily effort) has been applied to children and adolescent data [167].

Recent reviews have summarized considerations for assessing physical activity using pedometers in children and adolescents [10, 88, 98]. These reviews have provided recommendations regarding pedometer monitoring periods, wear time, data treatment, reporting and choice of pedometer. However, there are a number of issues relating to pedometer use in young people that have received little attention. First, systematic research comparing the quality of data obtained from different protocols is sparse [8, 10]. Specifically, few studies have explored the factors contributing to reactivity and tampering, especially in adolescent populations. Second, although Tudor-Locke and colleagues have provided evidence for a sedentary lifestyle index for adults (i.e., < 5,000 steps/day), [168] researchers have failed to yet identify an equivalent value for children and adolescents. Physical inactivity has serious health consequences for young people, [21, 169] but is there a minimum number of steps necessary to prevent ill-health in young people. Finally, pedometers and step counting devices have been used extensively in interventions to promote physical activity in adults [170, 171], but less is known regarding the utility of pedometers for increasing physical activity in young people. As technology evolves and proliferates, so does the potential for using pedometers in behaviour change interventions, raising the question, “How can pedometer-based interventions be implemented to optimally increase young people’s physical activity?”

Therefore, the aims of this narrative review are threefold: 1) to discuss pedometer monitoring protocols for young people and explore issues of reactivity and tampering: 2) to evaluate the evidence for establishing a step-defined sedentary lifestyle index, perhaps separately for children and adolescents: and, 3). to present pedometer-based interventions undertaken to date for young people and identify research directions focused on optimizing their positive effects on physical activity in children and adolescents.

2.3 Pedometer Monitoring Protocols

Although there has been a proliferation of studies using pedometers to measure physical activity in children and adolescents [10, 88, 98, 144], little research has focused on comparing different monitoring protocols (in terms of maximizing best quality data) and young people’s reactions to the assessment process. Reactivity (i.e., a change in normal activity pattern as a result of being monitored) is considered an inherent threat to the accuracy of pedometer data collection [172]. Although some studies have revealed little evidence of reactivity in children and adolescents [11, 52, 58, 144], others have shown reactivity is present in young people [100, 172]. Sealing pedometers (e.g., using cable ties or adhesive stickers/tape) limits access to feedback and the potential for peer competitiveness [10, 100]. Monitoring for extended periods of time may also diminish reactive behaviour attributed to device novelty [58, 141, 172], but the increased burden on participants may lead to lower levels of compliance. Daily un-sealing/sealing of pedometers by study staff recording data in schools can be an administrative burden for teachers in large-scale studies [144]. Pedometers that have on-board memory functions and thus the ability to record for multiple days are useful for addressing this logistical inconvenience, reducing the effect of visual feedback to the wearer, and eliminating any need for participants to record their own data. Such pedometers may also address the challenges of collecting step counts on weekend days when children are not as easily trackable as when they are gathered together on school days [173] .

Pedometer tampering ('shaking' or 'rattling' the pedometer to increase step count) may result in further inaccuracies in pedometer data collection [95, 100, 144, 174], however, there is little systematic research to illuminate the magnitude of this potential threat to validity. Almost half of 123 adolescents reported tampering with their pedometer in a recent study [172]. Similarly, 69% of 43 children admitted to shaking the device in another study [100]. Frequency of reported tampering alone does not quantify the potential magnitude of the threat. A few shaken steps produced as a result of a curious child's interest in a pedometer's mechanism may be a trivial issue relative to a day's worth of actual ambulatory steps. Characteristics of individuals given to tampering/reactivity are unknown. At odds with concerns for reactivity of measurement (which would theoretically produce inflated estimates) is the more pressing concern that children and adolescents actually accumulate fewer steps/day than expected, considering their age. Nevertheless, further study of pedometer tampering in child and adolescent populations is needed and strategies to understand, quantify and ultimately reduce/eliminate or tolerate/accommodate such behaviours to improve interpretation of pedometer monitoring studies.

Pedometers provide a feasible (e.g., practical, cost-effective etc.) way to collect objective physical activity data from large groups, but strategies to overcome potential reactivity and tampering, or at least interpret data cognizant of this possibility, require consideration. Further testing of pedometer monitoring protocols and innovative experiments, such as covert monitoring (when participants are unaware that their activity levels are being monitored) [98], may be necessary to identify the optimal measurement protocols for assessing physical activity in young people.

2.4 A Step-Defined Sedentary Lifestyle Index for Children and Adolescents

Lower levels of self-reported and accelerometer-determined physical activity have been associated with increased risk of detrimental health outcomes in children and adolescents, including higher cholesterol and blood lipid profiles [175], higher blood pressure [176], increased incidence of metabolic syndrome [175, 177], and increased incidence of obesity [178, 179]. Of the direct associations between low step/day and health outcomes in children and adolescents, less desirable body composition [180-182] and lower fitness levels [183-185] have been reported. In addition, Barreira and colleagues recently demonstrated that children and adolescents with higher peak cadence (i.e., steps/minute) had fewer cardiovascular disease risk factors [167]. Despite this emerging evidence, the question of “How many steps/day are too few for young people?” has not been answered.

Recently, Tudor-Locke et al [168] proposed a step-defined sedentary index of < 5000 steps/day in adults, that includes consideration of population distribution, socio-demographic characteristics, contextual factors, health risks associated with taking < 5000 steps/day, and the health effects associated with increasing steps/day above 5000. Low step counts may indicate that an individual has spent more time engaged in sedentary behaviour [i.e., described as activities that involve minimal energy expenditure (1 to 1.5 metabolic equivalent multiples of rest), typically performed while sitting or lying down] [186]. Tudor-Locke and colleagues [168] have argued that estimating time spent in sedentary behaviour from lack of steps is consistent with the approach of using low accelerometer counts (e.g., < 100 counts per minute) [187]. Using data from cross-sectional [187] and experimental studies [188], Tudor-Locke et al [168] provide evidence to support the use of low step counts to indicate a sedentary lifestyle (i.e., one characterized with by more sedentary behaviour and less ambulatory behaviour) in adults.

As yet, there is limited evidence to support the creation of a sedentary lifestyle index for children and adolescents. Population distribution data among Canadian young people [189] indicate the lowest 15th percentile performing < 8448 and < 7761 step/day in boys and girls, respectively (5 to 13 years). Utilizing the 15th percentile cut-point in US data [166] highlights the population specific nature of distribution data, with < 6040 and < 4855 steps/day in boys and girls, respectively. Whilst this normative information is valuable, it does not provide evidence of the health-related consequences of low step counts for children and adolescents.

To date, BMI referenced cut-points for normal weight and overweight/obese children have been used as a health-related index for steps/day. Using children's step count data from the US, Australia and Sweden, Tudor-Locke et al [182] identified step counts of 12000 for girls and 15000 for boys as criterion-referenced cut-points. These analyses get at "how many steps/day are enough?" and interpreted dichotomously (yes/no), suggest that those not achieving these cut points are not achieving "enough". A proposed graduated index [190] based loosely on these BMI determined cut-points (the posited values serve as anchors), includes multiple levels, including a sedentary lifestyle index for boys and girls of < 7000 steps/day. Using a recent suggestion of a non-sex-specific step-defined sedentary index for young people of < 7000 steps/day [168], approximately one-quarter of Canadian boys and one-third of girls accumulated < 7000 steps/day (5 to 19 years) [191].

Importantly, the question of "How many steps per day are enough?" is not the same as "How many steps per day are too few?" The former focuses on an optimal level and the latter on a minimal level to be interpreted as a "red flag" for intervention purposes. To clarify further, a sedentary lifestyle index for young people may enable the identification of individuals at the greatest risk of serious health consequences due to low ambulatory lifestyle behaviours. While the existing evidence base is limited, researchers are encouraged to investigate several cut-points (i.e., < 5000, < 6000, < 7000 steps/day) to identify the health consequences of falling below this threshold for children and adolescents.

2.5 Using Pedometers to Increase Physical Activity in Young People

Behavioural interventions incorporating pedometers have been used to increase physical activity in child, adolescent and adult populations [93, 170, 192]. The principle underlying the use of pedometers to increase physical activity is that the 'real time' step count feedback increases an individual's awareness of how their personal behavioural choices influences their physical activity [93]. Pedometer-based programs provide individuals with up-to-the-minute information and encourage them to self-monitor and set step goals using tailored (i.e., based on specified baseline values), standardized (e.g., percentage-based increments) or pre-determined (e.g., an increase of 2,000 steps/day each month) step targets [183, 193-195]. A range of new and innovative ways to use pedometers and deliver pedometer-based interventions is emerging in the literature.

A previous systematic review of pedometer-based interventions targeting children and adolescents identified three major pedometer-based strategies for increasing physical activity [93]: (i) self-monitoring and goal setting interventions based on personalized or standardized step targets [183, 193-195], (ii) open-loop feedback interventions which involve making access to desirable sedentary activities such as television watching contingent on achieving step targets [196, 197] and, (iii) physical activity integration interventions that involve using pedometers as educational tools to increase physical activity throughout the school day [11]. All three strategies were found to contribute to increased physical activity, but due to the small number of studies, the high risk of bias and lack of low term follow-up in published studies at that time, the authors of the review were unable to provide optimal guidelines for pedometer-based interventions for young people [93].

One of the limitations identified in the review was the lack of theory in guiding the development of pedometer-based interventions for young people. In adults, theory-based interventions appear to be more effective in changing behaviour than atheoretical approaches [198, 199] and are hypothesized to impact upon relevant cognitions, which in turn influence behaviour [200]. Despite evidence for the importance of theory, few pedometer-based interventions for young people have aligned their behaviour change strategies with a health behaviour theory. Notable exceptions were the Learning to Enjoy Activity with Friends [183, 201] and Program X [193, 202] interventions, which were guided by social cognitive theory (SCT) and designed to target hypothesized mediators of behaviour change (e.g., self-efficacy, outcome expectations, social support) [201]. While Zizzi and colleagues [203] did not explicitly cite their theoretical framework, their intervention appeared to be guided by SCT and they measured potential mediators from SCT. However, none of the three interventions [183, 193, 203] found evidence for the mediating effect of any measured SCT variables on changes in steps/day. The failure to identify the mechanisms of behaviour change is likely due to the poor measurement of theoretical mediators. Recent reviews examining the effects of physical activity interventions on mediating variables have noted the lack of significant findings and the challenges of accurately measuring constructs in young people [204-206].

Pedometer-based interventions designed to increase obese adolescents' steps/day have involved cognitive behavioural therapy [207] and coping skills training [208], also based on SCT. Similar to other pedometer-based interventions targeting healthy weight adolescents, participants in these studies [207, 208], were provided with pedometers and log books and encouraged to self-monitor their step counts. Participants were also encouraged to identify barriers to physical activity and formulate strategies to increase their steps and maintain positive health behaviour change. These studies however did not provide detailed descriptions of the self-monitoring procedures and therefore it is difficult to evaluate the strategies and recommendations. Goldfield and colleagues [209] employed an alternate approach to promote physical activity in obese children and demonstrated that making access to desirable sedentary activities (e.g., TV watching) contingent on physical activity can increase step counts [196, 210]. While this approach appears to have some utility, there is concern that treating sedentary activities as rewards may undermine children's autonomous motivation for physical activity and project an unhealthy message about the perceived value of sedentary behaviours.

One possible explanation for the failure of existing health behaviour models to adequately explain physical activity behaviour change in pedometer-based interventions for young people is that such models were originally designed for 'at-risk' adult populations. Motivation for physical activity changes over the lifespan [211], and while adults may engage in physical activity to reduce their risk of lifestyle diseases, such outcomes are unlikely to be important to young people. Furthermore, theoretical models that fail to address the social, cognitive and biological changes that occur during the transition from childhood to adolescence [212], are unlikely to provide a better foundation for behaviour change [213]. The importance of integrating health behaviour theories [214] and adopting socio-ecological models [215] has been noted in the literature, yet such frameworks have not been adopted in pedometer-based interventions for children and adolescents. Health behaviour models such as the Youth Physical Activity Promotion Model [216] and Competence Motivation Theory [217] may have utility for guiding pedometer-based interventions for young people, but they are yet to be tested in experimental studies.

Technological advancements and in particular, the proliferation of social media, exergaming, and smartphone technologies have provided researchers and health professionals with exciting opportunities to combine pedometers with eHealth technology (e.g., internet and smartphone applications) to promote physical activity in young people. Such approaches are appealing as public health initiatives due to their potential for cost effectiveness and their considerable reach [218]. Young people’s access to technology is increasing at a rapid rate and in developing nations there appears to be little evidence of a ‘digital divide’. For example, smartphone ownership among young people has accelerated rapidly in recent years [219] and does not appear to be moderated by socio-economic status [220], creating an ideal opportunity for equitable health promotion. Although smartphones have in-built accelerometers with step counting features and global positioning systems, their size and design may prevent them from being worn during certain types of physical activity (e.g., games and sports). Furthermore, the validity and reliability of such features are only starting to emerge in the literature [221] and due to the broad range of technologies and brands available, it will be difficult to standardize results across studies.

One of the first studies to incorporate eHealth technology into a pedometer-based intervention for adolescents was Program X [193, 202]. Participants in the Program X intervention attended interactive seminars on goal setting and self-monitoring and were provided with pedometers and sent personalized email messages encouraging them to achieve their step count goals derived from baseline step counts [193]. The intervention resulted in a significant increase in step counts for boys (approx. 1000 steps/day) and girls (approx. 2000 steps/day), but the strategy for generating personalized feedback was labour intensive for the research team and not feasible for large population groups. In contrast, the Nutrition and Enjoyable Activity for Teen Girls (NEAT Girls) intervention [222, 223], used bulk SMS messaging to reinforce health behaviour change. Participants in the NEAT Girls intervention were provided with pedometers and sent weekly generic SMS messages during the intervention period. However, there was no intervention effect on accelerometer-determined physical activity at the 12-month post-test [224]. Bulk SMS messaging was considered to have good reach, as messages were sent to 91% of girls, but the SMS messages were not rated highly by all participants, some of whom described the messaging as ‘intrusive’.

It appears that pedometer-based interventions incorporating eHealth technologies may require a tailored component to engage adolescents. The multi-component Active Teen Leaders Avoiding Screen-time (ATLAS) program, included a purposely built smartphone application (app) to promote physical activity and reduce sedentary behaviour in adolescent boys [225]. A unique aspect of the ATLAS app was that it included tailored physical activity messages, based on information reported by participants and once the app was downloaded, participants received biweekly messages sent via ‘push notifications’ through the app. Although research findings are yet to be published, feasibility data suggests that the app was rated highly by participants and may have utility for physical activity promotion in young people. Similarly, Thompson and colleagues [226] recently evaluated a 12-week pedometer-based intervention guided by Self-Determination Theory (SDT) for adolescents. Participants were not given a daily step goal; rather, consistent with SDT, they were told daily step goals that experts recommend for teenagers [182], along with their personal average step counts (extracted from 7 days of accelerometry at baseline). Preliminary evidence suggests modest increases in moderate-to-vigorous physical activity (MVPA) occurred in the expected directions.

Although the number and quality of pedometer-based interventions designed to increase physical activity in young people are increasing at a rapid rate, there are barriers to their successful implementation, evaluation and interpretation. First, there is little evidence to suggest that behavioural changes resulting from pedometer-based interventions are sustainable. It is possible that participants become fatigued with wearing their pedometers and regress to their pre-intervention physical activity levels. The majority of studies have been evaluated over short periods of time (i.e., < 6 months) and longer term studies are clearly needed. Second, pedometer-based interventions incorporating eHealth technologies must manage the congestion and competition from other commercial and social medial efforts competing for space using the same media. This may contribute to information overload, thus reducing the efficacy of such approaches for behaviour change in young people. Finally, as new measurement devices emerge (e.g., Fitbit® and Jawbone® monitors) that can synchronize with a user's smartphone and provide instant feedback regarding step counts, estimated energy expenditure and time spent in physical activity of various intensities, the basic pedometer may become obsolete. However, it is unlikely that pedometers will disappear any time soon. Pedometer-based interventions remain a feasible and effective strategy for increasing physical activity in people of all ages, in part due to their accessibility (i.e., pedometers can be cost-effectively distributed to a large group) and easy-to-interpret feedback. There is clearly a need for research comparing the effects and cost effectiveness of more simplistic pedometer-based interventions to those using new measurement devices (e.g., Fitbit® and Jawbone® monitors), both supported by similar eHealth methods.

2.6 Using Pedometers in Schools to Promote Physical Activity in Young People

Schools provide an ideal setting for physical activity promotion among children and adolescents as they have access to most of the population and have the necessary facilities, equipment and personnel to achieve this outcome [227]. Physical education (PE), school sport, physical activity integration into key learning areas (e.g., mathematics and science), active transportation, after school and break times represent opportunities for physical activity promotion in and around the school setting. Using pedometers to promote and monitor activity levels in primary and secondary schools is appealing because these devices offer an affordable and accessible technology that provides output in a simplistic format that is easy to understand (i.e., steps/day) [171].

PE is commonly recognized as the major vehicle for the physical activity promotion in young people and lessons that involve high levels of MVPA can make an important contribution to young people's overall physical activity levels and their health [228, 229]. Existing US guidelines suggest that students should be engaged in MVPA for 50% of PE lesson time [40]. Scruggs has demonstrated that pedometer steps/min intervals of 82 - 88 for Yamax SW651 and SW701 pedometers [230] and 76 - 80 for Walk4Life W4L LS2505 and DUO pedometers [231] are equivalent to the 50% MVPA recommendation for PE in middle schools. These step rates can be used by teachers to evaluate their PE lessons, by asking students to wear pedometers during class and then dividing students' total step counts for the lesson by the duration of the lesson. There are also commercial pedometers available that can track time above selected steps/min cut points, automating this practice if desired.

Integrating movement into key learning areas, such as mathematics, geography and science represents another opportunity for physical activity promotion in the school setting. In one of the earliest studies of its kind, Oliver and colleagues [11] evaluated the feasibility of implementing an intervention that used pedometry to integrate physical activity (subjects included English, social studies, mathematics, statistics and PE) throughout an elementary school curriculum. Although the overall intervention effect was not statistically significant, increases of approximately 2000 steps/day were observed among children with initially low activity levels. More recently, Riley and colleagues [232] evaluated the Encouraging Activity to Stimulate Young Minds (EASY Minds) physical activity integration program for elementary school students. Similar to the Take 10! program and other physical activity integration interventions that require teachers to provide bouts of MVPA related to curriculum outcomes [233, 234], EASY Minds aimed to improve student activity levels, engagement and attainment in numeracy through the use of cross-curricula teaching strategies. For example, pedometers were used as learning tools to reinforce key concepts regarding measurement, distance and speed. Preliminary findings suggest that the EASY Minds intervention significantly improved students' MVPA and reduced their sedentary time measured using accelerometers during the school day. The findings from these studies highlight the potential of pedometers for promoting physical activity within the school day by using their user-friendly and quickly accessible output for a range of learning outcomes across key learning areas.

Recess and lunch breaks, as well a time before and after school while children aggregate on campus, represent important school-based opportunities for young people to be physically active [235, 236]. However, the potential contribution of these key time segments is dependent upon the availability of school facilities and existing policies that support or inhibit student activity levels [237-240]. For example, schools might have high quality indoor gymnasiums and well-manicured fields, but only allow students access to facilities during scheduled PE lessons. Interestingly, a review of studies designed to evaluate the impact of school-based policies and built environment changes on energy expenditure found that mandatory PE, classroom activity breaks, and active commuting to and from school produced the largest effects [237]. Pedometers provide a feasible means for assessing such physical activity policy initiatives in schools [241] and their immediately available and interpretable feedback make them appealing to researchers and teachers.

2.7 Conclusions and Future Research

Pedometers are now used regularly in population surveillance studies to determine youth activity levels and in health behaviour interventions to promote physical activity. This review focused on three areas related to pedometer monitoring in young people, which have received limited attention in the research literature: pedometer monitoring protocols, minimal step counts necessary for maintaining basal levels of health, and appropriate pedometer-based interventions for young people. The challenges of objective monitoring of physical activity in children and adolescents reinforce the importance of using pedometer protocols that minimize participant burden and the potential for tampering and reactivity.

There is little evidence for a sedentary lifestyle cut-point in young people and the health consequences of very low ambulatory activity have not been established. Personalized messages and feedback may be necessary for health behaviour change in pedometer-based interventions for children and adolescents, but few long-term studies have been conducted. As a final note, we offer the following suggestions for future research:

1) There is a need to further explore the utility of different pedometer measurement protocols and identify optimal strategies for improving compliance in population monitoring studies, particularly in adolescent populations. While pedometers remain a valid and reliable method for establishing physical activity levels in youth, researchers should avoid using the same instrument to both measure and motivate physical activity in the same study sample.
2) Further study of the physiological and psychological health-related outcomes of excessively low ambulatory behaviours is required to develop a step-defined sedentary lifestyle index for young people. Researchers are encouraged to investigate several counts points (i.e., < 5000, < 6000, < 7000 steps/day) in child and adolescent populations to identify the health consequences of falling below this threshold.
3) Further research is warranted to identify the ideal theory or combination of theories to guide pedometer-based physical activity interventions for children and adolescents. Additional questions remain unanswered that were not explicitly covered here in details: What combination of procedures and components is most effective in the promotion of physical activity in pedometer-based studies with young people? What are the long-term effects of pedometer-based interventions? Can pedometer-based interventions be regularly repeated in the same population? What is the ideal program length for a pedometer-based intervention and is it necessary to include “booster” sessions or other forms of contact once the intervention period has ended to maintain step counts? Are tailored interventions (i.e., those including personalized feedback on performance) more effective at increasing physical activity in young people and if yes, what are the ideal characteristics on which to tailor pedometer-based interventions?

How can pedometers be integrated into the school environment to induce sustainable behaviour change?

CHAPTER 3: RELIABILITY AND VALIDITY OF A SINGLE-ITEM PHYSICAL ACTIVITY MEASURE FOR ADOLESCENTS

Preface: This chapter examines self-report measures and in particular, a single-item physical activity measure that was designed for the purposes of this study. The single item physical activity is tested against a previously validated physical activity questionnaire (The Oxford Physical Activity Questionnaire) and accelerometer output in a free-living adolescent population.

Citation:

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3 Reliability and validity of a single-item physical activity measure for adolescents

3.1 Abstract

Aims: The aim of this study was to examine the test-retest reliability and concurrent validity of an adolescent single-item physical activity measure by comparing it to the existing Oxford Physical Activity Questionnaire (OPAQ) and accelerometer output.

Methods: Participants were 123 adolescents (14.7 ± 0.5 years) from three secondary schools in NSW, Australia. To determine reliability, participants completed both questionnaires on two occasions separated by two weeks. To assess validity, participants wore ActiGraph GT3X+ accelerometers for a seven-day monitoring period and completed both physical activity questionnaires. Bivariate correlations between self-reported moderate-to-vigorous physical activity (MVPA) and accelerometer MVPA minutes/day were calculated.

Results: The single-item [Intraclass correlation coefficient (ICC) = 0.75, 95% CI = 0.64 - 0.83, $p < 0.001$)] and the OPAQ (ICC = 0.79, 95% CI = 0.69 - 0.86, $p < 0.001$) were both found to have moderate-to-strong reliability. Correlations between self-reported and objectively measured MVPA were similar for the single-item measure ($r = 0.44$, *95% CI* =0.24 - 0.63, $p < 0.001$) and the OPAQ ($r = 0.50$, *95% CI* =0.30 - 0.65, $p < 0.001$).

Conclusions: These findings suggest the single-item measure can provide a reliable and valid assessment of youth physical activity.

3.2 Background

The accurate assessment of physical activity is an on-going challenge for researchers [242] and in recent years there has been an escalation in the use of objective measures [243]. Whilst accelerometers provide an objective estimate of physical activity, there are limitations to the devices. They are expensive, don't provide activity type and there is still uncertainty as to the most effective data management and reduction protocols [125, 139, 244]. Alternatively, self-report measures are easy to administer and cost effective for large samples. However, they are subject to respondent bias, over and under-reporting and may require complex cognitive recall

[13, 15, 245, 246]. Physical activity measurement is used for determining prevalence/trends, identifying determinants and to evaluate interventions; hence the method of physical assessment (objective or subjective) is tailored to study aims/feasibility [247] (refer to figure 1; Hardy et. al, 2013).

The growth of physical activity measurement research has led to the development of a plethora of physical activity questionnaires making it challenging for researchers to identify the most appropriate instrument to address their study aims [13, 15]. A recent systematic review of adolescent physical activity self-report measures concluded that the Oxford Physical Activity Questionnaire (OPAQ) was one of the most reliable instruments assessing adolescent physical activity (ICC = 0.89 and 0.78 for males and females, respectively) although was only considered to hold acceptable validity [15, 79]. As more detailed questionnaires, such as the OPAQ, require higher level cognitions and take longer for participants to complete; simpler, less burdensome questionnaires have been developed [12, 248-250]. These shorter questionnaires are easy to administer and can be used for screening purposes and use in population surveys. Research has revealed that single-item or short physical activity measures compare favourably in terms of validity and reliability with more detailed questionnaires in adult populations [250, 251]. Milton and colleagues (2010) found satisfactory concurrent validity of a single-item measure against the commonly used Global Physical Activity Questionnaire (GPAQ) and Active People Survey (APS) in a sample of 480 adults. They also demonstrated test-retest reliability of the single-item measure in both weekly (Cohen's kappa = 0.63; 95% CI: 0.54 - 0.72) and monthly (Cohen's kappa = 0.76; 95% CI: 0.69 - 0.82) recall comparable with more complex physical activity questionnaires [12]. However, while single-item physical activity measures have been developed and tested in adult populations [12, 250], little is known regarding their validity and reliability in adolescent populations.

Considering the large number of existing subjective physical activity measures available [13, 15], more direct comparisons of questionnaires are required to improve our understanding of the most appropriate physical activity measures. To the authors' knowledge [14, 15], no single-item physical activity measures exist for the adolescent population; furthermore no previous study has examined the validity and reliability of a single-item measure by comparing it to both an existing physical activity questionnaire and accelerometer output. Milton and colleagues recently published a study focusing on an equivalent single item measure for use with adults and concluded that the single item questionnaire had potential for screening participants for physical activity interventions [12]. Based on this finding, we believe that there will be interest a single item measure for both clinicians and for researchers who are examining multiple health behaviours and determinants in population level surveys, where costs of items are at a premium. In addition, adolescents have a noted lack of concentration further illustrating the need for shorter questionnaires to capture physical activity accurately. Therefore, the aim of this study was to examine the test-retest reliability and concurrent validity of an adolescent single-item physical activity measure by comparing it to the existing Oxford Physical Activity Questionnaire (OPAQ) and accelerometer-based physical activity levels.

3.3 Methods

3.3.1 Study design

This study recruited six physical education (PE) classes from three secondary schools in the Hunter Region, NSW, Australia. To determine test-retest reliability, participants completed the OPAQ and the single item measure on two occasions, separated by two weeks. To assess concurrent validity, participants wore accelerometers (ActiGraph GT3X+, Pensacola, USA) for a seven-day monitoring period and completed both questionnaires on the final day of monitoring. The study was approved by the University of Newcastle review board (human research ethics committee) and parents and participants provided written informed consent and assent respectively.

3.3.2 Participants

For analysis, the sample consisted of adolescents (n = 123) (Mean age = 14.7 ± 0.5 years). One-way analysis of variance and chi-square analyses indicated there were no significant differences in cultural background or country of birth between the three different school groups ($p > 0.05$).

Of the 160 forms that were distributed, 123 participants returned signed consent letters (i.e., 76.9% response rate), although only 96 provided valid accelerometer data to be included in the analysis; 107 provided valid single item data and 104 participants provided valid OPAQ data.

3.3.3 Research questions:

1) What is the test-retest reliability of a single-item physical activity measure for adolescents?

2) What is the test-retest reliability of the OPAQ?

3) What is the validity of a single-item physical activity measure for adolescents against accelerometer-based physical activity levels? (480min wear time/day and 600min wear time/day)

4) What is the validity of the OPAQ against accelerometer determined accelerometer-based physical activity levels? (480min wear time/day and 600min wear time/day)

3.3.4 Procedures

Data were collected in the fourth school term of 2011 (i.e. October to December). Participants were blinded to the study aims and were told that the purpose of the study was to provide an estimate of their 'usual' physical activity [252]. Prior to the first day of monitoring, accelerometers were pre-set to record activity in 15 second epochs for the seven-day monitoring period with computer software Actilife 5, 2011, version 5.7.4 (ActiGraph, Pensacola, USA). On day 1, participants completed the OPAQ and the single-item measure recalling the last 7 days (Trial 1). Participants completed both questionnaires a second time 2 weeks later (Trial 2). Participants then wore accelerometers for 7 days and completed the questionnaires for a third time (Trial 3). Trials 1 and 2 were used for reliability and Trial 3 was used to establish concurrent validity. The single item questionnaire was a very short questionnaire that only took 1 - 2 minutes to complete, reported simple information and to limit any ordering effect, was always completed first. The longer measure (OPAQ) then followed and took approximately 10minutes to complete and questioned more detailed recall. Trained research assistants conducted all assessments, which were completed at the study schools using the same instruments at each time point.

3.3.5 Accelerometers

In adolescents, accelerometers provide good validity and reliability and are often used as the criterion measure for assessing the validity of physical activity questionnaires [66, 243, 253, 254]. ActiGraph accelerometers were used to measure the amount of time participants were involved in moderate to vigorous physical activity (MVPA). MVPA data were derived from the vertical axis only. Accelerometers were dispersed on an adjustable elastic waist belt so that it could be tightly fastened to reduce inaccurate measures [255]. The valid objective accelerometer data were compared to seven days of self-reported data (OPAQ and single-item measure data).

3.3.6 Single-item physical activity measure

A single-item measure that has been found to be reliable and valid in an adult population [12] was modified to match the population studied. It read as follows '*In the past week, on how many days have you done a total of 60 minutes or more of physical activity, which was enough to raise your breathing rate? This may include sport, exercise and brisk walking or cycling for recreation or to get to and from places'*. Participants then ticked the appropriate box ranging from zero to seven days.

3.3.7 Oxford Physical Activity Questionnaire

The OPAQ was selected as a 7 day recall measure as it has shown promise in the adolescent population [15, 79]. Participants are required to complete a table, indicating the time they spent in MVPA for each day of the week and activity type.

3.3.8 Treatment of data

The accelerometer data were downloaded using Actilife 5. An Evenson 15-second cut-point was applied to the data [256]. Missing data were defined as ≥ 20 minutes of consecutive zero counts [257]. Data were then cleaned and imported for analysis using IBM SPSS, 2010, version 22 (IBM Company SPSS. Inc.). Currently, there is existing disagreement regarding the required number of monitoring days required in youth studies [65, 119, 244, 258-260]. A recent review of physical activity studies using accelerometers found that 70% of studies in adolescents used a three to four day wear time criteria to provide an estimate of usual activity [114]. Therefore, to maximize sample size, a three-day inclusion criteria with 480min wear time/day (n = 96) and three days with a 600min wear time/day was applied (n = 72) [114, 261, 262]. The OPAQ data was reported by the participants in MVPA (mins/day). If the activity type listed was a MET count > 3 it was included as self-reported MVPA [7, 263-265]. Daily MVPA (mins) were collaborated to provide a weekly total of time spent in MVPA (mins). Total reported MVPA data (7 days) from the OPAQ and ordinal data from the single-item questionnaire reported in number of days that participants achieved 60mins of MVPA was entered into IBM SPSS for analysis [7, 263].

3.3.9 Analysis

Data were checked for normality based on a visual inspection of histograms and satisfied the criteria. Bivariate Pearson correlations between self-reported MVPA and accelerometer output (time spent involved in MVPA) were used to determine the concurrent validity of the two questionnaires. Reliability was analysed in three ways: 1. Intra-class coefficient (ICC) was used to provide an estimate of repeatability. For ICC calculations, we used consistency agreement, two-way mixed model and reported the single measures estimates; 2. Paired sample t-tests were used to determine change in mean values with between Trial 1 (single-item: mean = 4.29, SD = 1.63; OPAQ mean = 70.61, SD = 52.37) and Trial 2 (single-item: mean = 4.64, SD = 1.64; OPAQ: mean = 74.20, SD = 45.75); 3. Bivariate Pearson correlations between inter-trial difference (T2 - T1) and the mean of the trials [(T2 - T1)/2] were used to identify proportional bias. Bland-Altman plot analysis (Figure 1 and 2) were employed to determine potential bias and limits of agreement by the assessing the total magnitude of time spent in MVPA and the inter-trial difference for each questionnaire. Trial 3 was used for validity (single-item: mean = 4.31, SD = 1.77; OPAQ: mean = 61.44, SD = 46.99). Bivariate Pearson correlations between self-reported MVPA and accelerometer output (time spent involved in MVPA) were also used to determine the validity of the two questionnaires. Independent sample *t*-tests were also used to reveal if participants excluded from the analysis due not meeting the accelerometer inclusion criteria differed in terms of their self-reported physical activity.

3.4 Results

3.4.1 Reliability

Analysis of ICC revealed the single-item measure (n = 107) demonstrated similar overall reliability (ICC = 0.75, 95% CI: 0.64 - 0.83, $p < 0.001$) to the OPAQ (n = 104; ICC = 0.79, 95% CI = 0.69 - 0.86, $p < 0.001$). Paired sample t-tests revealed there was no significant group difference between T1 and T2 for the OPAQ ($p = 0.80$) or the single-item measure ($p = 0.169$). Bivariate Pearson correlations between inter-trial difference (T1 - T2) and the mean of the trials [(T2 - T1)/2] revealed the OPAQ had slight proportional bias ($r = -0.17$, *95% CI* =-0.43 - 0.10, $p = 0.139$) (Figure 1). The results suggested there was no relationship between participants' MVPA inter-trial difference for the single item measure ($r = 0.08$, *95% CI* = -0.12 - 0.26, $p = 0.465$) (Figure 2). Independent samples *t*-tests revealed that there was no significant differences between participants that met the accelerometer inclusion criteria (Single item measure 600MVPAmins/day: mean = 3.96, SD = 0.20 and OPAQ 600MVPAmins/day: mean = 65.06, SD = 49.46) and participants that did not meet the accelerometer inclusion criteria ($p > 0.05$) (single item measure 600MVPAmins/day: mean = 4.80, SD = 0.22 and OPAQ 600MVPAmins/day: mean = 80.63, SD = 56.88). When the accelerometer inclusion criteria was reduced to 480MVPAmins/day, similar trends were found. Although there were no outliers for the single item due to the response format (i.e., 0 to 7), two outliers were removed from the OPAQ data. In terms of missing data, the OPAQ had more missing data at all three time points (6.1%, 17.5%, 45.7% respectively) in comparison to the single-item questionnaire (5.2%, 13.1%, 33.3% respectively). However, it is important to note that the majority of missing data for both measures was due to students being unavailable on assessment days.

3.4.2 Validity

Correlations between accelerometer MVPA and self-reported MVPA were of moderate strength. For the shorter wear-time of 480MVPAmins/day (n = 96), the OPAQ and the single-item both demonstrated similar validity (r = 0.43, *95% CI* = 0.23 - 0.62, $p < 0.001$) and (r = 0.46, *95% CI* = 0.24 - 0.63, $p < 0.001$) respectively. When the accelerometry wear time was increased to 600MVPAmins/day (n =72), the OPAQ (r = 0.50, *95% CI* = 0.30 - 0.65, $p <0.001$, n = 96) again showed slightly higher validity than the single-item measure (r = 0.44, *95% CI* = 0.24 - 0.63, $p < 0.001$).

3.5 Discussion

The primary aim of this study was to investigate the test-retest reliability and concurrent validity of simple physical activity measures in a sample of adolescents. The three main measures of test-retest reliability, correlation (e.g., ICC and Pearson bivariate correlation), systematic change in the mean (e.g., paired samples t-test) and within-subject random variation (e.g., typical error and limits of agreement), provide evidence for the different types of reliability. For example, paired samples t-tests can be used to determine if there was a significant mean difference between trials (i.e., Trial 1 and Trial 2) However, this measure is based on group means and does not account for individual variability (i.e., there might be no statistical difference between trial means, but there may have been considerable variability among individuals' two scores). Alternatively, within-subject random variation is concerned with random variability of a single individual's values on repeated testing. It has been suggested that within-subject variation is perhaps the most important type of reliability for intervention research because it will influence the precision of change score estimates [266].

Our results revealed that the single-item measure compares favourably with an existing comprehensive physical activity measure (i.e., OPAQ) in both test-retest reliability and concurrent validity against accelerometers. The single-item measure showed high repeatability (ICC = 0.75) and moderate validity (r = 0.44) which is promising, given a recent systematic review of 31 youth physical activity questionnaires found that no questionnaires showed acceptable both reliability and validity [15]. Previous research into existing adolescent physical activity questionnaires revealed that reliability is often poorly assessed with most studies using Spearman's or Pearson's correlations which are not recommended over ICC [57]. Furthermore, ICC provides evidence of consistency between trials, but does not address the other types of reliability (i.e., typical error or proportional bias) which were addressed in the current study [13]. For reliability, an ICC > 0.70 is considered acceptable (Pearson's correlation or Spearman's rank of 0.80 was also considered to be acceptable) [15]. There is no consensus regarding what is considered to be an acceptable correlation coefficient for physical activity questionnaire validity in young people, but a recent systematic review reported that validity correlation coefficients were in the range of 0.30 - 40 [71]. The single item measure showed equivalent validity to that of existing adolescent physical activity questionnaires.

The Bland-Altman plots and Bivariate Pearson correlations revealed evidence of proportional bias for the OPAQ (r = -0.17). Participants, who reported higher levels of MVPA, were also found to have larger inter-trial differences. This finding may reflect limitations of the OPAQ, but also the large weekly variability in young people's activity patterns, particularly at higher intensities. There was no relationship between participants' MVPA and the inter-trial difference for the single-item measure. Although both the OPAQ and the single-item measure showed high reliability coefficients, the Bland-Altman analysis revealed relatively wide limits of agreement for both measures, indicating that they are more reliable for group physical activity estimates rather than individual estimates.

Accelerometers have been used extensively to validate larger, more detailed questionnaires [243, 261, 262], but evidence for the validity of single-item physical activity measures in youth is minimal [12, 249-251]. In the current study, accelerometer output (time spent involved in MVPA) was used as the reference measure [15]. As this study used two questionnaires of differing lengths, our examination of the single-item measure was strengthened as we could compare it to, not only the accelerometry, but also the OPAQ; a proven valuable tool in adolescent physical activity measurement [15]. The single-item measure was found to be equally valid and reliable as an in-depth questionnaire with regard to the amount of days that adolescents are involved in 60mins of MVPA, but obviously lacks further detail regarding type, exact duration and intensity of activity. It is possible that shorter questionnaires may result in fewer outliers; inaccuracies and less missing data; particularly among adolescents who have shorter attention spans [80, 81, 267].

The bivariate correlations with accelerometry for 480MVPAmins/day of wear time, demonstrated that both the OPAQ and the single-item measure had similar validity (r = 0.43), and (r = 0.46) respectively. When the accelerometry wear time was increased to 600MVPAmins/day, the OPAQ (r = 0.50) again showed slightly higher validity than the single-item measure (r = 0.44). Systematic reviews of physical activity questionnaires have reported that validity correlation coefficients were in the range of 0.25 - 0.41 [14] and 0.30 - 40 [71]. In terms of validity, the single-item measure and the OPAQ therefore compare favourably with existing adolescent physical activity questionnaires.

The study differed from the existing literature as it attempted to test the validity and reliability of a single-item measure in an adolescent population. Additional study strengths include the use of accelerometers to validate the measure and the assessment of three types of reliability (i.e., repeatability, change in mean and proportional bias). However, compliance to the accelerometer protocols was lower than desired and the inclusion criterion was subsequently amended to maximize the sample used in the analysis. Secondly, participants' were required to remove the accelerometers for water activities resulting in loss of data [268, 269]. Thirdly, socio-demographic variables may limit the generalizability of findings and the study sample size was relatively homogenous and similar in age. It is possible that younger students may have more difficulty interpreting the OPAQ instructions, which may limit the generalizability of our findings. Fourthly, individual inter-trial differences were not analysed. Fifthly, our failure to randomise the ordering of questionnaire completion is a potential study limitation. However, the single item questionnaire was a very short and was always completed first. The longer measure (OPAQ) then followed that took approximately 10minutes to complete and questioned more detailed recall. Finally, feasibility limitations prevented reliability and validity to be analysed on two separate sample groups.

3.6 Conclusions

The single-item measure was found to have comparable validity and reliability to an existing physical activity questionnaire (OPAQ) that has shown merit in an adolescent population. It also had a higher response rate and less missing data than the OPAQ. The single-item measure is easy to administer and may have utility for screening purposes and for use in population surveys. This measure however, does not provide the detail of more comprehensive questionnaires (i.e. activity type, duration, intensity, time of day/week, daily activity patterns etc.) and may lack the necessary sensitivity to detect change in habitual physical activity. We encourage researchers to compare the utility of different physical activity questionnaires in various populations and against objective physical activity measures. Further research into the appropriate length and detail of physical activity questionnaires will lead to more efficient and accurate data collection.

Table 3.1 - Characteristics of participants

Characteristics	Males n (%)[1]	Females n (%)[1]	Total Group n (%)[1]
Born in Australia	74 (97.4)	46 (97.9)	120 (97.6)
English spoken at home	72 (94.7)	46 (97.9)	118 (95.9)
Ethnicity			
Australian	61 (82.4)	38 (80.9)	99 (81.8)
Aboriginal/Torres-strait Islander	1 (1.4)	1 (2.1)	2 (1.7)
European	9 (11.8)	5 (10.6)	14 (11.6)
Other	3 (3.9)	3 (6.4)	6 (4.8)
	Mean (SD)	Mean (SD)	Mean (SD)
Age	14.67 (0.47)	14.70 (0.46)	14.68 (0.47)
Height (cm)	171.66 (9.52)	165.49 (8.37)	169.27 (9.54)
Weight (kg)	62.55 (12.26)	56.73 (7.90)	60.35 (11.15)
OPAQ MVPA (mins/day)	80.22 (41.26)	65.21 (50.61)	74.30 (45.54)
Single-item measure (days/wk)	4.90 (1.61)	4.26 (1.64)	4.65 (1.64)
Accelerometer MVPA 480mins/day[2]	28.29 (9.85)	19.54 (7.75)	24.74 (9.99)
Accelerometer MVPA 600mins/day[3]	30.46 (10.13)	20.72 (8.49)	26.54 (10.59)

[1]Percentage of participants in study.
[2]Accelerometer output MVPA mins/day (Inclusion criteria: 3 weekdays, 480mins wear time/day).
[3]Accelerometer output MVPA mins/day (Inclusion criteria: 3 weekdays, 600mins wear time/day).

Figure 3.1 - Bland-Altman Plot for the OPAQ with 95% confidence limits comparing mean self-reported MVPA and inter-trial difference (trial 1 and trail 2)

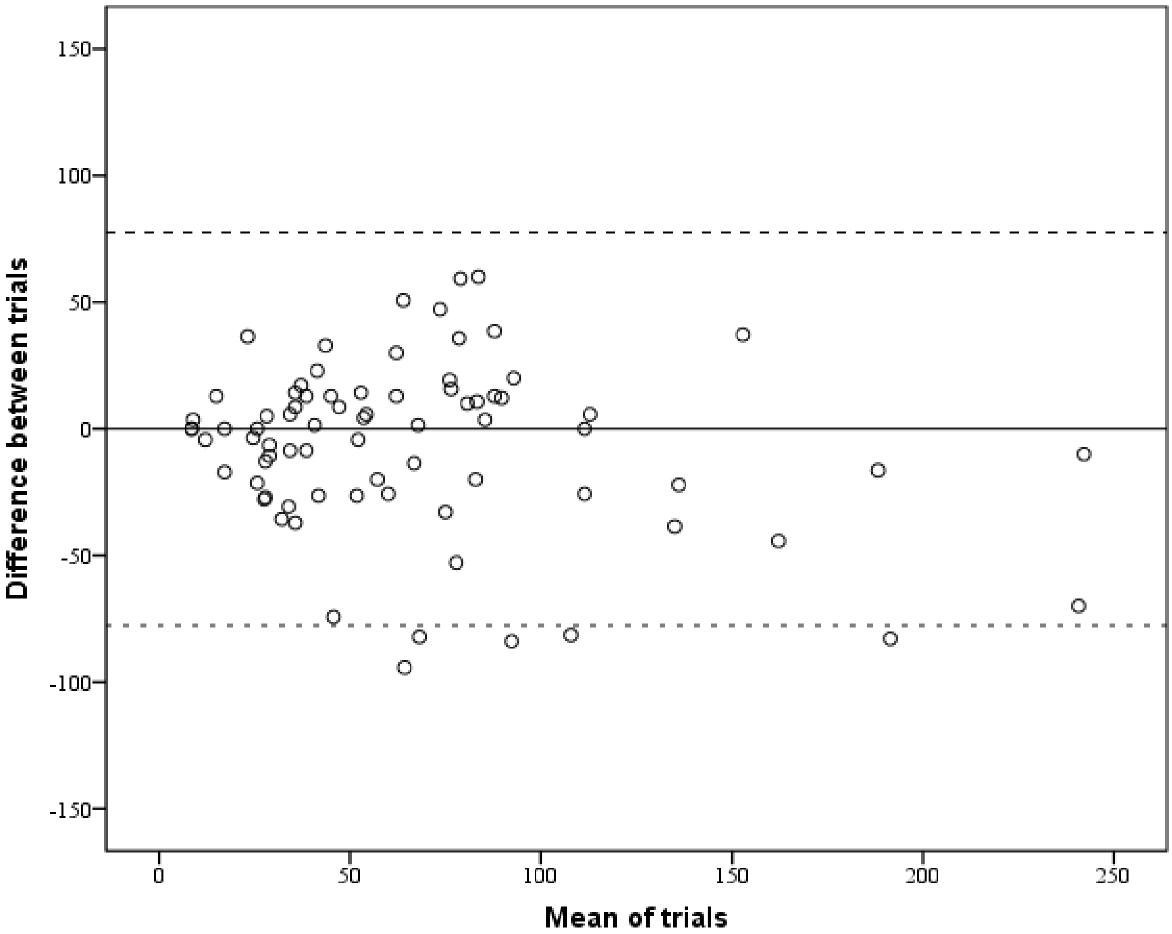
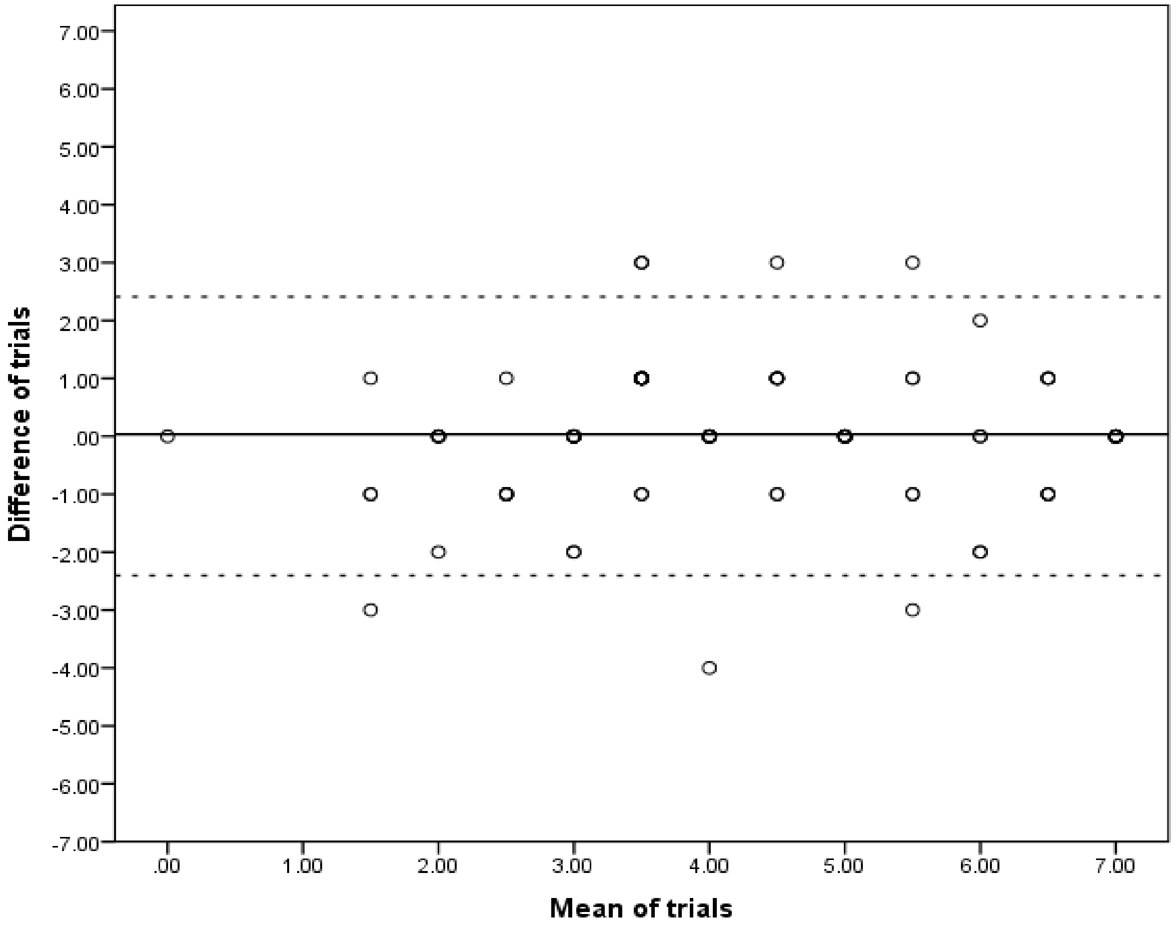


Figure 3.2 - Bland-Altman Plot for the single-item measure with 95% confidence limits comparing mean self –reported MVPA and inter-trial difference (trial 1 and trail 2)



CHAPTER 4: ADOLESCENT PEDOMETER PROTOCOLS: EXAMINING REACTIVITY, TAMPERING AND PARTICIPANTS' PERCEPTIONS

Preface: This chapter examines the current adolescent pedometer protocols and focuses on the current issues with objective monitoring that are an inherit threat to reliability and validity. This research is novel as it was first of its kind provide insights into why participants may not comply with objective monitoring protocols by exploring their perceptions with self-report measures.

Citation:

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4 Adolescent pedometer protocols: examining reactivity, tampering and participants' perceptions

4.1 Abstract

Background: Little is known about reactivity and tampering in adolescent pedometer-based research.

Methods: The sample included adolescents (N = 123, Age range = 14 to 15 years) from three secondary schools in NSW, Australia. Schools were randomized to one of three pedometer protocols: i) Daily sealed pedometer group: steps recorded daily by research team, ii) Unsealed pedometer group: steps recorded daily by participants and iii) Weekly sealed pedometer group: step counts recorded by research team at the end of monitoring period. Participants wore pedometers (Yamax CW700) and accelerometers (ActiGraph GT3X+) simultaneously for seven days. Repeated measures analysis of variance was used to examine potential reactivity. Bivariate correlations between step counts and accelerometer output were calculated to explore potential tampering.

Results: The correlation between accelerometer output and pedometer steps/day was strongest among participants in the weekly sealed group (r = 0.82, $p \leq 0.001$), compared to the unsealed (r = 0.63, $p = \leq 0.001$) and daily sealed (r = 0.16, p = 0.324) groups. The daily sealed ($p \leq$ 0.001) and unsealed (p = 0.003), but not the weekly sealed (p = 0.891), groups showed evidence of reactivity

Conclusion: The results suggest that reactivity and tampering does occur in adolescents and contrary to existing research, and that pedometer protocol may influence participant behaviour.

4.2 Introduction

Although there has been a proliferation in the use of objective measuring devices for measuring physical activity, they are subject to reactivity and potential tampering [9, 100, 159]. Reactivity is a potential threat to the accurate assessment of physical activity and can be defined as a change in normal activity pattern when participants are aware that they are being monitored [141]. Studies examining reactivity in children and adults have produced mixed findings.

Although many studies have failed to identify reactivity [11, 58, 141, 270], others have found a feedback effect resulting in a change of activity usual pattern [9, 100, 159]. For reactivity to be identified, it is expected that participants will exhibit an increase in activity at the start of the monitoring and then return to a more stable pattern once they are accustomed to wearing the devices [270]. Ozdoba and colleagues used sealed and unsealed pedometers with 4th grade children (N = 45) for 14 days and found that over the period, reactivity was not present [58]. Clemes and colleagues examined reactivity in adults and concluded that the reactivity was present but may only last a few days [9, 159, 161], contrary to other findings in young adults [160, 270, 271].

Device tampering (e.g. shaking) and non-adherence to monitoring protocols are additional threats to the accuracy of physical activity assessment using pedometers. Surprisingly, research exploring pedometer tampering is sparse and it is not known if different pedometer monitoring protocols influence participant behaviour. A recent study examining adolescent adherence to a pedometer protocol found that 30 out of the 43 participants self-reported tampering with their pedometers [100]. Adolescents remain a difficult group to measure due to their poor compliance with monitoring protocols [115] and further understanding of their behaviours while being monitored and their perceptions of the monitoring process, may help to improve the accuracy of physical activity assessment in this population.

To the authors' knowledge no previous study has examined reactivity in adolescents and only one study has examined pedometer tampering among adolescents [100]. The current study attempts to compare existing objective protocols to identify the method which provides the most accurate representation of adolescents' physical activity. The primary aim of this study was to investigate adolescents' potential reactivity and tampering while wearing pedometers by comparing different monitoring protocols to accelerometer output. A secondary aim was to explore adolescents' perceptions and experiences relating to wearing pedometers. Such information may help guide monitoring protocols and improve participant compliance.

4.3 Methods

4.3.1 Study design

This study recruited six physical education (PE) classes (approximately 20 students in each class) from three secondary schools in the Hunter Region, NSW, Australia. Schools were randomized to one of three pedometer protocols and all participants wore pedometers (Yamax Digi-Walker CW700, Japan) and accelerometers (ActiGraph GT3X+, Pensacola, USA) simultaneously for seven consecutive days. The study was approved by the relevant institutional review boards and all participants provided written informed consent. The sample included adolescent boys (n = 76) and girls (n = 47) ($Mean_{age}$ = 14.7 ± 0.5). Participants were blinded to the study aims. One way ANOVA's and Chi-square analyses indicated that there were no significant differences in age, height, cultural background or country of birth between groups ($p > 0.05$) (Table 4.1). Of the 160 dispersed forms, 123 returned consent (i.e., 82% response rate).

4.3.2 Measures

Trained research assistants conducted all assessments, which were completed at the study schools using the same instruments at each time point.

4.3.3 Pedometers

The Yamax Digi-Walker pedometer is recognized as one of the most accurate pedometers in terms of correctly estimating step counts and distance covered [122, 126, 141]. The accuracy of the pedometers was initially assessed by research assistants, using a brief walking test [272]. The Yamax Digi-Walker has high inter-instrument reliability ($r = 0.96$) when estimating step counts of children in a school setting [121, 174]. This study used the Yamax Digi-Walker CW-700 as it automatically resets itself each day and has the ability to record and store data for seven days.

4.3.4 Accelerometers

ActiGraph (GT3X+) accelerometers were used to measure physical activity level as the reference measure to validate the accuracy of pedometer step counts. Counts per minute (CPM) data were derived from the vertical axis only. CPM was used in the current study because it is the most widely used physical activity outcome in accelerometer studies as it is not dependent on cut-points or adjusted for wear-time [260]. Accelerometers and pedometers were dispersed on an adjustable elastic waist belt so that it could be tightly fastened to reduce inaccurate measures [255]. The pedometers were clipped onto the same belt, adjacent to the accelerometer.

4.3.5 Pedometry behaviour questionnaire (PBQ)

This questionnaire was developed specifically for this study. The brief questionnaire was composed of 10 questions, each scored on a 5-point Likert-type scale. The first five questions focused on behaviours that the students exhibited whilst wearing pedometers, with responses ranging from 1 = *never* to 5 = *every day*. i) *'I opened my pedometer even though it was sealed* ii) '*I wore my pedometer throughout the day, other than swimming/showering',* iii) '*When I wore a pedometer I was more active than normal'*, iv) *'I shook my pedometer to increase my step count'* and iv) *'I purposely wrote down more steps than I actually did' (if applicable).* The next five questions explored students' perceptions of wearing pedometers with responses ranging from 1 = *strongly disagree* to 5 = *strongly agree*. i) *'I wanted to get a high step count to impress the researchers'* ii) *'I wanted to get a high step count to impress my peers'* iii) *'I found that wearing a pedometer was uncomfortable* iv) *'I found that wearing a pedometer was embarrassing'* v) *I found that wearing a pedometer was a waste of time.* The questionnaire was administered on the last day of the measuring phase (day 8).

4.3.6 Procedures

Data were collected in the fourth school term of 2011 (i.e. October to December). Prior to measuring, schools were randomized to one of the three pedometer protocols. Face-to-face contact with the participants occurred in their normal PE lessons. On the first day of the measuring period, a member of the research team explained the general purposes and functions of pedometers and accelerometers. Participants were blinded to the study aims and were told that the purpose of the study was to provide an estimate of their 'usual' physical activity [252].

A member of the research team explained the importance of correct placement and the method of recording step counts if relevant, which was dependent on their designated protocol:

1. *Daily sealed group:* Participants in this group wore a pedometer that was sealed with a sticker. At the start of each school day they took their pedometer to an allocated classroom and met a researcher who removed the small sticker, recorded the daily step count and attached a new sticker to the pedometer. Participants were permitted to see their recorded count. Step counts for the weekend were recorded on the Monday morning.

2. *Unsealed group:* Participants in this group wore an unsealed pedometer for seven days. At the end of each day, participants recorded their steps on a personal log sheet.

3. *Weekly sealed group:* Participants in this group wore pedometers sealed with a sticker for seven days so that the step count could not be seen by the participant for the monitoring period. Daily step counts were recorded by the researchers when pedometers were re-collected at the school after seven days.

On the morning of the first measuring day, pedometers were checked by researchers that they were functioning properly. All participants were given an activity belt (pedometer and accelerometer) and a log folder (to log step counts and removal of activity belt). As part of consent, participants were required to provide a personal mobile phone number. A large majority of the participants had their own personal mobiles (87.3%). The remaining 16.3% provided a parental/guardian contact number. Each morning participants were sent a brief text message to remind them to put on their activity belt each day and also ways to correctly log their step count (if appropriate).

On the seventh day of measuring, students were sent an additional text message reminding them to return their measuring devices the following day. To encourage participants to bring back activity belts on the collection day, gift bags (containing a drink bottle and stickers) were provided on return of undamaged pedometers and accelerometers. When participants returned their activity belts on Day 8, they then completed the Pedometry Behaviour Questionnaire.

4.3.7 Treatment of Data

Currently there is no consensus regarding the treatment of extreme high or low pedometer scores for adolescents. Based on the previous studies, we applied inclusion cut-points of < 1000 and ≥ 30,000 steps/day, which were originally developed for children [102, 144, 272]. The replacement of missing pedometer data followed the procedures Kang and Rowe's previous studies [144, 273]. Data were then cleaned and merged, for analysis using IBM SPSS, 2010, version 19 (IBM Company SPSS. Inc.). From the 96 participants included in the analysis, there were nine scores of over 30,000 steps (1.2%) and 43 scores of less than 1000 steps (5.8%) These extreme values were deleted and replaced with the appropriate weekday or weekend personal mean. Days with no activity were excluded. Non-wear time was determined by strings of consecutive 0 counts ≥ 20minutes. Participants were included in data replacement if they had at least three valid days of data. Neither pedometer nor accelerometer data were adjusted in terms of self-reported non-ambulatory and water activity.

The accelerometer data were downloaded using Actilife 5, 2011, version 5.7.4 (ActiGraph, Pensacola). A 15-second epoch length was applied to the data. Activity counts/minute (CPM) were then calculated and imported into SPSS for analysis. While four days of monitoring is recommended as the minimum [119], there is a growing recognition for a more flexible framework with researchers selecting alternative thresholds depending on their objectives and the population studied [258]. Because the current study was focused on comparing different protocols rather than estimating habitual physical activity, a three-day inclusion criteria with 480min wear time/day was applied to maximize the sample size [n = 96 (not inclusive of a weekend day) and n = 54 (inclusive of a weekend day)].

Analysis

Data were checked for normality and satisfied the criteria. Alpha levels were set at $p < 0.05$. The data file was split by group (i.e., pedometer protocol) and repeated measures analysis of variance (ANOVA) was used to explore potential reactivity during weekdays. To explore potential pedometer tampering (e.g. shaking), bivariate correlations between mean step counts and mean CPM were calculated. We hypothesized that participants in the unsealed groups would shake their pedometers, resulting in a weaker correlation between step counts and accelerometer CPM. One way analysis of variance with Bonferroni post-hoc procedures were used to compare participants' perceptions of, and behaviours while wearing monitoring devices between groups. Independent samples t-tests were used to explore gender differences.

4.4 Results

4.4.1 Reactivity

Both the daily sealed and unsealed groups showed evidence of reactivity (initial increase of physical activity followed by levelling off) over the monitoring period (Table 4.2). The decline of physical activity in the daily sealed group occurred between Day 3 and Day 4 ($p \leq 0.001$). This decline occurred earlier in the unsealed group, between days 2 and 3 ($p \leq 0.001$). The weekly sealed group showed no significant differences over the monitoring period ($p = 0.886$).

4.4.2 Tampering

To examine tampering of pedometers, correlations between accelerometer output (mean CPM) and mean steps/day were calculated (Table 4.3). Correlations between weekday CPM and pedometer steps/day were strongest among participants in the weekly sealed group ($r = 0.82$, $p \leq 0.001$), compared to the unsealed ($r = 0.63$, $p \leq 0.001$) and daily sealed ($r = 0.16$, $p = 0.324$) groups. Correlations in the weekly sealed group were again strongest with the inclusion of a weekend day ($r = 0.81$, $p \leq 0.001$).

4.4.3 Self-reported behaviours and perceptions

In total 111 participants satisfactorily completed the PBQ (90.2%). There were no significant gender differences in participants' self-reported behaviours and perceptions ($p > 0.05$). Participants in the weekly sealed group were less likely to report a '*desire to impress the research team'* with their step counts than those in the daily sealed ($p = 0.021$) and unsealed (p

= 0.003) groups. Participants in the daily sealed group reported that they did more activity than normal whist being measured (p = 0.010). For all other responses, there were no significant differences between groups (p > 0.05). Of the participants that completed the questionnaire, 49% reported shaking their pedometers to increase their step count. In regards to participants' perceptions of the monitoring process, 40% indicated that they did not like wearing pedometers, 81% found wearing a pedometer uncomfortable and 69% reporting that they found wearing a pedometer embarrassing at times.

4.5 Discussion

The primary aim of this study was to investigate adolescents' reactivity and tampering while wearing pedometers by comparing different monitoring protocols to accelerometer output. Our findings suggest that reactivity and tampering occur in adolescents and the protocol selected for pedometer monitoring impacts on behaviour and compliance. Our secondary aim was to explore adolescents' perceptions and experiences whilst wearing pedometers. Based on our findings, it appears that adolescents find objective measuring devices uncomfortable and embarrassing and a large proportion report a desire to impress their peers and/or researchers with elevated step counts.

In previous studies, ICC and repeated measures ANOVA have typically been used to explore reactivity to pedometer monitoring. The assumption is that participants will increase their activity at the start of the monitoring period and then return to a more stable pattern once they are accustomed to wearing the devices [270]. In the current study, we found evidence of reactivity among students in the weekly unsealed group, suggesting they increased their activity at the start of the study period. However, studies have found substantial intra-individual variation in objectively measured physical activity in youth [274]. Consequently, changes in physical activity over the week due to sports training or physical education might be misclassified as reactivity. These findings highlight the need for more rigorous methodologies examining reactivity in different populations.

To explore the possibility of pedometer tampering, adolescents were required to wear accelerometers and pedometers simultaneously for seven days. Previous studies have used accelerometers to validate pedometer step counts [91, 275]. A recent study of free-living adolescents found moderate to strong correlations (r = 0.65 - 0.74) between pedometer step counts and CPM [276], but no previous study has used this method to compare different pedometer monitoring protocols in youth. Based on our previous trials and anecdotal evidence [183, 193], we hypothesized that unsealed group would provide the least accurate pedometer values. The relationship between CPM and steps was non-significant in the daily sealed group and this group was also significantly more likely to report a desire to impress the research team. Whilst non-significant (p = 0.33), the trend showed that those in the daily sealed group participants were more likely to shake their pedometers (DS mean = 2.05, SD = 1.21; US mean = 1.68, SD = 1.02; WS mean = 1.77, SD = 1.17). These findings suggest that adolescents who have daily contact with members of a research team as part of the monitoring process are more likely to exhibit reactivity, even if the pedometers are sealed.

As hypothesized, there was evidence of reactivity in the unsealed group, yet step counts remained relatively stable across the monitoring period in the weekly sealed group. This may be due to the sealing of pedometers and the removal of step count feedback. Although a pattern of reactivity was evident in the daily sealed and unsealed groups, we cannot be certain that this was reactivity and not a ‘day to day’ difference in physical activity, although this seems unlikely as the weekly sealed groups showed no significant differences across days. The unsealed groups were required to log their own step counts which resulted in the most missing pedometry data of all groups. Correlations of step counts and CPM were strongest in the weekly sealed group implying that this was the most reliable protocol of the three and reduced pedometer tampering. Correlation was weakest in the daily sealed group (r = 0.16) indicating higher tampering most likely due to daily contact with researchers. This was reinforced when the inclusion of a weekend day was added to the analysis and the correlation was raised to be similar to that of the unsealed group (r = 0.54).

Responses from the questionnaire revealed that almost half of students that completed the questionnaire admitted to tampering with their pedometer with no statistical difference between boys and girls. Furthermore, a third of all participants reported that they did more physical activity than normal while wearing the pedometers. Few studies have examined participants' behaviours and perceptions of the monitoring process and an improved understanding of the measurement barriers may improve the accuracy of pedometer protocols. These findings suggest that reactivity and tampering are threats to the accuracy of objective physical activity measurement in adolescents.

Bulk internet text messaging proved to be a very useful strategy to remind participants to wear measuring devices log step counts and to return activity devices at the end of the measuring phase. Instead of giving the students a log sheet, they were provided a log 'folder' and encouraged to personalize it. Participants also chose various stickers to put on the top of their measuring devices to ensure that the devices were not worn upside down to reinforce accurate measurement.

The strengths of this study include the simultaneous assessment of physical activity using accelerometers and pedometers and the triangulation of findings using questionnaires. Despite these strengths, there are some limitations that should be noted. First, compliance to accelerometer protocols was lower than anticipated (78%) and we subsequently adapted our wear-time criteria to include as many subjects as possible in the analyses, a longer monitoring time frame may have more accurately detected reductions in step counts (i.e. reactivity). Second, pedometers were sealed with stickers and although, researchers could tell if the pedometers had been tampered with more stringent sealing measures may be necessary to prevent pedometers from being opened. We encourage manufacturers to produce lockable pedometers for research purposes. Thirdly, we did not assess participants' behaviour with regard to the accelerometer. However, this was not part of the research design. Finally, we did not use a cross-over design which would have provided us with an opportunity to assess the adolescents using each of the three monitoring protocols (although cross-over designs have their own inherent weaknesses).

4.6 Conclusions and Recommendations

Contrary to existing research [58, 141, 144, 270], our results suggest that the protocol selected for pedometer monitoring impacts on behaviour and compliance. With regard to adolescent behaviour, half of the students self-reported tampering; 40% state that they didn’t like the process; 81% found it uncomfortable and 69% found it embarrassing. Clearly, more qualitative research is warranted in this area to learn more about the adolescent population and their perceptions of monitoring processes. Weekly sealed pedometer step counts were found to have the strongest association with accelerometer CPM and there was no evidence of reactivity in this group. Based on our findings, we recommend seven days of sealed pedometer monitoring using pedometers capable of storing at least 7 days of step count data in their internal memory. While longer monitoring periods may reduce reactivity, this may not be feasible among adolescents who often feel burdened by the monitoring process. Further research on pedometer protocol and the development of guidelines to improve the accuracy of adolescent pedometer protocols is clearly warranted.

Table 4.1: Characteristics of sample across three groups

Pedometer Protocol	Daily sealed		Unsealed		Weekly sealed	
Number of participant in sample	n = 46		n = 44		n = 33	
Number of participants meeting inclusion criteria (480mins, 3 valid days of wear time).	n = 39		n = 31		n = 26	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	14.7	0.44	14.6	0.48	14.7	.49
Country of birth[1]	46	100%	42	95%	32	97%
Language spoken at home[2]	43	94%	42	95%	33	100%
Ethnicity						
Australian	37	80%	33	75%	29	88%
Aboriginal/Torres-strait Islander	-	-	2	5%	-	-
European	7	15%	5	12%	2	6%
Other	-	-	4	9%	2	6%
Height (cm)	171	8.80	168	10.71	169	8.49
Weight (kg)	59	8.48	64	13.40	59	10.26

[1]Participants born in Australia.

[2]Participants who speak English at home.

Table 4.2: Changes in daily step counts and reactivity by pedometer group

Pedometer protocol	Day 1 Mean (SD)	Day 2 Mean (SD)	Day 3 Mean (SD)	Day 4 Mean (SD)	*F*	*p*- value	*n*
Daily sealed	11486 (4991)	10819 (5345)	12041 (5818)	8935 (3986)	7.587	≤ 0.001	39
Unsealed	10213 (3684)	11244 (5345)	8387 (3917)	9820 (4232)	4.991	0.003	31
Weekly sealed	8715 (3321)	8189 (3888)	8487 (8487)	8590 (5205)	0.215	0.886	26

Note. Repeated measures analysis of variance used to test for reactivity.

Table 4.3: Relationship between mean steps/day and accelerometer counts per minute

		Pedometer protocol		
		Daily sealed	Unsealed	Weekly sealed
Step/day[1]		10833 (3682)	9915 (3388)	8495 (3380)
CPM[1]		554 (145)	426 (133)	393 (117)
Weekdays only	n	39	30	26
	p-value	0.342	≤ 0.001	≤ 0.001
	r	0.156	0.632	0.822
Including weekend day	n	18	20	15
	p-value	0.021	0.021	≤ 0.001
	r	0.540	0.514	0.810

Note. Bivariate correlation used.

[1]Means (standard deviation) reported

CHAPTER 5: YOUNG PEOPLES' PERCEPTIONS OF THE OBJECTIVE PHYSICAL ACTIVITY MONITORING PROCESS: A QUALITATIVE EXPLORATION

Preface: This chapter examines adolescents' perceptions of objective physical activity monitoring. This builds on the finding of the previous chapter by providing a more in-depth look at adolescents' compliance to physical activity protocols. This research is novel as it was first of its kind provide insights into why participants may not comply with objective monitoring protocols by exploring the participants' perceptions through focus groups.

Citation:

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5 Young Peoples' perceptions of the objective physical activity monitoring process: a qualitative exploration

5.1 Abstract

Objective: To explore young peoples' perceptions of pedometers and investigate behaviours exhibited whilst being monitored.

Design: Qualitative design using six focus groups with participants (mean age 14.7).

Setting: Study participants (n= 24) were randomly selected from a previous study of 123 young people age 14-15years, from three secondary schools in New South Wales (NSW), Australia.

Methods: Participants wore pedometers (Yamax CW700) and accelerometers (ActiGraph GT3X+) simultaneously for seven days. Accelerometer output was used to categorize participants into one of six focus groups (three boys groups, 3 girls groups) i) low active (<30 mins MVPA/day), ii) Medium active (30-60mins MVPA/day), iii) High active (≥60 mins MVPA/day). Participants were questioned on their perceptions of the monitoring process and the behaviors' that they exhibited whilst wearing pedometers. A hybrid approach to data analysis identified key concepts which were thematically analysed.

Results: The two main themes observed were: i) participants' perceptions of the monitoring process and, ii) behaviour exhibited while being monitoring. Overall, participants' attitudes towards objective monitoring were positive. A large proportion reported changing their levels of physical activity during the monitoring process, and 87.5% of the focus group participants reported shaking their pedometers to increase their step counts. The medium and high active groups reported changing their activity patterns more than the low active groups.

Conclusion: Our findings are consistent with previous quantitative studies that suggest reactivity and tampering are commonplace among young people. Pedometers may have more utility as an intervention strategy for increasing activity rather than a method for assessing habitual activity levels.

Key Words: Focus Group, Pedometers, Young People, Behaviours, Physical Activity

5.2 Background

Pedometers are regularly used to measure habitual physical activity, assist in identifying the determinants of physical activity and to evaluate physical activity interventions [10, 93, 247]. Despite their ubiquity, little is known regarding young peoples' perceptions of, and behaviours during, pedometer-based research [100, 277]. Despite the challenges of ensuring young peoples' adherence to objective physical activity monitoring protocols [222, 278], there is a paucity of research examining their perceptions of the monitoring process [61]. As objective monitoring is regarded as the gold standard for measuring physical activity in population level studies [65], there is a clear need to improve our understanding of the monitoring process in young people.

Current research on pedometer protocols has identified 'reactivity' and 'tampering' across different population groups of children, young people and adults [9, 141, 172]. '*Reactivity'* is defined as a change in normal activity patterns when the participants are aware their physical activity level is being monitored [141]. *'Tampering'* is the term generally used when participants purposefully shake their pedometers to increase their step count; this is also sometimes referred to as 'cheating' [100]. Reactivity and tampering are an inherent threat to accurate physical activity measurement [172]. Kahan and colleagues studied adolescent adherence to pedometer protocols and found that 30 out of the 43 participants self-reported tampering with their pedometers during the monitoring process [100]. With growing quantitative research to support the existence of reactivity and tampering among young people, qualitative research may help improve our understanding of why participants feel the need to change their activity patterns during monitoring.

A recent qualitative study by Kirby and colleagues (n = 35) concluded that children's and young peoples' attitudes toward accelerometers were mixed [61]. Whilst some reported positive experiences, such as feeling 'special' and attaining increased attention, others reported that they perceived they were at higher risk of being bullied whilst wearing the devices and that they were uncomfortable. A further study focusing on the utility of accelerometers in child obesity interventions used parental interviews (n= 12) to collect information on participants' perceptions of the monitoring process and reported similar reasons for non-adherence including comfort issues and higher risk of stigmatisation [279]. As young peoples' adherence to monitoring protocols is such a complex phenomenon, further research in this area has been recommended [61, 100, 115].

Most pedometers provide direct feedback of activity level in an easily understood 'step-count'; previous research has shown that this feedback effect can enhance the amount of reactivity and tampering [61, 100, 141, 159]. However, no previous study has employed focus groups to investigate young peoples' perceptions of pedometers, which due to device feedback, affect young peoples' adherence to protocol differently to that of accelerometers [172, 277]. As pedometers are still being used in physical activity research to collect data on population groups and evaluate interventions, further research into the amount of reactivity and tampering and its effect on validity is warranted. To provide deeper analysis of issues surrounding objective physical activity monitoring, rich qualitative data derived from focus groups may provide useful and important insights. This will assist researchers in their attempts to accurately measure physical activity.

Numerous studies have demonstrated that young boys engage in more physical activity than girls [280-282]. Recent research has suggested that social relationships, environmental factors and biological differences may be responsible for the sex-based differences in physical activity levels [283]. To the authors' knowledge, no previous studies have investigated if participants' perceptions of objective monitoring process differ according to sex and physical activity levels. Further research is warranted to address these gaps in the literature.

The primary aim of this study was to explore young peoples' perceptions of pedometers and investigate the physical activity behaviours exhibited by participants during the monitoring process. A secondary aim was to investigate if participants' perceptions differed depending on physical activity level.

5.3 Methods

5.3.1 Study design and procedures

The focus group sample (n = 24) for this study was randomly selected from a previous study that investigated different pedometer protocols, which used a convenience sample of 123 young people aged 14-15 years, from three secondary schools in New South Wales (NSW), Australia. The 123 participants were divided into three pedometer protocol groups: i) daily sealed group: wore sealed pedometers and step counts were checked by researchers daily, ii) weekly sealed group: wore sealed pedometers and step counts were checked by researchers at the end of the week, iii) unsealed group: wore unsealed pedometers and step counts were checked by researchers at the end of the week. Regardless of the pedometer protocol, all participants were told not to look at or shake their pedometer, and also not to change their normal activity pattern [172].

Participants wore pedometers (Yamax Digi-Walker CW700, Kumamoto City, Japan) and accelerometers (ActiGraph GT3X+, Pensacola, USA) simultaneously for seven days. Contact with participants was made in their Physical Education (PE) classes. Participants were blinded to the study aims and were told that the researchers were attempting to gain an estimate of their normal activity pattern. They were also told that the researchers would be the only people who would see their step counts and it was confirmed with the students that their activity level (step counts) would not be compared across individuals or classes. Accelerometers were worn solely to categorize participants into focus groups based on accelerometer-determined moderate to vigorous physical activity (MVPA).

5.3.2 Measures

5.3.3 Pedometry/accelerometry

The pedometers were pre-set with date and time to record a 7-day period. Yamax CW700 pedometers were chosen, as they are able to record steps over a period of seven days. The pedometer has an in-built 24-hour reset and records the step count daily. The accelerometers were preset to collect data at 15second epochs. After the monitoring period, the data were downloaded using ActiLife5 software version 6.5.3 (ActiGraph, Pensacola, USA). Evenson cut-points were then applied to obtain accelerometer-determined time spent in MVPA [284].

5.3.4 Focus Groups

A qualitative design using a focus group methodology was applied due to the likely benefits of group interaction which may elicit information and insights that may be less accessible during individual interviews [285]. This benefit of focus groups may be particularly true of groups in which members possess some level of group affinity and connection, as was the case in the current study [285]. Additionally, a focus group methodology is considered particularly appropriate for use with children and young people, and considered the method of choice when there is a concern of socially desirable responding [286].

All participants from the larger sample (n = 123) provided written assent and parental consent to be involved in the study and focus groups if were selected after the monitoring phase. After the seven days of objective monitoring, six focus groups, each consisting of four participants were conducted to determine participants' perceptions of the monitoring process. Participants in all of three pedometer groups were given the same instructions. More specifically, participants were told not to open their pedometer and or look at their step counts. Random selection was stratified to have equal number of boys and girls. Smaller groups comprising of 4 to 6 provide an ideal environment where the participants can discuss actively in the group [287, 288]. This study therefore selected four participants for each focus. Data saturation was achieved (n = 4). None of the participants that were selected to participant in the focus groups declined to be involved.

Participants were categorised as follows (each having one boy and one girl group):

1. *Low-active groups*: participants in these two focus groups achieved an average of <30 minutes/day in MVPA over their monitoring period.
2. *Medium-active groups*: participants in these two focus groups achieved an average of 30-60 minutes/day in MVPA over their monitoring period.

3. *High-active groups*: participants in these two focus groups achieved an average of ≥60 minutes/day in MVPA over their monitoring period.

The trained researcher who administered the focus groups was not associated with the involved schools and had no prior relationships with the students (participants). On average, the focus groups ran for between 20-25minutes. Interviews were conducted following the development of questions designed by the research team to facilitate discussion and reflection of the overall aims of the qualitative study component. The focus group questions were developed and peer-reviewed by three Professors with extensive experience physical activity research. Of particular relevance to this project, the research team are familiar with the challenges of measuring physical activity in children and young people using objective monitoring devices.

The questions were specifically designed to explore the participants' general perceptions of wearing pedometers, perceived need to, and reasons for, altering their step count, the perceived honesty of others, as well as views on the usefulness of assessing physical activity using pedometers. Further questions explored a range of behaviours relating to pedometer use, such as reasons for removing, opening, shaking or lending out the pedometer, as well as changes to physical activity levels during the monitoring period. Participant honesty and prevention of socially desirable responding was promoted by several means including an overt statement of facilitator independence as well as through iterative questioning. Focus group participants were told that they would not get into 'trouble' for providing honest answers, and that when the responses were transcribed all names would be removed and replaced with ID numbers so no individuals could be identified. Prior to conducting the study, focus group questions and study design proceeded through rigorous internal peer-review and the university and educational institutional ethics approval process.

5.3.5 Analysis

The focus groups were digitally recorded with the participants' consent and transcribed verbatim. To classify each individual within each focus groups, each participant was allocated an ID number. The first letter represented the level of activity (L = low, M = medium and H= high); the second letter identified sex (B = boy, G = girl) and third, a number between one and four (e.g., LB1). A computer program (NVIVO 10, Burlington, USA) was used to assist with the organisational aspects of data analysis. Analysis was conducted by a qualitative researcher, who was independent to the main study. To ensure reliability, a second researcher then conducted separate thematic analysis for categorisation of themes. Intercoder reliability analysis revealed a good level of agreement the two coders ($k = 0.72$, $p < 0.001$) [289].

A hybrid approach to data analysis was adopted [290, 291] allowing for identification and refinement of the key concepts which had been developed as part of the study framework, as well as identification of concepts arising from in vivo coding. Initially, codes or labels were formulated which were firmly grounded in the overall study aims, with the purpose being the development of a taxonomy which would enable a detailed description of the domains that characterised the multifaceted attitudes, perceptions and experiences of participants. The developing coding scheme was revised and further expanded during the initial open coding process. Following coding of all focus group transcripts, the key domains, and the dimensions that emerged within these, were thematically analysed and described in detail.

5.4 Results

The focus groups participants had similar characteristics to the main study sample in terms of sex, age, physical activity level. The participants self-reported characteristic data were imported and analyzed using IBM Statistics (SPSS 12 Inc. Chicago, USA) software with alpha levels set at ($p < 0.05$). One way ANOVA's and Chi-square analyses indicated that there were no significant differences in self-reported height and weight, or body mass index (BMI) ($p > 0.05$), (see Table 1). The qualitative analysis yielded a detailed and descriptive account of a range of domains surrounding the participants' attitudes towards, and behaviours relating to, pedometer use.

5.4.1 Attitudes relating to pedometers and their usefulness

5.4.2 General perception of wearing pedometers

Overall, pedometer use was well received among participants, with no distinct differences between participant groups, with the exception of some girls of varying activity levels, who were bothered by wearing them. Generally, participants had taken an interest in wearing the pedometers from the perspective of self-monitoring. While close to half of the participants had been somewhat annoyed by wearing them initially (i.e., bulky, rubbing, uncomfortable), almost all reported having quickly become accustomed to it, with the pedometer becoming part of daily routine;

"…I noticed the first day, then after that it was just a daily routine put it on, take it off… go for a swim, take it off beforehand, put it back on afterwards. It was pretty much normal day except for putting it on." (LB4)

"I found it really annoying, it's like this massive bulge just hanging… out of the side of you (LG3)"

5.4.3 Perceived need to impress others

Apart from one low active girl, who acknowledged occasionally feeling the need to impress the researchers by exhibiting an increased step count; the other participants across the focus groups did not report a perceived need to increase their step counts to impress either teachers or researchers. However, a number of participants in the high active boys and high active girls' groups as well as medium active girls group, admitted to having engaged in some level of peer competition to achieve higher than normal step counts to impress their peers.

"We just all competed for who had the highest each day ... we were just sort of all trying to get the best." (HG2)

A number of participants alluded to the importance of self-monitoring their step count in determining whether they would feel the need to "catch up [to their peers]" by engaging in more physical activity or artificially increasing their step count;

"I looked at mine like all the time and especially …if I wanted to see who was doing the best with our steps we’d check it...[I would increase my steps by] walking and then if I was losing, I’d probably stand out there and jump because it like skips a couple of times." (MG2)

Additionally, four boys and girls across all activity levels reported they felt a need to engage in some form of informal self-competition:

"...I felt like impressing myself, I wanted to impress myself with the amount of steps I could get." (MG1)

5.4.4 Perceived dishonesty amongst others

Analysis revealed no clear differences between sexes or activity levels, the vast majority of participants perceived most of their peers to have engaged in some level of dishonest behaviour, with the only anomaly being a more positive appraisal of other participants' honesty given by the high active boys group. In this group, there was a predominant belief that a majority would have refrained from artificially increasing their step count. In the other groups, the perceived level of dishonesty among other members of the study population ranged from 'half' to 'most’, with dishonest behaviour seen mainly to have manifested itself as engaging in more sport than usual, pedometer shaking, deliberate non-purposeful physical activity such as walking on the spot, jumping up and down etc. with the commonly perceived notion of this being largely due to peer competition.

"I think it’s half and half, some people would try and do more exercise… I know for a fact a couple of my friends were shaking it or doing a lot more exercise than they normally would". (LB4)

A couple of female participants alluded to dishonesty being associated with some level of guilt, while honesty on the contrary was promoted by fear of negative consequences (i.e., getting into trouble);

"…I think some of them …did it right, they didn't shake it or anything but then the other half did shake it because…they wanted to get higher [steps] …when I shook it…I felt bad, I wanted you [the researcher], to get the right information." (MG2)

Some participants had perceived everyone to have changed their behaviour in some way, with a few questioning whether assessment of physical activity levels is at all possible without somehow affecting the behaviour being measured;

"Everyone would probably change because you can't act the same when you're being measured as when you're not, you kind of feel like you need to impress someone or be more active just so you're not the...laziest kid." (HB1)

5.4.5 Perceived usefulness of assessing physical activity with pedometers

While the participants acknowledged that the majority of pedometer results may not represent an accurate picture of participants 'usual' or 'normal' activity levels due to dishonest behaviours, most participants felt that the use of pedometers still afforded a meaningful measure of physical activity levels; which by some in particular were seen as useful for raising peoples' awareness of their own activity level, for assessing within-person changes over time, or for exploring differences between groups;

"No, I don't think they're a waste of time because it shows how many steps people take every day and how active we are...for the people that aren't cheating, they're actually doing it properly, it's good for them." (LB4)

However, while approximately a quarter of participants did not perceive pedometers to be a useful measurement tool due to the high prevalence of dishonest behaviour, another quarter felt that their usefulness was solely dependent on the honesty of the group.

5.4.6 Behaviours relating to pedometer use

5.4.7 Reasons for removing pedometers

The participants provided a range of reasons for removing the pedometers during the study phase. Apart from the logistical/practical ones of showering, sleeping, water activities and contact sports, some participants had (or knew of others who had) removed them due to discomfort;

"Some people… they just didn't want to wear it, ... one person said that they wore it two days of the whole week so some people just didn't want to wear it at all." (LG2)

A small number of girls (across activity groups) identified social reasons (embarrassment) for temporarily removing their pedometers. One medium active boy reported removing his pedometer due to his dislike of being measured.

"I felt embarrassed [wearing the pedometer], it felt like everyone was seeing me wearing it (MG3)"

Apart from four female participants, who admitted to letting others wear their pedometer (mainly physically active friends or siblings) to increase their step count, the remainder reported not having lent out the pedometers at any stage with the main reason being that it would not show their own results and hence have both moral implications as well as negatively impact the validity (and interest-value) of the results;

"I wanted to get my accurate reading and I wanted to see how fit I am on a daily basis so I chose not to give it to anyone else." (LG3)

5.4.8 Tampering with pedometers

Even though all participants involved in the pedometer monitoring were told not to open or shake their pedometer, 87.5% of focus group participants reported shaking their pedometers to increase their step count. Only three participants reported not having intentionally opened their pedometers. The remainder admitted to having opened the unit (ranging from only 'once' to 'often'). The main reason given was simply being curious as to how many steps they had done, while others alluded to peer interest, peer competition or peer pressure as having contributed to them opening their units to check step counts;

"Yeah I did [open it] because I just wanted to see the step count and all my friends would be like, what are you are up to now? then they'll ask 10 minutes later, what are you up to now?, ...so I did." (HG3)

"Yeah, I opened it...I was curious to check my step count and I was quite proud of it actually...not for opening it because that was rebellion...and I kind of did feel pressured because other people...all my friends they're like "Oh, open it" so I was just like, do it." (LG3)

5.4.9 Changes in physical activity levels while wearing pedometers

More than half of the participants, especially within the high active groups (both sexes) and medium active girls group, revealed having engaged in more physical activity than normal during the measuring phase. Amongst those few participants who did offer an explanation, some admitted to having been motivated by peer competition. However, it appeared that the increased efforts mainly were a result of knowing their activity levels were being measured.

"Yeah… we just wanted to get [our steps] up and because… you want it to be high, then higher again…you just want it to go up every day." (HG3).

"I'd tried to stay on longer for touch footy or bowl more in cricket [or] something like that, to just keep my steps up...because I was getting measured, I guess" (HB1)

None of the low active boys taking part in the focus group reported changing their normal activity levels. The reasons given for not doing so included having forgotten that they were wearing the pedometer and not feeling the need to increase their activity level. All other participants admitted to changing their normal activity pattern in some way. While this mostly comprised increased activity during sports for the high active boys, the remainder of the groups of both sexes mostly reported increased incidental and low intensity intentional physical activity such as walking (n = 11); more general physical activity such as running and jumping (n = 4).

"...I would help more around the house and walk back and forth to do things… usually I would stay home but now I go out and stuff like that." (MG1)

5.5 Discussion:

The aim of this study was to explore young peoples' perceptions of pedometers and gain insight into the way young people behave while wearing pedometers. An additional aim was to investigate if participants' perceptions differed depending on their physical activity level. Responses from the focus groups indicated that the majority of participants' enjoyed wearing pedometers. However, some found them uncomfortable and embarrassing to wear which affected their level of adherence. Participants in the medium and high active focus groups reported changing their activity patterns more than the low active groups. The study findings not only support this existence of reactivity and tampering, but also provide future insight into why young people subconsciously or consciously change their activity patterns when being measured.

Missing data due to non-adherence to monitoring protocols is a widespread limitation of objective physical activity measurement [87, 144]. Participants were therefore questioned as to why they removed the pedometers. Most responses were expected (i.e. water activities, showering, contact sports.); other common responses were that it was 'embarrassing, annoying and/or uncomfortable'. This shows the need for more comfortable and less inhibiting devices to improve adherence in young populations. Emerging research suggests that participants consider wrist-worn devices to be more comfortable, less embarrassing and burdensome to wear than hip-worn devices [292-294]. Wrist-worn objective monitoring could address some of the issues that arose in the focus groups in relation to size, comfort and confidence in how they are perceived by their peers. However, it should be noted that some participants enjoyed wearing the pedometers, with some even reporting that they forgot that they were wearing it once they had it on.

Overall, participants' attitudes towards objective monitoring were positive. Most believed that pedometers are a useful tool for measuring young peoples' physical activity patterns. A large proportion of the participants reported purposely changing their normal activity and stated that they believed most of their peers did the same. The majority reported having done so through increasing incidental physical activity (e.g., walking on the spot while watching TV) and planned physical activity (e.g., going for a walk or jog), as well as increased effort and time in usual sports participation (e.g., running harder than they usually would during a game).

Most of the participants in the low active groups (both boys and girls) reported that they did not attempt to increase their step count during the monitoring period. The reported reasons for not changing their activity pattern ranged from having forgotten about the pedometer to not perceiving a need to increase their activity levels. It is has been reported that low active participants are less compliant with physical activity intervention protocols due to fear of the way they will be perceived by the researcher or peers [279]. On the contrary, our research suggests that the low active participants were less likely to change their activity patterns than the medium and high active participants.

Pedometer tampering has been identified as a threat to the accurate measurement of physical activity in young people [100, 172]. This study revealed that 21 out of the 24 (87.5%) participants in the focus groups reported shaking their pedometers to increase their step counts. As a high proportion of participants reported shaking their pedometers and changing their activity patterns as a result of being measured, future pedometer research in young peoples should examine various protocols that attempt to limit tampering and reactivity. For example, a pedometer protocol where participants were informed prior to the monitoring period that pedometer shaking would be detected may limit tampering. Alternatively, pedometers may have more utility as an intervention strategy for increasing activity rather than a method for assessing habitual behaviour in young people.

Although there is growing support for the existence of reactivity and tampering in young people [10, 172, 277], there is little research into how and why participants may change their behaviour whilst being measured. Our findings suggest the majority of participants in the study were reactive to the monitoring process, and reported most of their peers were also. This was interesting, as there was no reinforcement or incentive for participants to increase their step count; participants were told the study aim was to gain an estimate of their 'normal' activity pattern. Many participants reported 'peer competition' as another motivator to change their activity patterns. Others also reported they liked knowing what their step count was and were motivated to complete more daily physical activity than normal. Although this study is in a different context (not an intervention), it potentially confirms previous research that pedometers can be used as a useful tool to motivate young peoples to increase physical activity levels, although without knowledge and behavioural skills it is questionable whether this would be maintained [93]. Our findings indeed highlight the need for researchers to evaluate the study protocol when using pedometers prior to collecting data as it affects adherence, level of reactivity and amount of tampering. Greater understanding of participant perceptions and behaviours exhibited will lead to more efficient and accurate data collection.

Despite the novelty of this study, there are some limitations that should be noted. First, the study sample may not be fully generalizable to the target population, more qualitative studies in different young people populations are needed. Second, the monitoring period only seven days, a longer monitoring period would allow researchers to determine if reactivity and tampering would taper or be sustained. Third, triangulation with objective pedometer data was not completed. Future studies are encouraged to complete triangulation of data sources to improve conformability of findings. Fourth, due to feasibility limitations, the focus group questions were not pilot tested. Finally, participants were not questioned on pedometer protocol or whether behaviours differed on each day of the week, or in particular the first day of monitoring. Although a large proportion of the participants reported changing their normal activity patterns and tampering with their pedometers, we did not ask the participants about daily differences of reactivity and tampering. It is therefore difficult to determine if reactivity and tampering are ongoing or taper off over time. Future research in this population group should investigate whether reasons for changing activity pattern and pedometer tampering is consistent throughout the monitoring phase.

5.6 Conclusion:

This study is novel as it provides insights into young peoples' perceptions of, and behaviours during, the objective physical activity monitoring process. Our findings are consistent with previous quantitative studies that suggest reactivity and tampering are commonplace among young boys and girls. Of note, the vast majority of participants reported changing their activity patterns and tampering with the devices. In addition, there was unanimous agreement among participants that their peers also changed their activity patterns. Although the majority of participants believed that pedometers have value as a research tool, their behaviours and previous research [93] suggest that pedometers have more utility as an intervention strategy for increasing activity rather than a method for assessing habitual activity levels. As the research remains relatively sparse in this area, to properly understand participants' behaviours and perceptions, the authors recommend further qualitative research related to physical activity monitoring across populations groups and in free-living conditions.

Table 5.1: Characteristics of larger and focus group sample

	Sample (n = 123)		Focus group sample (n= 24)		Daily sealed group (n = 46)		Unsealed group (n = 44)		Weekly sealed group (n = 33)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	14.7	0.4	14.7	0.5	14.7	0.4	14.6	0.5	14.7	0.5
Height (cm)	169	9.6	168	9.9	171	8.8	168	10.7	169	8.5
Weight (kg)	60.4	11.3	62.7	13.4	58.8	8.5	63.6	13.4	58.7	10.3
Body Mass Index (BMI)	21.1	3.0	22	3.9	19.8	3.8	22.7	3.4	20.3	3.5
	n	%	n	%	n	%	n	%	n	%
Country of birth[1]	118	97	23	95.9	46	100	42	95	32	97
Language spoken at home[2]	116	96	23	95.9	43	94	42	95	33	100
Ethnicity[3]										
Australian	102	84.4	23	96	37	80.5	33	75	29	88
Aboriginal/Torres-strait Islander	2	1.6	1	4	0	0	2	4.5	0	-
European	14	11.6	0	0	7	14.5	5	11.4	2	6
Other	3	2.4	0	0	0	0	4	9.1	2	6

[1]*Participants born in Australia (missing n= 3)*
[2]*Participants who speak English at home (missing n= 1)*
[3]*Ethnicity (missing n= 2)*

Table 5.2: Examples of focus group questions

Question
Tell me what you thought of wearing a pedometer?
Did you feel that you had to get a high step count to impress the researchers, teachers or your friends? Why or why not?
Do you think that most people are honest or dishonest about their step count?
Do you think that trying to find physical activity levels with pedometers is a waste of time? Why or Why not?
Did you do more physical activity than normal when wearing a pedometer? Why or why not?
Did you attempt to increase your step count in anyway? If so, how?
What were the other kids doing? Do you think they changed their behaviours because they were being measured?
Did you let anyone else wear your pedometer? Why/why not?

CHAPTER 6: COMPARABILITY AND FEASIBILITY OF WRIST- AND HIP-WORN ACCELEROMETERS IN FREE-LIVING ADOLESCENTS

Preface: This chapter investigates that feasibility and concurrent validity the wrist-worn (GENEActiv) accelerometer in comparison to the hip-worn (ActiGraph GT3X+) in free-living adolescents. This chapter presents particularly novel findings as it uses 7 days of accelerometry in free living adolescents and self-report information to explore participants preferred accelerometer placement site on the body, which was more comfortable and if they would be willing to wear it on the hip or the wrist again. The findings from this chapter are important for researchers attempting to increase adolescent compliance to measurement protocols.

Citation:

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6 Comparability and feasibility of wrist- and hip-worn accelerometers in free-living adolescents

6.1 Abstract

Objective: To determine the comparability and feasibility of wrist- and hip-worn accelerometers among free-living adolescents.

Design: 89 adolescents (age = 13 - 14y old) from eight secondary schools in New South Wales (NSW), Australia wore wrist-worn GENEActiv and hip-worn ActiGraph (GT3X+) accelerometers simultaneously for seven days and completed an accelerometry behaviour questionnaire.

Methods: Bivariate correlations between the wrist- and hip-worn out-put were used to determine concurrent validity. Paired samples t-test were used to compare minutes per day in moderate-to-vigorous physical activity (MVPA). Group means and paired sample t-tests were used to analyse participants' perceptions of the wrist- and hip-worn monitoring protocols to assist with determining the feasibility.

Results: Wrist-worn accelerometry compared favourably with the hip-worn in average activity (r = 0.88, p < 0.001) and MVPA (r = 0.84 p < 0.001, mean difference = 3.54 mins/day, SD = 12.37). The wrist-worn accelerometer had 50% fewer non-valid days (75 days, 12%) than the hip-worn accelerometer (n = 152, 24.4%). Participants reported they liked to wear the device on the wrist (p < 0.001), and that it was less uncomfortable (p = 0.024) and less embarrassing to wear on the wrist (p < 0.001). Furthermore, that they would be more willing to wear the device again on the wrist over the hip (p < 0.001).

Conclusions: Our findings reveal there is a strong linear relationship between wrist- and hip-worn accelerometer out-put among adolescents in free-living conditions. Adolescent compliance was significantly higher with wrist placement, with participants reporting that it was more comfortable and less embarrassing to wear on the wrist.

Key words: ActiGraph, GENEActiv, Physical Activity, Compliance, Perceptions, Youth.

6.2 Introduction

Poor adherence to accelerometer monitoring protocols and subsequent missing data are major issues for researchers [104, 114, 140]. Low compliance reduces the sample size and subsequent statistical power, while high compliance is desirable because it provides a more accurate representation of habitual activity patterns [295]. Adolescents, in particular, have been a challenging population to measure with accelerometers [115, 172]. Reasons for poor compliance among adolescents include: dissatisfaction with the size and comfort of devices [172]; unwanted attention and increased risk of being bullied [140]; and feelings of embarrassment [61, 172]. Various strategies have been employed by researchers to increase compliance to accelerometer monitoring protocols, including: i) increasing the amount of researcher contact [296], ii) calls and SMS reminders [297], iii) activity logs [224], iv) gifts and cash incentives [140]. However, even with these strategies, compliance to accelerometer monitoring protocols among adolescents is poor, especially in longitudinal and experimental studies that require individuals to wear devices on multiple occasions [278, 298].

There is clearly an urgent need to reconsider accelerometer-monitoring protocols with adolescent populations. While the ActiGraph accelerometer is the most commonly used validated accelerometer in physical activity research [114], it is typically worn on the hip rather than the wrist and removed whilst sleeping, resulting in non-wear time prior to sleep time and after waking [260]. ActiGraph recently released the GT9X accelerometer which is designed to be worn at the wrist, which reflects a recent shift toward wrist-worn activity monitoring. Emerging research suggests that participants consider wrist worn devices to be less burdensome, resulting in higher levels of compliance [292, 293]. Notably, the National Health and Nutrition Examination Survey (NHANES) 2011–2012 revealed wear time was 100% greater for wrist-worn accelerometers in comparison to the previous years, when monitors were worn on the hip [157]. Such findings highlight the potential for using wrist-worn accelerometry increase participant’s compliance to protocols.

In recent years, there has been a proliferation in the number of commercially available accelerometers designed for both hip and wrist placement (e.g. Fitbit®, Smartband®, Archos Activity Tracker®, Vivofit®). While this has helped to reduce the cost of accelerometers and increase their use in large-scale research, it has introduced new challenges in the interpretation and comparability of accelerometer outputs [110]. The GENEActiv is a relatively new accelerometer, and laboratory studies using calibration with oxygen consumption, have shown that this wrist-worn device can accurately assess children's and adults' physical activity intensity [156, 299]. Moreover, a recent field-based study [104] compared the wrist-worn GENEActiv and the hip-worn ActiGraph GT3X+ monitors in children and found higher compliance for the wrist-worn device, regardless of the wear-time criteria applied. In terms of concurrent validity, the authors reported a strong positive association between output from the two accelerometers (MVPA, $r = 0.83$, $p < 0.001$).

To the authors' knowledge, no previous study has examined the acceptability and comparability of wrist- and hip-worn accelerometers among adolescents in free-living conditions. Therefore, the primary aim of this study was to test the comparability and feasibility of wrist- and hip-worn accelerometers in a sample of free-living adolescents. A secondary aim was to compare wear-time, missing data and participant perceptions of the wrist and hip device placement in this population. Improving our understanding of adolescents' perceptions of the monitoring process is vitally important, and will help guide researchers to improve the accuracy of assessment in a sub-population who have been largely neglected in physical activity research.

6.3 Methods

Data for the current study were collected during baseline assessments as part of the existing Switch-off 4 Healthy Minds' (S4HM) cluster randomised controlled trial [1]. S4HM was a recreational screen-time reduction intervention targeting male and female adolescents in Grade 7 (first year of secondary school) in eight independent schools in NSW, Australia (2014). Ethics approval for the study was obtained from the Human Research Ethics Committees of the University of Newcastle, Newcastle-Maitland Catholic Schools Office and the Diocese of

Broken Bay. All students in grade 7 were invited to be involved in the study and were considered eligible to participate in the S4HM study if they self-reported ≥ 2 hrs/day of recreational screen time per day. Students who satisfied the eligibility criteria and provided signed written informed parental consent, were invited to participate in the study. Of the 322 eligible participants, every third student from each school (n = 113) was randomly selected and invited to participant in this study component. Data were collected in New South Wales (NSW), Australia in April/May 2014 (Term 2 of the school year). Participants were asked to wear both wrist- and hip-worn accelerometers simultaneously for seven full days and complete an accelerometry behaviour questionnaire that was designed for the purpose of this study.

Participants wore the Gravity Estimator of Normal Everyday Activity (GENEActiv), seismic acceleration sensor, dynamic range +/- 8g, ActivInsights, Cambridgeshire, UK) on their non-dominant wrist. Using the GENEA software (version 2.2), the devices were initialized to collect tri-axial acceleration data at a sample rate of 100 Hz. Participants also wore the ActiGraph GT3X+ (monolithic differential capacitance sensor, dynamic range +/- 6g, ActiGraph LLC, Pensacola, FL, USA) on the non-dominant hip. Using the Actilife5 (version 6.5.3) software the ActiGraph GT3X+ devices were initialized to collect tri-axial acceleration data at a sample rate of 80 Hz. This study used different sampling frequencies for each monitoring device, however due to the nature of the signal processing (summarising output over 15 s epochs) this difference in sampling frequency would not have impacted on the output [111]. The accelerometry behaviour questionnaire was based on a previous pedometer questionnaire designed to examine participants' perceptions of the objective monitoring process [172]. The questionnaire consisted of eight questions, each scored on a 5-point Likert- scale. The questions explored students' perceptions of wearing accelerometers with responses ranging from 1 = *strongly disagree* to 5 = *strongly agree*. The wording of the items was derived from a previous pedometer questionnaires designed for adolescents. They were then reviewed by academics that have an expertise in physical activity interventions for input and feedback. The questionnaire was administered on the last day of the monitoring phase. Responses from the accelerometry behaviour questionnaire were used to provide insights into participants' perceptions of the monitoring process and to compare feasibility of the wrist- and the hip-worn devices among adolescents in free-living conditions.

The monitoring process was a total of nine days from dispersal to collection of the monitors, the first and last day were excluded from the analysis as they were only partial monitoring days, leaving seven-days. This study used a 24hour/day wear-time accelerometer protocol, compliance has been shown to be higher with 24 h/day protocols for both wrist-worn [300] and hip-worn monitors [301]. Both accelerometers were time and date synchronised using the same clock to start recording at 00:01am on Day 1 and finish recording at 11:59pm on Day 9. On completion of the monitoring period, participants returned both accelerometers and completed the accelerometry behaviour questionnaire. The GENEActiv data were downloaded with GENEActiv software (version 2.2). R-package GGIR version 1.2-2 (http://cran.r-project.org) and was used to process and analyse GENEActiv .bin files (This includes auto-calibration using local gravity as a reference) [302]. The software was used to detect abnormally high values and non-wear time, and to calculate the average magnitude of dynamic acceleration (Euclidean Norm minus 1 g, ENMO) over 15-seconds epochs, with negative values rounded up to zero.

$$\text{ENMO} = \sum \sqrt{x^2 + y^2 + z^2} - g$$

The cut-points applied to calculate MVPA based on ENMO values were taken from a recent study by Phillips et al [299] and adjusted for the 100 Hz sampling frequency and 15-second epochs. The adjusted ENMO value used in the current study was ≥20gs. Individual days were classed as invalid and excluded if wear-time was less than 10h. The detection of non-wear followed the procedures of Van Hees and colleagues [302]. Non-wear was estimated using the standard deviation (SD) and value range of each axis, calculated for 60 minute windows with 15-minute moving increments. If the SD on two of the three axes was less than 13mg or the value range was less than 50mg, the time window was classified as non-wear. In this study, there was no reclassification activity or imputation of missing data for the GENEActiv data, nor the GT3X+ data. Mean daily activity (ENMO, m*g*) and MVPA were the output variables used in the analysis.

The hip-worn ActiGraph GT3X+ data were downloaded with the Actilife5 (version 6.5.3) software. The GT3X files were converted to 15s epoch AGD files for analysis of count data. The data were cleaned and scored using Actilife5 software (version 6.5.3). Non-wear was defined as ≥20 minutes of consecutive zero counts [303]. To remain consistent with previous studies, the wear-time criteria for both monitoring devices was ≥10hours/day on ≥3 days/week. Any participants that did not meet the minimum wear-time criteria were excluded from the analysis [114]. MVPA was estimated by applying the commonly used adolescent Evenson cut-points to the vertical count data (i.e. ≥ 2296 CPM) [284]. Mean daily activity (average daily vector magnitude counts (VM, cpm) and daily MVPA (mins/day) were the output measures used in analysis.

The mean daily activity and MVPA (mins/day) data, along with responses to the accelerometry behaviour questionnaire were imported and analysed using IBM Statistics (SPSS 12 Inc. Chicago, IL) software and alpha levels set at $p < 0.05$. The data for the GT3X+ and GENEActiv were matched on concurrent valid whole days where participants were wearing both devices at the same time (at least three valid week days of wear-time at ≥10hrs/day on both wrist- and hip-worn accelerometer). A more sensitive approach such as epoch matching may have allowed a more accurate assessment of concurrent validity, however this approach may lack ecological validity. Pearson bivariate correlations between the wrist- and hip- (daily mean physical activity and daily MVPA) accelerometer output were calculated to examine the relationship of the wrist- and hip-worn accelerometer data over the monitoring period. Paired samples t-tests were used to explore individual difference in MVPA mins/day for week and weekend days. Frequency analysis was used to reveal the amount of days that participants did not wear either device; or wore one device and not the other. Responses to the accelerometry behaviour questionnaire were coded and imported into SPSS to be analysed quantitatively. Analysis of group means and paired sample *t*-tests were used to analyse the differences in participants' perceptions of the monitoring process.

6.4 Results

A total of 113 participants were involved in the monitoring process, of which 89 (41 boys, 48 girls) met the inclusion criteria (at least three valid week days of wear-time at ≥ 10hrs/day on both wrist- and hip-worn accelerometer) and were included in the concurrent validity analysis. If the participant wore only once device and not the other, this day was removed and excluded from the analysis and treated as missing data (n = 132 days removed, 21.18%). Only 57 participants provided both wrist and hip accelerometry data for weekend days. Due to one participant being absent at the time of questionnaire completion, 112 participants completed the accelerometry behaviour questionnaire. The questionnaire responses were only included in the analysis if the participant had met the accelerometry inclusion criteria, the remaining (n = 23) were excluded.

Pearson bivariate correlations (shown in Table 1) revealed strong associations between the wrist- and hip-worn output in both daily mean activity ($r = 0.88$, $p < 0.001$, 95% CI = 0.82 - 0.93) and MVPA ($r = 0.84$, $p < 0.001$, 95% CI = 0.77 - 0.89) over the 7 days. When analysing the weekdays only, the correlations were strong but slightly lower in both daily mean activity ($r = 0.84$, $p < 0.001$, 95% CI =0.76 - 0.89) and MVPA ($r = 0.79$, $p < 0.001$, 95% CI = 0.72 - 0.85). Furthermore, weekend days only, whilst lower again, there was moderate association for daily mean activity ($r = 0.71$, $p < 0.001$, 95% CI = 0.56 - 0.82) and MVPA ($r = 0.53$, $p < 0.001$, 95% CI = 0.37 - 0.71). Paired samples t-tests (shown in Table 2) revealed a low mean MVPA difference between the wrist and hip output on both weekdays (mean difference = 3.54 mins/day, $p = 0.001$) and weekend days (mean difference = 1.57 mins/day, $p = 0.632$). Tests for proportional bias indicated that there was a correlation between mean physical activity and the difference in estimates for acceleration (r = 0.18, p > 0.05) and MVPA (r = 0.46, p <0.001).

Participant compliance to the monitoring protocols ranged from 3-7 days and is presented in Table 3. Overall the hip-worn accelerometer (152 days, 24.4%) had twice as many non-valid (missing) days than the wrist-worn accelerometer (75 days, 12%). In boys, there was minor difference in compliance between wrist and hip (wrist = 43 days, hip = 56 days), whereas for girls; there were three times as many non-valid days for the hip-worn accelerometer (n = 96), compared to the wrist-worn accelerometer (n = 32). Paired samples t-tests of non-valid (missing) days revealed that the mean difference between wrist- and hip-worn data was 11days (SD = 10.6, p = 0.031), for weekdays only (mean difference = 5.4, SD = 4.5, p > 0.05) and weekend days only (mean difference = 25, SD = 7.1, p > 0.05). Analysis of the excluded data due to participants only wearing one device revealed that participants were three times more likely to wear the wrist-worn accelerometer (n = 33 missing days) than only wear the hip-worn accelerometer (n = 99 missing days).

Participants reported a preference for the wrist-worn accelerometer (mean = 3.18, SD = 0.10), compared to the hip-worn accelerometer (mean = 2.51, SD = 1.01). Participants reported wearing the device on the wrist to be less uncomfortable and less embarrassing (mean = 1.93, SD = 0.10) to wear, compared to the hip-worn accelerometer (mean = 3.35, SD = 1.06; mean = 2.42, SD = 1.20, respectively). Participants reported they would be more willing to wear the wrist-worn accelerometer (mean = 3.65, SD = 1.06) than the hip-worn accelerometer (mean= 2.74, SD = 1.33) in future assessments. Participants, particularly adolescent females, reported the wrist-worn accelerometer to be more comfortable (p = 0.032), and less embarrassing (p < 0.001), to wear than the waist-worn accelerometer, but there were no other statistical differences between the wear sites based on mean scores for both sexes.

6.5 Discussion

This study investigated the concurrent validity and feasibility of wrist- and hip-worn accelerometers in a free-living adolescent population. We found that the wrist-worn accelerometer output compared favourably with the hip-worn accelerometer output in both mean daily activity and MVPA. In addition, the participants reported that they liked wearing the wrist-worn accelerometer more than the hip-worn accelerometer and would be more willing to wear it again on the wrist over the hip. Furthermore, there was three times as much missing data for the hip-worn accelerometer than that of the wrist-worn accelerometer.

By comparing the wrist-worn (GENEActiv) accelerometer output to the previously validated hip-worn (ActiGraph GT3X+) output under free-living conditions, this study provides an important contribution. Our findings revealed that the physical activity outcomes from the wrist-worn accelerometer were strongly associated with hip-worn accelerometer output for both physical activity patterning ($r = 0.88$, $p < 0.001$) and ranking of activity level ($r = 0.84$, $p < 0.001$) within the sample, however absolute values differed. In MVPA minutes, there was also a low mean difference (3.54 mins/day weekdays, 1.57 mins/day weekend days) between the devices with the hip-worn accelerometer estimating slightly higher activity on both weekdays and weekend days. A strength of this study was that it reported the mean difference (minutes) between the wrist- and hip-worn accelerometers, which has not previously been done in previous adult and child GENEActiv validation. These findings may have relevance for researchers interested in evaluating physical activity intervention effects, but it is important to note that the results are dependent on the selected cut-points, population group and monitor used. Our results support previous findings reported in children and adults, where the wrist-worn GENEActiv compared well to the hip-worn ActiGraph GT3X+ in both acceleration and MVPA [104]. Moreover, the small mean difference between the monitors provides a unique contribution to the literature.

However, our findings differ to the previous findings of GENEActiv studies that concluded that the wrist worn GENEActiv had higher physical activity estimates than the hip worn ActiGraph [104, 111]. Further equivalency studies are required to determine the interchangeability of the devices, application of cut-points and site placement of the accelerometer. To remain consistent with the literature, the application of cut-points was based on previous studies in adolescents that have used ActiGraph and GENEActiv accelerometers to quantify activity [145, 284, 304]. For the GENEActiv monitor, this study used the Phillips et al [299] left wrist cut-points. Evenson cut-points were applied to the ActiGraph GT3X+ data. As cut-points are developed specifically for each accelerometer monitoring device and are both protocol- and population-specific, direct comparison of devices is very difficult, and further research into the application of different cut-points and the influence on estimates of sedentary, light, moderate and vigorous physical activity is clearly warranted.

A recent study in free-living adult women compared physical activity estimates for both hip and wrist site placements and concluded that there was only moderate correlation between the two sites [305]. A further study in an older adult population compared physical activity estimates for different wear-time protocols and hip and wrist placement with GT3X+ accelerometers. Findings revealed that wear-time adherence for the hip and wrist only varied by 2.7%, however, activity estimates for hip and wrist were statistically different and varied by as much as 41% [306]. These results differed to a study that compared GT3X+ accelerometer activity estimates at both the hip and wrist in pre-school aged children, which found a strong correlation between hip and wrist ($r = 0.81$, $p < 0.01$) accelerometer output. However, but large systematic bias with wide limits of agreement were observed [307]. Differences in accelerometer protocol and data reduction techniques for both hip and wrist accelerometers may explain the current inconsistencies found in the literature. Standardisation of hip and wrist accelerometer protocols are clearly warranted.

A recent study concluded that the GENEActiv can accurately assess physical activity intensities in children when worn at the hip or wrist [299]. Although previous research has also highlighted decoupling differences in hip and wrist accelerations depending on the type of activity and level of intensity in children [308]. This becomes more complex in free-living conditions when hip and wrist accelerations can be more disproportionate [157]. As the research is currently limited on preference for site placement in adolescents [104, 309], our study compared the wrist and hip placement site in a free-living adolescent population. It was expected that the hip and wrist accelerometer would be subjected to slightly different movements, which would account for some minor degree of error. Of note, correlations were lower on weekend days in comparison to weekdays. This finding may reflect the way that young people spend their weekends. For example, emerging research suggests that children are more active during weekdays, while on weekends they spend large amounts of time sedentary engaged in seated screen-based recreation [104, 157]. It has also been reported in the literature that activity in free-living adolescents is different on weekend days in comparison to weekdays where activity is commonly more routinized and structured [310]. These differences of daily activity patterns may also influence the accuracy of both hip and wrist activity estimates.

Previous research has identified the challenges of assessing physical activity using objective measures in adolescent populations [115, 277]. Studies in children have revealed that compliance is higher when devices are worn on the wrist, in comparison to hip placement [104]. This study was designed to confirm this finding among adolescents in free-living conditions and assess participants' perceptions of the two placement sites. To determine feasibility, adolescents self-reported their perceptions of the two placements sites and the research team compared accelerometer protocol compliance. Compliance to the monitoring protocol was operationalized as whole days that the monitor was worn, rather than periodic removal. Our results revealed twice as much non-valid (full days) for the hip-worn accelerometer (n = 152, 24.4%), compared to the wrist-worn accelerometer (75 days, 12%). The boys (wrist = 43, hip = 56) had fewer total missing days for the wrist-worn accelerometer. In girls, there was three times more missing days on the hip-worn accelerometer than the wrist-worn accelerometer (wrist = 32, hip = 96). Hence, in both sexes there was less missing data for the wrist-worn accelerometer indicating higher compliance to the seven-day protocol. The results also revealed that participants were three times more likely to wear only the wrist-worn accelerometer.

This study is novel as it used a self-reported questionnaire, to not only investigate participants' preferred accelerometer site placement, but also investigated some of the potential reasons why. Our findings showed that adolescents found the wrist-worn device to be more comfortable and less embarrassing to wear. Interestingly, there were sex differences; girls reported that they found the hip-worn accelerometer more embarrassing to wear than the boys. Previous research has shown that girls have higher dissatisfaction with body image and concerns with body changes than boys [311], which could be a reason for preferring to wear the device on the wrist rather than around their waist. This may be an important finding as adolescent girls are a target population for physical activity interventions due to low activity levels [140, 222].

Both the hip-worn GT3X+ and the wrist-worn GENEActiv devices are robust, waterproof, light weight and have long battery life. An additional advantage of the GENEActiv is its watch-like appearance. Indeed, the design and appearance of the accelerometer may be a key determinant in increasing adolescent compliance, especially in girls who have previously shown poor adherence to physical activity intervention protocols and reported a dislike to the physical appearance of accelerometers [61, 224]. Wrist-worn GENEActiv accelerometer data correlated with the previously validated hip-worn GT3X+data (mean activity: $r = 0.88$, $p < 0.001$; MVPA: $r = 0.84$, $p < 0.001$), and also daily compliance was far higher. The participants reported they liked wearing the accelerometer on the wrist more than the hip, and reported a higher willingness to wear it again on the wrist over the hip. This may be an important finding, as previous physical activity intervention research in adolescents have found poorer compliance to accelerometer protocols in post-test and follow-up assessments [224, 278]. As non-compliance to accelerometer protocols is such a complex issue in the adolescent population [114, 140], further investigation into reasons why participants choose to wear one device over the other or simply not comply with protocol is warranted.

To our knowledge, this the first study to examine the concurrent validity and feasibility of wrist- and hip worn accelerometers among adolescents in free-living conditions. Despite the importance of our study findings, some limitations should be noted. First, the sample was relatively small and findings may not be generalizable to the entire adolescent domain. Second, for MVPA, the cut-points used for each device may have affected the classification of intensity of activity. Third, Other than sex, no other participant characteristics were analysed for association with wear time. Fourth, this study primarily focused on comparability of hip and wrist accelerometer placement rather than the equivalency of the ActiGraph GT3X+ and the GENEActiv; further research using raw accelerometer data is warranted to determine the interchangeability of the two monitoring devices. Finally, the accelerometry behaviour questionnaire was not piloted with a group of adolescents prior to data collection and has not been fully validated in adolescents.

6.6 Conclusion

The wrist-worn accelerometer (GENEActiv) showed good concurrent validity when compared to the previously validated hip-worn accelerometer (ActiGraph GT3X+) in both daily mean activity and MVPA. Our findings reveal there is a strong linear relationship between the wrist- and hip-worn accelerometer output and that daily wear-time compliance was far higher for the wrist-worn accelerometer. Overall, adolescents reported a preference for the wrist-worn accelerometer. More specifically, adolescents considered the wrist-worn accelerometer to be more comfortable and less embarrassing to wear and importantly, that they would be more willing to wear it again on the wrist rather than the hip. The use of wrist-worn accelerometer may assist researchers to increase participant compliance to accelerometer protocols in free-living adolescents. The authors recommend further adolescent physical activity studies utilise wrist-worn accelerometry to increase the probability of higher compliance to protocol, as greater wear time will provide a more accurate assessment of habitual physical activity.

Table 6.1: Relationship between the wrist- and hip-worn accelerometer output

		Wrist vs Hip	
		Mean acceleration *(VM vs ENMO mgs)*	MVPA *(Minutes)*
All days	*r*	0.88*	0.84*
	p-value	< 0.001	< 0.001
	n	89	89
Weekdays only	*r*	0.84*	0.79*
	p-value	< 0.001	< 0.001
	n	89	89
Weekend days only	*r*	0.71*	0.53*
	p-value	< 0.001	< 0.001
	n	58	58

**Significant at 0.05*

Table 6.2: Paired sample t-tests to explore individual differences in MVPA

	Wrist	Hip		
	Mean (SD)	Mean (SD)	Mean difference (SD)	*p*-value
Weekday MVPA mins/day (n= 89)	31.1 (19.2)	34.6 (19.1)	3.5 (12.4)	< 0.001
Weekend days mins/day (n= 57)	32.7 (21.5)	34.3 (27.3)	1.6 (24.2)	0.632

Table 6.3: Comparison of non-valid (missing) days

		Wrist			Hip		
		All	Boys	Girls	All	Boys	Girls
	n	89	41	48	89	41	48
Monday	(Days missing)	0	0	0	1	1	0
	(%)	0	0	0	1.2	2.4	0
Tuesday	(Days missing)	5	3	2	10	2	8
	(%)	5.6	7.3	4.2	11.2	4.9	16.7
Wednesday	(Days missing)	13	7	6	17	7	10
	(%)	14.6	17.1	12.5	19.1	17.1	20.8
Thursday	(Days missing)	10	7	3	23	8	15
	(%)	11.2	17.1	6.3	25.8	19.5	31.3
Friday	(Days missing)	24	12	12	28	11	17
	(%)	27.0	29.3	25.0	31.5	26.8	35.4
Saturday	(Days missing)	16	8	8	36	14	22
	(%)	18.0	19.5	16.6	40.4	34.2	45.8
Sunday	(Days missing)	7	6	1	37	13	24
	(%)	7.9	14.6	2.1	41.6	31.7	50.0
Total days missing/week		75	43	32	152	56	96
Total missing/week (%)		12.1	6.9	5.1	24.4	9.0	15.4

Figure 6.1. Scatter plot showing linear fit of acceleration measured by hip-worn GT3X+ (VM) against the wrist-worn GENEActiv ENMO (mg)

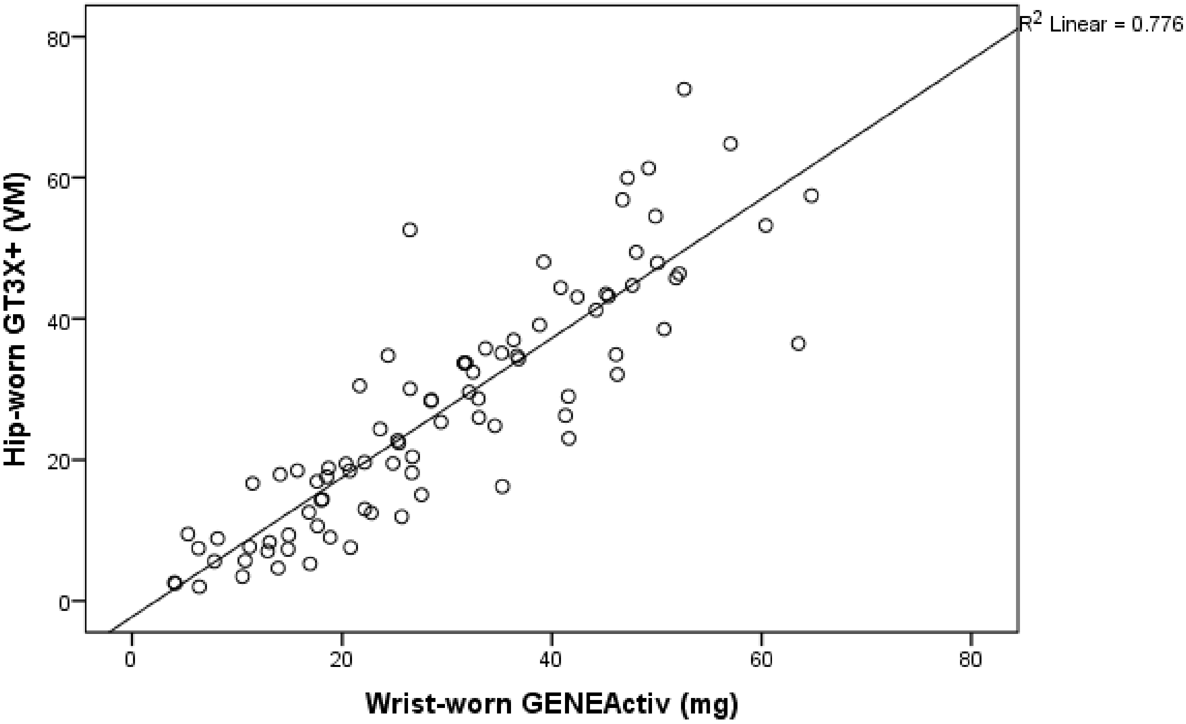
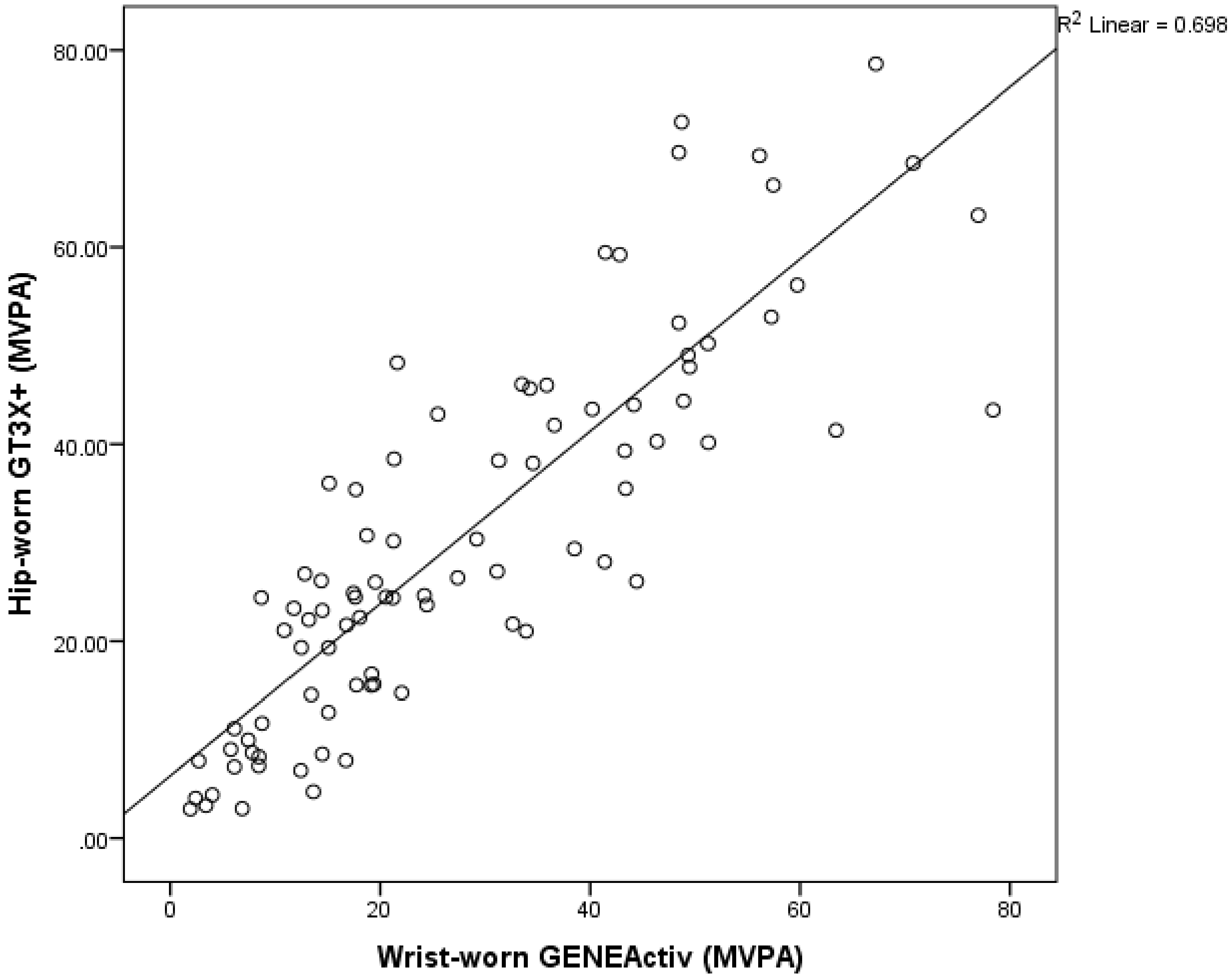


Figure 6.2. Scatter plot showing linear fit of MVPA (minutes) measured by hip-worn GT3X+ against the wrist-worn GENEActiv



Note: Moderate-vigorous physical activity (MVPA) reported in minutes

7 CHAPTER 7: DISCUSSION

7.1 Overview

As this thesis is presented as a series of publications, the findings for each of the research aims have been reported and discussed comprehensively in the preceding chapters. Therefore, the purpose of this chapter is to synthesise these findings and address the thesis overall aim and study objectives of the thesis.

The overall aim of this thesis was to investigate current physical activity measurement protocols to assess physical activity levels in adolescents.

The study objectives of this thesis were to:

1. Assess the test-retest reliability of a single-item physical activity questionnaire for adolescents;
2. Determine the concurrent validity of a single-item physical activity measure for adolescents, by testing it against accelerometer output;
3. Explore the impact of different pedometer monitoring protocols on compliance, reactivity and tampering in a sample of adolescents;
4. Explore adolescents' perceptions of wearing pedometers and investigate behaviours exhibited by participants while wearing pedometers;
5. Test the comparability of hip- and wrist-worn accelerometers in the free-living adolescent population; and
6. Compare wear-time, missing data and participant perceptions of hip- and wrist-worn accelerometers in the adolescent domain.

Furthermore, this chapter highlights the strengths and limitations of the studies conducted in this thesis, and provides a series of evidence-based recommendations for future research and practice.

This chapter includes the following sections:

1. Section 7.3: reliability and validity of a single-item physical activity questionnaire;
2. Section 7.4: pedometer monitoring protocols in adolescents: compliance, reactivity and tampering;
3. Section 7.5: a qualitative investigation of adolescents' perceptions of the pedometer monitoring process; and
4. Section 7.6: comparability and feasibility of wrist- and hip-worn accelerometers in adolescents.

7.2 Research gaps addressed by this thesis

This thesis addressed the following existing gaps within the evidence base:

1. Current physical activity questionnaires designed for young people vary in length and complexity [15]. There is a need for standardised self-report measures designed specifically for adolescents that are not burdensome for participants to complete. Short physical activity questionnaires have been validated in both child and adult populations [12, 53, 248, 312]. However, no single-item screening measure for adolescents has been validated against both an existing physical activity questionnaire and accelerometer output. Further research is warranted to determine the utility of single-item physical activity questionnaires for adolescents.
2. While there have been numerous pedometer validation studies [10, 313] and reviews of existing methodological elements in this domain [16, 87, 95], there is a lack of consensus regarding the optimal pedometer protocol for measuring habitual physical activity in adolescents.
3. Few studies have investigated adolescents' perceptions of, and behaviours exhibited, during objective pedometer monitoring [61]. Consequently, there is little evidence in relation to adolescents' perceptions of pedometer monitoring and the behaviours that they exhibit during the monitoring phase in free living conditions.

4. Little is known regarding the comparability of physical activity estimates from wrist- and hip-worn accelerometers in free-living adolescents. In addition, no previous study has investigated participants' perceptions of both devices among adolescents in free-living conditions.

7.3 Validity and reliability of a single-item physical activity questionnaire

7.3.1 Overview of findings

With the growth of physical activity research in the last two decades, there has been a large number of physical activity questionnaires developed [314]. It has been suggested that shorter questionnaires may reduce the amount of missing data, reporting inaccuracies and participant fatigue [81]. As existing questionnaires vary in length and complexity [15], more simplified questionnaires may prove to be particularly useful in adolescents, who have shorter attention spans than adults [80].

Chapter 3 investigated the test–retest reliability and concurrent validity of a single-item physical activity questionnaire in a sample of adolescents, by comparing it to an existing physical activity questionnaire (OPAQ) and accelerometer-determined MVPA. The single-item questionnaire for the study was modified from a previous single-item measure that was validated in adults [12]. The single item questionnaire asked participants to report the amount of days in the past week in which they had engaged in 60 minutes of MVPA/day. Overall, the single-item measure compared well with the more comprehensive physical activity questionnaire (OPAQ) in both test–retest reliability and concurrent validity.

It should be noted that although the ActiGraph GT3X+ accelerometer was used as the criterion measure to validate the single-item questionnaire, accelerometers quantify physical activity differently to self-report measures. The single item measure asks respondents to report time spent in MVPA in the last 7days. However, the OPAQ, ask respondents to report time spent in a particular activity (i.e. type of activity, start/finish time). This can then be converted into a MET count based on an intensity of the activity type [264]. Time-spent in various intensities can then be calculated which was completed for the OPAQ. However, inaccuracies can occur as this assumption is that the intensity of activity stays the same for the duration reported, researchers could therefore significantly over report activity intensity with the application of a MET count. This could account for the overestimation of self-reported MVPA in comparison to the accelerometer determined MVPA.

The single-item measure was found to have good repeatability (ICC = 0.75). Previous research has reported that reliability of physical activity questionnaires is often poorly assessed, and ICC is considered preferable to Spearman's rank or Pearson's correlation [14]. This is encouraging, as the research suggests that ICC values > 0.70 are considered to be acceptable [315], and a recent review of physical activity questionnaires in youth reported that most existing questionnaires were found to have moderate reliability (i.e., ICC = 0.64 - 0.80). The study in Chapter 3 was strengthened as the reliability testing also addressed proportional bias and typical error, as ICC only tests consistency between trials [13]. Pearson correlations between inter-trial difference and the mean of the trials revealed that the OPAQ had slight proportional bias (r = -0.17, 95% CI = -0.43 - 0.10, p = 0.139) and no relationship between participants' MVPA inter-trial difference for the single-item measure (r = 0.08, 95% CI =-0.12 - 0.26, p = 0.465). Although there were significant linear relationships between the single item measure and accelerometer output, absolute differences were large.

For concurrent validity, self-reported MVPA from the single-item questionnaire was then compared with participants' accelerometer-determined MVPA and self-reported MVPA from the OPAQ. Bivariate correlations between the single-item questionnaire and accelerometers and self-reported physical activity were r = 0.50 and r = 0.44, respectively. Recent reviews of youth physical activity questionnaires that have been validated against accelerometers reported that correlation coefficients ranged from 0.25 - 0.41 [14] and from 0.30 - 0.40 [71]. Thus, findings from this study suggest that the single-item questionnaire had comparable reliability and superior concurrent validity, compared with existing physical activity measures in adolescents.

7.3.2 Strengths and limitations

This study was novel as it tested a single-item physical activity measure in an adolescent population by validating it against accelerometer output and self-reported data from an existing physical activity questionnaire. Previous reviews of the validity of physical activity questionnaires have noted that reliability is often not assessed appropriately, as the majority of studies have used Spearman's and Pearson's correlations [57, 114]. In an attempt to overcome the limitations of previous research, this study assessed reliability in three ways (that is, repeatability, change in mean and proportional bias).

There are some limitations that should be noted. First, the convenience sample used for this study was small and relatively homogenous, which may limit the generalisability of findings. Second, adherence to accelerometer protocols was lower than desired, and the inclusion criteria were subsequently modified to maximise the sample size. The low adherence to the seven-day monitoring protocol meant that it was could not be determined whether participants met the recommended physical activity guidelines, based on output from both the single-item measure and the accelerometer. Third, this study did not randomise the order of questionnaire completion. Finally, due to feasibility restrictions, it was not possible to test the reliability and validity in a broader age range of adolescents (i.e., ages 12 - 18). Consequently, further testing of this measure in other adolescent populations is warranted.

7.3.3 Implications for practice and recommendations for future research

- The single-item measure is simple to administer and appears to have utility as a screening tool for adolescents, to determine whether or not they are meeting physical activity guidelines. This measure does not, however, provide the detail of more comprehensive questionnaires (e.g., activity type, duration, intensity, time of day/week, daily activity patterns) and may lack the necessary sensitivity to identify and quantify associations with health outcomes and physical activity invention effects.

- Physical activity questionnaires have many limitations. There is a vast number of existing physical activity questions that vary in accuracy, type, length and complexity. Researchers should base their choice of physical activity questionnaire on both study aims and the age of the study population. Further research into the appropriate length and detail of physical activity questionnaires will lead to more efficient and accurate physical activity data. Due to the noted limitations with self-report measures, researchers should consider using an objective method for assessing physical activity in addition to any self-report questionnaire.

7.4 Pedometer monitoring protocols in adolescents: compliance, reactivity and tampering

7.4.1 Overview of findings

Research in child and adult populations suggests that reactivity does not exist if pedometers are sealed [58, 160, 270]. Moreover, research on pedometer tampering in adolescents is sparse, and the level of tampering based on the type of pedometer protocol administered has not been investigated [100]. The aim of the study in Chapter 4 was to investigate adolescents' reactivity and tampering while wearing pedometers, by comparing different monitoring protocols to accelerometer output. A secondary aim of Chapter 4 was to explore adolescents' perceptions of wearing pedometers and investigate some of the behaviours they may exhibit while being measured.

In the study discussed in Chapter 4, participants were randomly allocated to one of three pedometer protocols (daily sealed, weekly sealed and unsealed pedometers). Repeated measures ANOVA was used to explore potential reactivity during week days. There was evidence of reactivity in both unsealed groups, yet step counts remained relatively stable across the monitoring period in the weekly sealed group. This was most likely due to sealing of the pedometer and minimising adolescents' step count feedback. Of note, participants in the daily sealed group reported a higher desire to impress the researchers by changing their normal activity pattern, most commonly by inflating their step counts. This was an important finding, as participants in this group were required to report to a researcher each day to have their step counts recorded. Almost half (49%) of participants reported tampering with their pedometers (shaking to increase step-counts) during the seven days of monitoring. Furthermore, 40% indicated they did not like wearing pedometers, with 81% finding them uncomfortable, and 69% finding them embarrassing to wear at times. These statistics provide some insight into why non-compliance with pedometer monitoring protocols is so high among adolescents. These findings also highlight the need for less burdensome and more discreet and comfortable devices, to increase compliance in this population.

The findings clearly demonstrate that reactivity and tampering occur in adolescents and that the protocol selected for pedometer monitoring may influence compliance. Correlations between step counts and accelerometer counts were strongest in the weekly sealed group, suggesting that this was the most reliable protocol of the three. Correlations with accelerometer output were weakest in the daily sealed group, suggesting potential tampering, perhaps due to daily contact with researchers. The results revealed that adolescents find objective measuring devices uncomfortable and embarrassing to wear, and a large proportion reported a desire to impress their peers and/or researchers by inflating their normal step count (e.g. by increasing activity or shaking their pedometer). Almost half the participants self-reported tampering with their pedometers.

7.4.2 Strengths and limitations

This study used seven days of objective monitoring to evaluate three different pedometer protocols. The protocols differed not only with various restrictions in the nature of feedback of step counts, but also in the level of contact with the researchers. A major strength of this study was the simultaneous assessment of physical activity using accelerometers and pedometers and the triangulation of findings using questionnaires. Indeed, the self-report questionnaire data provided valuable insights into the way that adolescents behaved during pedometer monitoring and some of the reasons for changing their activity patterns.

Despite these strengths, there are some limitations that should be noted. First, the compliance with objective monitoring protocols was lower than expected. The wear-time criteria was modified to include as many participants as possible for the analysis. Second, a pattern of reactivity was evident in the daily sealed and unsealed groups, but it is not definitive that it was not a ‘day-to-day’ difference in physical activity (e.g., participation in physical education or sport training). This is unlikely, however, as the weekly sealed group showed no significant differences across days. Third, pedometers were only sealed with stickers. The CW700 pedometers were selected due to their ability to record steps over seven days. However, these devices are not lockable and cannot be sealed with ‘zip-ties’. Stickers were used to give researchers daily access to step counts in the daily sealed group and also to enable researchers to tell if the pedometers had been opened or tampered with. Of note, many of pedometers that were returned displayed evidence of tampering (i.e., torn sticker). Finally, due to feasibility limitations, this study did not use a cross-over design, which would have provided an opportunity to assess the adolescents using each of the three monitoring protocols.

7.4.3 Implications for practice and recommendations for future research

- As the weekly sealed pedometer monitoring protocol was the most accurate and least influenced by reactivity and tampering, researchers should use at least a seven-day pedometer monitoring timeframe with sealed pedometers.
- Due to the level of reactivity and self-reported tampering with pedometers, researchers may instead use accelerometers, which normally do not provide a step count feedback to participants. The level of researcher contact may influence participants' desire to impress. Hence, reducing the contact between researchers and participants may lower the chance of participants feeling the need to change their normal activity patterns. It is therefore recommended that researchers use pedometers that have the ability to store data in their internal memory for seven days (or longer). These pedometers are required to be time set prior to monitoring; however, once initialised, they will automatically restart the step-count each day. This eliminates the risk of accidental reset and the requirement for participants to self-report daily step counts.
- Pedometer sealing is recommended to limit the feedback effect. Stickers are useful to determine whether the pedometer has been opened or tampered with; however, more stringent measures (such as the use of lockable monitors) will ensure that the pedometer is not opened for the entire monitoring period. Furthermore, manufacturers may need to consider the production of lockable pedometers for research purposes.
- This study revealed that a third of participants reported completing more activity than normal when being measured. The feedback of step counts appears to be an added

advantage of pedometers, and may still be a useful motivator for adolescent physical activity interventions.

- Manufacturers of pedometers and accelerometers for research purposes should endeavour to design devices that possess the ability to detect shaking through machine learning. This may enable researchers to exclude additional step counts derived from tampering (shaking) and therefore obtain a more accurate assessment of activity.
- Adolescents reported a variety of reasons for changing their activity pattern while being measured, which may differ from those of child and adult populations (e.g., peer competition). More research in this area is warranted to learn more about adolescents' perceptions of the monitoring process and reasons why they feel the need to change their activity patterns while being measured. Additional strategies are needed to incentivise adolescents to adhere to objective monitoring protocols.

7.5 A qualitative investigation of adolescents' perceptions of the pedometer monitoring process

7.5.1 Overview of findings

Although pedometers are commonly used in adolescent populations [85, 193, 247], little is known about adolescents' behaviours during the monitoring process and their perceptions of the monitoring process. Therefore, the aim of the study in Chapter 5 was to explore adolescents' perceptions of pedometers and investigate the physical activity behaviours exhibited by participants during the monitoring process. A secondary aim was to investigate whether participants' perceptions differed depending on their physical activity level.

Six focus groups were conducted to obtain participants' perceptions of the pedometer monitoring process in order to gain novel insights. Participants were purposely selected and organised into focus groups based on sex (boy/girl) and physical activity level (low/medium/high), as determined by accelerometers. The in-depth qualitative analysis yielded some unique insights about adolescents' attitudes towards, and behaviours relating to, pedometer use. Multiple themes were developed to: (i) provide insight into participants' perceptions of pedometer monitoring; (ii) identify the behaviours that participants exhibited while wearing pedometers; and (iii) investigate reasons why participants felt the need to inflate their step counts during the monitoring phase. Although some participants reported that the monitors were uncomfortable and/or embarrassing to wear, generally the attitudes towards objective monitoring were positive and the majority considered pedometers to be a useful tool for measuring physical activity.

Study findings suggest that most participants involved in the focus groups reported changing their activity pattern during the monitoring phase, with almost all participants believing their peers did the same. Many reported that peer competition was a strong motivator for changing normal activity patterns; however, this was more common in the medium- and high-active groups. Participants reported that they modified their normal activity pattern through increasing incidental physical activity (e.g., walking on the spot while watching TV) and planned physical activity (e.g., going for a walk or jog), as well as increased effort and time in usual sports participation (e.g., running further than they usually would during a game). It was reinforced at the start of the monitoring phase that there was no incentive for a high step count and that researchers were attempting to obtain participants' 'normal' habitual activity. Participants were encouraged not to change their activity pattern, but for the majority of participants the opposite occurred.

In addition, 21 of the 24 participants in the focus groups reported shaking their pedometers to increase their step counts. 'Peer competition' was reported as a motivator for shaking the pedometer. This finding revealed the importance of sealing pedometers for adolescents if researchers are attempting to obtain accurate assessments of activity patterns. If the aim of pedometer use is to promote and increase physical activity in adolescent participants, then unsealed pedometers may be of great value.

The findings in Chapter 5 not only reveal the existence of reactivity and tampering in free-living adolescents, but also provide insight into why adolescents subconsciously or consciously change their activity patterns when being measured. The majority of participants in the focus groups reported changing their normal patterns while being measured, and believed their peers did the same. The findings indicate that reasons for changing activity patterns were not related to sex or physical activity level. As there is limited existing qualitative research in this area, further research investigating participants' perceptions of objective monitoring is warranted.

7.5.2 Strengths and limitations

A qualitative design using a focus group methodology was applied due to the likely benefits of group interaction, which elicits information and insights that may be less accessible during individual interview. The analysis was conducted using NVIVO software (QSR international Pty. Ltd, Melbourne, Australia) by a qualitative researcher, who was independent from the main study. To ensure reliability, a second researcher then conducted separate content analysis for categorisation of themes. Finally, for consistency with data collection, the same researcher conducted all focus group interviews at all time-points.

Despite these study strengths, there are some limitations that should be noted. First, the study involved 24 participants from a homogenous sample of adolescents; therefore, the findings may not be generalisable to all adolescents. Second, although a period of seven days of objective monitoring is commonly recommended when measuring adolescents [120], this timeframe is relatively short when attempting to understand habitual physical activity. A longer monitoring period may allow researchers to determine whether reactivity and tampering are sustained or if they taper off over time. Finally, participants were not asked specific questions in relation to ‘day to day’ differences in amount of physical activity [316]. To further understand reactivity, future qualitative studies should investigate the key factors that contribute to day to day differences in perceptions and behaviours, to determine whether these would remain constant or taper.

7.5.3 Implications for practice and recommendations for future research

- A large proportion of adolescents reported changing their activity pattern while being measured. Future research should attempt to tailor pedometer protocols for the population group and the study aims. For example, adolescents may require a more stringent protocol than adults or children and, potentially, greater incentives to comply with study requirements. Adolescents need to be reminded before and during the monitoring phase that they should not change their activity patterns. Researchers could also advise the participants that shaking their device could be detected.
- Peer-competition is clearly an issue when attempting to accurately quantify activity in adolescents. The study findings suggest that peer competition may increase reactivity and tampering. Researchers need to devise strategies that deter adolescents from engaging in peer-competition, by providing incentives to comply with monitoring protocols.

- Many of the participants reported that the pedometers were annoying and/or uncomfortable to wear. Again, this shows the need for more comfortable and less inhibiting devices. Adolescents, especially girls, reported that the pedometer was embarrassing to wear. In the adolescent population, the appearance of the pedometer may be a very important factor in improving compliance, maybe more so in than child and adult populations. As the monitors available on the commercial market are designed for consumer appeal rather than for scientific research purposes; they may be a useful tool for increasing compliance with monitoring protocols in adolescent populations. Future qualitative research should investigate the effect that appearance of the pedometer has on compliance in the adolescent domain. Researchers should also trial the use of more discreet monitoring devices that can be hidden under clothing, and popular commercially available wearable trackers (such as Fitbits, Jawbones etc.) to improve protocol compliance.
- The study findings highlight the need for researchers to evaluate measurement protocols when using pedometers in pilot studies. Greater understanding of participants' perceptions and behaviours during the monitoring process may help improve measurement accuracy and efficiency.

7.6 Comparability and feasibility of wrist- and hip-worn accelerometers in adolescents

7.6.1 Overview of findings

Missing data due to non-compliance with protocols is a major weakness of objective monitoring using pedometers and accelerometers [104, 114, 140], particularly in adolescent populations [115, 147]. Accelerometers have traditionally been worn at the hip, and issues such as discomfort, size and feelings of embarrassment are some of the reasons adolescents have chosen not to adhere to accelerometer monitoring protocols [61, 140]. Accelerometers such as the GENEActiv have been developed specifically to be worn on the wrist. The study in Chapter 6 investigated the comparability and feasibility of wrist- and hip-worn accelerometers in free-living adolescents. The findings suggest that the wrist-worn GENEActiv output compared favourably to that of the hip-worn ActiGraph (GT3X+) for both mean daily activity ($r = 0.88$, $p < 0.001$) and MVPA/day ($r = 0.84$, $p < 0.001$). The results also revealed that there was a low mean difference between the wrist-mounted and hip-mounted monitors (3.54 minutes/day on week days, 1.57 minutes/day on weekend days).

Overall, there were twice as many missing days for the hip-worn accelerometer, when compared with the wrist-worn accelerometer. In boys, compliance was slightly higher for the wrist-worn device, whereas girls had three times as many missing days when the monitor was worn at the hip. Analysis of participants' choosing to wear only one device instead of both (as per the accelerometer protocol), revealed that participants were three times as likely to wear the wrist-worn accelerometer only. This is an important contribution to the literature, as it highlights the potential use of wrist-worn accelerometers to address the widespread issue of low compliance levels in adolescents.

Participants reported a preference for wearing the device on the wrist. Furthermore, they reported the device to be less uncomfortable and less embarrassing to wear when worn on the wrist. These findings are important, as the placement site, appearance and comfort of the monitor are factors that clearly affect the level of compliance with accelerometer protocols in adolescents. It is important that researchers assess the appearance of the device and the effect it may have on compliance during assessment, as these findings reinforce previous findings in the literature that some adolescents, especially girls, feel at higher risk of being teased when wearing monitoring devices [61]. The findings of this study are consistent with the previous research, and highlight the importance of comfort and appearance of the accelerometers and the effect this can have on compliance with monitoring protocols in adolescents.

In recent years, there has been a large increase in the number of commercially available physical activity monitors [17]. The commercially available monitoring devices are predominantly designed to be worn on the wrist; potentially showing the shift from hip-worn accelerometer measurement. These commercial available activity monitors potentially reveal a new way to increase adolescent compliance in free-living conditions. The commercially available Fitbit® and Jawbone® accelerometers have recently been trialled in laboratory based studies, by comparing them with the previously-validated ActiGraph GT3X+ and GTX9. While there have only been two studies completed in youth populations, findings from these studies indicate high inter-device reliability ($r \geq 0.80$) [17]. Although these monitors show promise, the findings are only preliminary and further research in free-living conditions is required [317].

Although commercial wrist-worn accelerometers have been used in physical activity interventions, a recent systematic review have revealed that they have commonly been combined with other intervention approaches such as goal setting and research feedback, rather than for activity measurement [317]. Preliminary feasibility studies are consistent with the findings of the study in Chapter 6, highlighting the importance of design and comfort factors in children and adolescents [318, 319]. It has also been reported in the literature that the feedback is an important feature for adolescents, to motivate participants to be more active and comply with intervention monitoring protocols [317]. Many of the commercially available activity monitors use wireless connectivity to smartphone apps and provide participants with instant feedback about how much activity they have accumulated. Similar to pedometers, such devices may have limited utility for measuring habitual physical activity due to reactivity. There is currently a paucity of studies in this area of commercially available accelerometers, and no recommendations exist for physical activity researchers attempting to limit the feedback effect and potential reactivity. Further research in this area is warranted.

The findings in Chapter 6 also revealed that participants self-reported that they would be more willing to the wear the monitoring device again on the wrist, rather than at the hip. This is an important finding, as longitudinal and intervention studies have shown that compliance is often poorer in subsequent assessment periods [115, 298, 320]. Overall, these findings suggest that free-living adolescents have a preference for wrist-worn accelerometers over hip-worn. Based on the findings in Chapter 6, the wrist-worn GENEActiv accelerometer, and others like it, may assist research to increase adolescent compliance with accelerometer protocols.

7.6.2 Strengths and limitations

This was the first study to examine the comparability and feasibility of wrist- and hip-worn accelerometers in adolescents in free-living conditions. A further strength and novelty of this study was that it used a self-report questionnaire to investigate adolescents’ preferred accelerometer site placement and some of the potential reasons ‘why’. A third strength was that this study used both mean activity and MVPA/day to compare the two monitoring placement sites. Fourth, experienced and trained researchers completed all of the assessments at all time-points.

Although this study had many strengths, there are some limitations that should be noted. First, the sample was relatively homogenous and study findings might not be generalisable to other populations of adolescents. Second, the accelerometer wear-time inclusion criteria were modified (that is, from 10 to 8 hours/day and from 4 to 3days/week) to increase participant numbers in the analyses. Third, as two brands of monitoring devices were used, different cut-points for each device were applied to classify intensity of activity for MVPA/day analysis. Fourth, non-wear time was only analysed in full days, and periodic removal throughout the day was not assessed. Finally, the accelerometer behaviour questionnaire was developed for the current study and has not been validated.

7.6.3 Implications for practice and recommendations for future research

- The study findings suggest a strong linear association between the wrist- and hip-worn accelerometer outputs. However, due to the small sample size and limited analysis, further equivalency studies are required to determine the interchangeability of the ActiGraph GT3X+ and the GENEActiv accelerometers.
- As the study used two different brands of accelerometers (GENEActiv and ActiGraph), further comparability studies on accelerometer site placement should be completed with the same brands.
- Participants reported a preference for wearing the GENEActiv device on the wrist. Importantly, they found it more comfortable and less embarrassing to wear than the ActiGraph. These are very important findings, as adolescent compliance with accelerometer monitoring protocols is inherently poor. Appearance of the accelerometer is clearly important for adolescents, especially girls, who report a higher rate of feeling embarrassed when wearing the devices. Comfort and design appears to be a paramount issue affecting compliance. This highlights the need for more comfortable and discreet accelerometers to be developed for physical activity research purposes in adolescents, to address the current widespread non-adherence issue. When designing accelerometer protocols for specific study aims, researchers should be selective about the size and appearance of the accelerometer, as this has an effect on participant adherence. A further recommendation may be to use accelerometers that can be hidden under clothing, to reduce the chance of participants' feeling embarrassed during the monitoring period.
- The findings from this study indicate that comfort and appearance of the accelerometer are factors that can influence compliance in adolescents. Researchers could potentially trial a variety of types of wrist-worn accelerometer that differ in design, including

commercially available activity monitors, in an attempt to increase adolescent compliance with monitoring protocols. There is currently a paucity of research to determine the utility of commercially available accelerometers in physical activity measurement research across population groups. In addition, caution should be exercised when using commercially available monitors that provide instant feedback, as this may increase potential reactivity.

- Researchers are encouraged to use wrist worn accelerometers when measuring physical activity in free-living adolescents. This may be particularly important in intervention and longitudinal studies where the participants are required to wear the monitoring devices on multiple occasions. The findings suggest that participants are not only more likely to comply with protocols when the device is worn on the wrist, but also that they would be more willing to wear it again on the wrist.

7.7 Concluding remarks

The accurate assessment of physical activity in adolescents is a challenging but important endeavour. The lack of consistent measurement protocols in the field of physical activity measurement is a result of the interplay that exists between cost/burden and accuracy/quality of data. Subsequently, researchers' choice of physical measure is not solely based on accuracy of the measure, it is dependent on a number of factors associated with the research aims, study design, sample and resource availability.

Physical activity questionnaires should be selected based on the specific study aims/design, and, importantly, the age and cognitive capacity of participants. Future researchers are encouraged to conduct additional testing of shorter, less complex self-report measures with adolescents, in an attempt to reduce participant burden and improve accuracy. The findings of the studies in this thesis suggest that reactivity to objective monitoring devices and pedometer tampering do exist in adolescents and are an inherent risk to validity. Strategies to limit reactivity and tampering should be considered by researchers during studies when attempting to accurately assess adolescents' physical activity patterns.

Further qualitative research may help to increase adolescents' compliance with objective monitoring protocols. In an attempt to increase compliance in this population, it is recommended that future research use wrist-worn accelerometers. The refinement of existing measurement tools, and the improvement of objective monitoring protocols in the adolescent domain, will consequently lead to more accurate assessments of adolescents' habitual activity patterns. This will be of particular importance in the improvement and success of physical activity interventions for this target population.

8 Bibliography

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9 Appendices

Appendix 1: The University of Newcastle thesis by publication guidelines

Office of Graduate Studies
Information Sheet
Thesis by Publication

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

A thesis may be submitted in the form of a series of published papers and the additional rules specific to this style of thesis are presented below. **It is important to note that the general rules for a University of Newcastle thesis are also applicable. Please ensure you also refer to** The Rules Governing Research Higher Degrees for the full scope of applicable rules.

Rule 39.1 A thesis by publication will include:

i. a full explanatory overview that links the separate papers and places them in the context of an established body of knowledge;
ii. a literature review;
iii. if detailed data and descriptions of methods are not otherwise given within the separate papers, they must be included in the body of the thesis or as appendices to the thesis;

Rule 39.2 For a thesis by publication:

i. the separate papers provided under sub-clause 39.1(i) must be published, in press or submitted to scholarly media only, i.e. refereed publications classified by current national standards and refereed conference papers, however at least 50% of these papers must have been published. Papers published up to three years prior to enrolment may be included provided they were published in scholarly media and do not represent more than 50% of the total papers;
ii. publications submitted by the candidate for another degree may only be referred to in the thesis literature review;
iii. the number of papers submitted should demonstrate that the body of work meets the requirements of the degree as outlined in the relevant schedule;
iv. the candidate must be the lead author in at least 50% of the papers written in the time of their formal Research Higher Degree candidature. Any published paper of which the candidate is a joint author may only be included in the thesis provided the work done by the candidate is clearly identified. The candidate must include in the thesis a written statement from each co-author attesting to the candidate's contribution to a joint publication included as part of the thesis. These statements must be endorsed by the Assistant Dean (Research Training).
v. the Assistant Dean (Research Training) may seek the approval of the Dean of Graduate Studies to include a paper that is outside the scope of these rules.

Office of Graduate Studies, East Wing, The Chancellery
Telephone: (02) 4921 6537 Fax: (02) 4921 6908 Email: research@newcastle.edu.au

Considerations

- Each discipline area will have different issues to consider in the decision to submit a thesis in the form of a series of published papers.
- It is essential that you discuss your options carefully with your supervisor(s). The thesis by publication must reflect a sustained and cohesive theme, an integrated whole that sits logically in the context of the available literature. Overall the material presented for examination needs to equate to that which would otherwise be presented in the traditional thesis format.
- The review process for some journals is significant resulting in lengthy waiting periods for papers to be accepted and this can delay thesis submission/completion. Time management and selection of journals/publishers is critical. Focusing on publication rather than research may lead to candidates being tempted to publish sections of their work prematurely and missing opportunities to fully capitalize on the significance of the work.
- Consider the thesis from the examiners' view point - if the publications do not have a clear cohesion and the contribution to knowledge is not clearly demonstrated, then the thesis may attract criticism and be rejected by examiners. The content of the thesis remains a matter of professional judgment for the supervisor(s) and candidate.
- Any published paper of which the candidate is a joint author may only be included in the thesis provided the work done by the candidate is clearly identified. The candidate must include in the thesis a written statement from each co-author attesting to the candidate's contribution to a joint publication included as part of the thesis. The statement/s need to be signed by the Faculty Assistant Dean (Research Training). A sample statement is provided below.
- We strongly advise that you arrange for the signatures from co-authors to be collected as soon as the paper is prepared or submitted for publication rather than trying to collect them at the time of thesis submission.
- There is no minimum or maximum requirement on the number of papers. Of equal, or perhaps more importance than quantity, is the quality of the journals. Please refer to your school or faculty for more specific guidance on the number and length of papers that would normally be expected in your discipline.

Alternative option

As discussed above, you need to consider if your publications will form a sufficient body of cohesive work to meet the requirements of thesis by publication. You may like to consider the other option of including publications within a standard thesis format, either in the body or as an appendix as supported in the rule below.

Rule 38.5. A thesis may:

i. Include publications arising as a consequence of the research undertaken for a thesis.
When the candidate includes a co-authored published paper or co-authored scholarly work, or a substantive component of a co-authored published paper or co-authored scholarly work in the body of the thesis, the candidate must include in the thesis a written statement attesting to their contribution to the joint publication. This statement must be signed by the supervisor. A statement is not required when publications are included as an appendix to the thesis.

2

Components and Layout

PLEASE NOTE: the layout and ordering of the contents is flexible and should be based on the judgement and experience of candidates and supervisors as well as discipline norms. Please use your own discretion and seek expert advice. The following is a suggested layout only.

1. **Title Page**

2. **Declarations**

Originality
I hereby certify that to the best of my knowledge and belief this thesis is my own work and contains no material previously published or written by another person except where due references and acknowledgements are made. It contains no material which has been previously submitted by me for the award of any other degree or diploma in any university or other tertiary institution.

Thesis by Publication
*I hereby certify that this thesis is in the form of a series of *papers. I have included as part of the thesis a written statement from each co-author, endorsed in writing by the Faculty Assistant Dean (Research Training), attesting to my contribution to any jointly authored papers. (*Refer to clause 39.2 of the Rules Governing Research Higher Degrees for acceptable papers).*

3. **Acknowledgements**

4. **List of publications included as part of the thesis**

4.1 List all of the included published work with the full bibliographic citations in the order they appear in the thesis.

4.2 Provide a statement to indicate that where necessary permission regarding copyright has been obtained from copyright owners. For example, the statement may say "I warrant that I have obtained, where necessary, permission from the copyright owners to use any third party copyright material reproduced in the thesis (e.g. questionnaires, artwork, unpublished letters), or to use any of my own published work (e.g. journal articles) in which the copyright is held by another party (e.g. publisher, co-author)."

5. **Table of Contents**

6. **Abstract**

An abstract of approximately 300 words is required to describe the content of the thesis.

7. **Overview**

A full explanatory overview is required to link the published papers to the research thesis. This may include sections for Literature Review (if not included separately), Research Design and Review/Discussion. Not all of these sections may be necessary. **Choose the format that underpins the academic argument so that the contents of the thesis are established as a substantial and significant body of work, but without unnecessary repetition.**

8. **Literature Review**

3

9. Statement of Contribution of Others

In the thesis, at the front of each paper, include a written statement from each co-author attesting to the candidate's contribution to a joint publication included as part of the thesis. The purpose of this statement is to summarise and clearly identify the nature and extent of the intellectual input by the candidate and any co-authors.

9.1 Sample co-author statement

By signing below I confirm that [Candidate Name] contributed [insert outline of contribution]) to the paper/publication entitled [insert reference details].

List:
Full Name of Co-Author/s, Date, Signature of Co-Authors

Full Name of Faculty Assistant Dean Research Training, Date, Signature

10. Papers/Chapters

Each paper/chapter should have an introduction to explain how it contributes to the overall body of knowledge. It is not necessary to reformat published papers in the thesis. Where appropriate publications can be included in full or in parts thereof.

11. Appendices

12. Bibliography

4

Appendix 2: University of Newcastle ethics approval letter

HUMAN RESEARCH ETHICS COMMITTEE

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Notification of Expedited Approval

To Chief Investigator or Project Supervisor:	**Associate Professor David Lubans**
Cc Co-investigators / Research Students:	**Professor Ronald Plotnikoff** **Professor Philip Morgan** **Mr Joseph Scott**
Re Protocol:	**The measurement of physical activity in adolescents: Testing objective monitoring protocols and validation of self-reporting measures**
Date:	**28-Jun-2011**
Reference No:	**H-2011-0137**
Date of Initial Approval:	**22-Jun-2011**

Thank you for your **Response to Conditional Approval** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under **Expedited** review by the Chair/Deputy Chair.

I am pleased to advise that the decision on your submission is **Approved** effective **22-Jun-2011**.

For noting: Please provide a copy of the revised risk assessment form for our records, as referred to in your response letter.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. *If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.*

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request. Your approval number is **H-2011-0137**.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants You may then proceed with the research.

Conditions of Approval

This approval has been granted subject to you complying with the requirements for *Monitoring of Progress*, *Reporting of Adverse Events*, and *Variations to the Approved Protocol* as detailed below.

PLEASE NOTE:
In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.

- ***Monitoring of Progress***

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

- ***Reporting of Adverse Events***

1. It is the responsibility of the person **first named on this Approval Advice** to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
    - Causing death, life threatening or serious disability.
    - Causing or prolonging hospitalisation.
    - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
    - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
    - Any other event which might affect the continued ethical acceptability of the project.
5. Reports of adverse events must include:
    - Participant's study identification number;
    - date of birth;
    - date of entry into the study;
    - treatment arm (if applicable);
    - date of event;
    - details of event;
    - the investigator's opinion as to whether the event is related to the research procedures; and

    - action taken in response to the event.

6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- ***Variations to approved protocol***

If you wish to change, or deviate from, the approved protocol, you will need to submit an *Application for Variation to Approved Human Research*. Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. **Variations must be approved by the (HREC) before they are implemented** except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (i.e. those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

Best wishes for a successful project.

Professor Alison Ferguson
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration

Research Services
Research Integrity Unit
HA148, Hunter Building
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 18999
F +61 2 492 17164
Human-Ethics@newcastle.edu.au

Linked University of Newcastle administered funding:

Appendix 3: Maitland-Newcastle Catholics schools' ethics approval letter

DIOCESE OF MAITLAND-NEWCASTLE
CATHOLIC SCHOOLS OFFICE
841 HUNTER STREET ■ PO BOX 714, NEWCASTLE NSW 2300 ■ PH (02) 4979 1200 ■ FAX (02) 4979 1209

9 August 2011

Mr Joseph Scott
PO Box 338
Watatah
NSW 2298

Dear Mr Scott,

Thank you for your Application to Conduct Research in the Diocese of Maitland-Newcastle which we received on 15 June 2011. Your research application has been approved. I am happy for you to approach the following high schools in our diocese in order to test objective monitoring protocols in the measurement of physical activity in adolescents:

- San Clemente, Mayfield
- St. Marys, Gateshead
- St. Pius X, Adamstown
- St. Pauls, Booragul
- All Saints College, St. Peters Campus, Maitland

Although the CSO has approved this project it is still up to the the school principal to give final permission for research to be carried out in their school. They are uniquely aware of school specific circumstances and timelines that may make the research proposal difficult to implement.

We also stress the following points in relation to research requests:

- Confidentiality needs to be observed in reporting and must comply with the requirements of the Commonwealth Privacy Amendment (Private Sector) Act 2000.
- There should be some feedback to schools and a copy of the findings of the research forwarded to this office.
- This letter of approval should accompany any approach to schools.

I look forward to the results of this study and wish you the best over the coming months. If you would like to discuss any aspect of this research in our diocese, please do not hesitate to contact me on 02 4979 1201 or vicki.sheriff@mn.catholic.edu.au.

Yours sincerely,

Vicki Sheriff
Professional Assistant to the Director
Catholic Schools Office
Diocese of Maitland-Newcastle

Appendix 4: Funding acknowledgement: Priority research centre for physical activity and nutrition (PRCPAN) seed funding grant approval letter

PRIORITY RESEARCH CENTRE
PHYSICAL ACTIVITY & NUTRITION

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Wednesday 15th June, 2011

Mr Joseph Scott
School of Education
Faculty of Education & Arts
The University of Newcastle
Callaghan NSW 2308

PRC in Physical Activity & Nutrition - 2011 Seed Funding Application

Dear Joseph

Thank you for submitting your application for Seed Funding in 2011 for consideration by the PRC in Physical Activity & Nutrition. The PRC Research Management committee have reviewed your application and have decided to support the proposal – Congratulations!

You have been awarded **$5,000** to be used towards your proposal titled **- The measurement of physical activity in adolescents: testing objective monitoring protocols and validation of self-reporting measures.**

Applications were assessed on the quality and approach/methodology of the research project, the potential for strategic growth of research within the PRC, including the potential of the project to attract external research funding, and the researcher/s track record/s relative to opportunity.

You are required to liaise with the Theme Leader Dr David Lubans to finalise your budget. The PRC does not accept responsibility for the provision of general equipment and facilities, including basic desk top computers. This is the responsibility of Chief Investigator & Theme Lead to organise within your School. You are also required to liaise with relevant School staff to arrange any staff appointments.

Staff on fixed-term contracts should clearly state their period of appointment, for example, 1 July 2011 to 31 December, 2011. Staff on a fractional appointment should indicate percentage, for example, 50%. Discuss any queries relating to the appropriate level of staff appointments with Human Resource Services staff http://www.newcastle.edu.au/service/recruitment/contacts.html. Ensure that salary on-costs are included in the budget as appropriate. Information on salary rates and on-costs can be found from the relevant links on the following website: http://www.newcastle.edu.au/service/grants-and-contracts/internal-grants/preparing-research-budgets.html

All staff appointments should quote the cost collector **10.21720.** No 'overspending' on staff salaries will be permitted. Any overspends will be the responsibility of the Chief Investigator. Copies of all staff appointments should be forwarded to the PRC Centre Coordinator, Airlie Johnson.

You have been allocated a unique code **PRCSF11-22** to be used in all cost coding in *Spend-vision*. In the comments section please use the code **PRCSF11-22** followed by a brief description of the expenditure. This will be used for reporting purposes. All purchase orders are to be processed through your School. Copies of purchase orders should be forwarded to the PRC Centre Coordinator, Airlie Johnson.

Restrictions on Expenditure

Funding Exceptions – funding **may not** be spent on:

- Equipment over $1,000 each; *and*
- any item that was not originally included in the budget proposal of the application form.

PRIORITY RESEARCH CENTRE
PHYSICAL ACTIVITY & NUTRITION

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Where a researcher wishes to **vary approved expenditure** and/or include any of the items listed under *Funding Exceptions* above, permission should be sought in writing from the PRC Director. Reasonable requests for variation will be accommodated wherever possible, but permission should be sought in advance of expenditure.

Forfeiture of Grant Funding
Grants not spent or committed within the nominated funding period of the grant will not be carried forward to the following year. All monies that you have been awarded must be spent by **9 December 2011**. No monies can be carried over to 2012.

If you are aware for any reason that the monies cannot be spent please advise the PRC Director as soon as possible so that any unspent balances can be re-allocated.

Ethics Clearances: The University is bound by legislation to ensure research does not commence without appropriate ethics and safety approvals. Research projects conducted within the University or in the name of the University must comply with the AVCC Guidelines for Responsible Practice in Research and must have the relevant Human/Animal ethics and/or Safety approvals. Separate application must be made, if appropriate, for ethics approval of the Animal Care and Ethics Committee and/or the Human Research Ethics Committee. Approval must be obtained before the project commences. Projects which raise safety issues cannot proceed until they have been cleared by the Safety Committee.

Safety Approvals: There are statutory requirements for the control of risks arising from workplace hazards which both the University and the Chief Investigator are obliged to meet. Accurate identification of the hazards associated with the research project is vital to meeting this obligation.

Reporting Requirements for Successful Applicants: Final reports are required by 30 March 2012. The report is to be submitted on the PRC Grants Scheme 2011 Report Form. Failure to submit a final report will prevent eligibility for future PRC seed funding rounds. The Final report must include details of external grant applications, manuscripts and presentations. The PRC must be acknowledged in all publications and conferences that result from this funding.

If you have any question please contact the Centre Co-ordinator, Airlie Johnson via email: Airlie.Johnson@newcastle.edu.au or Telephone: 02-4921 7792. Again, congratulations on your application and good luck with your research!

Best regards,

Ronald C. Plotnikoff, PhD
Professor and Chair in Physical Activity and Population Health Education
Director, Priority Research Centre in Physical Activity and Nutrition
HPE3.08, HPE Building
University of Newcastle
Callaghan, NSW 2308 Australia
Tel: 61 2 49854465
E-mail: ron.plotnikoff@newcastle.edu.au

Appendix 5: Measuring activity with through energy expenditure: The strengths and weaknesses of doubly labelled water and heart-rate monitoring

Doubly labelled water

The doubly labelled water (DLW) method is based on the kinetics of two stable isotopes of water, ^2H_2O (deuterium-labelled water) and $H_2{}^{18}O$ (oxygen-18-labeled water). Deuterium-labelled water is lost from the body through the usual routes of water loss (urine, sweat, evaporative losses). Oxygen-18-labeled water is lost from the body at a slightly faster rate because this isotope is also lost via carbon dioxide production in addition to all routes of water loss. The difference in the rate of loss between the two isotopes is a function of the rate of carbon dioxide production. This is therefore reflection of the rate of energy production over time [321]. By combining this with the measurement of resting energy expenditure, DLW can be used to estimate energy expenditure (EE) as a result of physical activity.

Strengths and weaknesses of Doubly labelled water

The DLW method has been regarded as the 'gold standard' and the most valid and reliable way to measure EE in free living conditions [52]. This is reflected in validation studies in adults and children that have shown a small measurement error of 5-10% [321, 322]. Due to the high level of reliability and validity, the DLW method has also been used to validate physical activity questionnaires in adolescents [323]. Further strengths of the DLW method is that it is unobtrusive and non-invasive to the participant [49].

A major limitation in the use of DLW is its very labour intensive for researchers and very expensive and burdensome for participants, making it only suitable for small studies with a large of amount of resources and funding. The use of the DLW method is therefore most seen in well-resourced research activities rather than health promotion and intervention studies [324, 325]. The greatest weakness of the DLW method is it does not provide frequency, intensity or type of activity [65, 269]. For these reasons, there are limited studies within the literature where DLW has been used to measure physical activity in free-living adolescents.

Although the research shows the DLW method can accurately measure EE, the labour intensive nature of data collection and the costly expense does not make it feasible for use with large samples[65]. As the DLW is a biological method, and the participant is provided with a dose rather than a monitor (such as a pedometer or accelerometer), non-wear time and missing data is eliminated which is a common issue among free-living adolescents [114]. In summary, the DLW method provides an accurate, yet not particularly feasible method of assessing physical activity in free-living adolescents.

Heart rate monitoring

Heart rate monitoring has been used in various populations to provide an objective assessment of the physiological effect of physical activity [49]. The monitor is fixed to the participant via an elastic belt normally across the chest (more modern devices can be worn on the wrist or arm) under the clothing and provides minute-by-minute heart rate data that can be stored over multiple days [326]. It has been reported that heart monitors are more useful for classifying groups of individuals rather than estimating individuals' physical activity level [15]. Nonetheless, they have shown usefulness when estimating children's and adolescents' physical activity in small-to-moderate sample sizes [52].

Strengths and limitations of heart rate monitoring

Heart rate monitors have been used to provide an estimate of adolescents' physical activity levels as it now well-documented in the literature that heart rate has a strong linear association with energy expenditure [327, 328]. Heart rate monitors are reasonably inexpensive in comparison to pedometers and some accelerometers other objective measures, especially those that measure energy expenditure. They also have the ability to store data over consecutive days which is an added advantage for their use with adolescents [65]. Heart rate monitoring compares well to the DLW method, self-report physical activity questionnaires, pedometry and accelerometry [65, 163, 322].

Heart rate monitoring does not measure physical activity, it is an indirect estimate of physical activity which is based on linear relationship between heart rate and oxygen uptake [49]. A further weakness of the measure is heart rate can be affected by temperature and emotional stress and other factors such as age, body size, proportion of muscle mass and cardiorespiratory fitness, therefore making physical activity assessment more complex [65]. In addition, heart rate tends to lag momentarily behind movement and also tends to remain high after the cessation of movement and therefore masks intermittent and sporadic movement patterns [269]. Heart rate monitoring also provides no contextual information of the physical activity that has been completed. Researchers have developed techniques such as heart rate indices that control for individual differences and individualised HR-VO_2 calibration curves [56, 269]. However, these in-depth approaches are time consuming and burdensome for researchers and hence are not feasible for studies with large sample sizes.

Due to the sporadic and intermittent movement patterns adolescents, heart rate monitoring alone may not capture the true activity pattern of the individuals in free-living conditions. However, as stable exercise has been shown to strongly correlate with heart rate and respiration, there continues to be clinical studies validating the use of heart rate monitoring [65]. For heart rate monitors to accurately measure an individual's physiological change in heart rate a result of physical activity, the monitor needs to be calibrated to the wearer. This involves collecting and entering an individual's information which may not be feasible for larger studies [50]. In summary, heart rate monitoring will remain a useful and unobtrusive tool for measuring free-living adolescents, although it has been recommended that it be used in conjunction with other measures such as accelerometers which have the ability to capture duration and intensity of activity [49, 56].

Appendix 6: Parent information letter and consent forms

Research Project: The Measurement of Physical Activity in Adolescents: Testing Objective Monitoring Protocols and Validation of Self-Reporting Measures

PARENT INFORMATION SHEET

Dear Parents/Guardians,

Your child's school has been invited to participate in a study being conducted by A/Prof David Lubans, Prof Ron Plotnikoff, Prof Philip Morgan and Research Higher Degree student Joseph Scott from the University of Newcastle.

Why is this research being done?
The measurement of physical activity is an important and challenging venture. Accurate measurement of physical activity is necessary to estimate how active young people are and to evaluate programs to promote activity. With more and more physical activity studies now using objective measurement devices, there is an urgent need to identify optimal assessment protocols for various populations. By comparing existing physical measurement protocols and validating a series of physical activity questionnaires we are attempting to refine and improve physical activity measurement.

Who can participate in this research?
Two Personal Development, Health and Physical Education (PDHPE) classes in years 9 or 10 will be invited to participate in the study. Students with pre-existing health issues and/or special needs can participate in the study if it does not impede their ability to wear a functional pedometer.

What is involved in this study?
If your child agrees to participate, s/he will take part in a study which will be conducted at school by a member of the research team. The study will involve your child wearing a pedometer and an accelerometer (devises for measuring physical activity) for 7 days and completing a physical activity questionnaires three times and a pedometer questionnaire once. Students will also be asked to self-report their height and weight (no physical measures will be taken). These questionnaires will focus solely on your child's physical activity levels and behaviours that they exhibited whilst wearing a pedometer. A small number of students (four from each class) may also be selected to be involved in a focus group. As part of a focus group, your child will then be asked questions by a member of the research team regarding their perceptions and attitudes of the measuring process. Discussion during the focus group will be recorded using a digital recorder. During the recording students, will not be identified by name and are not required to answer a question if they do not wish to. Should your child like to withdraw any comments personally made during the recording, this will be noted by the researcher conducting the focus group and written transcripts of the recording will be amended. Focus group questioning will occur only once in your child's normal Physical Education lesson on school grounds in a room allocated by the school and will run for no more the 30 minutes.

How much time will it take?
On day 1, the researchers will explain the study, provide each student with a pedometer and an accelerometer and then students will complete two brief physical activity

questionnaires. (20 minutes). Students will then wear a pedometer and accelerometer for the next 7 days. On Day 8; students will their return pedometers and accelerometers complete the same physical activity questionnaires and answer questions regarding their perceptions of wearing the devices and (25 minutes). The following week students will be asked to complete the same physical activity questionnaire for a third time (10mins) and a selection of students will be invited to participate in focus groups to explore students' perceptions and attitudes of the measuring process.

What choice do participants have?
The school principal has agreed to your child's school being involved in the study. However, participation in the study is entirely you and your child's choice. If consent to participate is provided, your child can still choose to withdraw from the study at any time and will be free to discontinue participation in the assessments. A decision not to participate or discontinuation of involvement in the study will not jeopardise you or your child's relationships with the University of Newcastle or the school. Withdrawal from this task will not result in any disciplinary action, nor will it affect your child's academic grades, given that this is a purely voluntary research task. Students' participation is entirely voluntary. Students who choose not to participate in the study will be with their normal teacher and will continue lessons as per usual.

What are the benefits and risks of participating?
Taking part in this research project will allow students to benefit from an increased awareness of the importance of physical activity and leading a healthy lifestyle. Students will gain experience in physical activity measurement and an understanding of how research is conducted. The topic of 'physical activity measurement' fits into the Personal Development, Health and Physical Education (PDHPE) syllabus. Teachers can easily link the content of this study to the students' curriculum and hence increase their knowledge in certain areas of the syllabus. Mr Joseph Scott will provide a presentation to the schools on the results along with an overview of physical activity assessment methods. There are no foreseeable risks and students can choose to withdraw from the study at any time.

How will the information collected be used?
Steps counts, questionnaire responses and audio recorded data obtained during the focus groups will be used to further refine the physical activity measuring protocols and validate existing physical activity questionnaires. This information may be used for journal publications and conference presentations and will contribute to Mr Joseph Scott research higher degree.

How will privacy be protected?
Any personal information provided by you or your child will be confidential to the researchers. Any data collected from the focus group will be published in general terms and will not allow the identification of individuals or schools. Audio recorded data will be transcribed by a member of the research team and stored. All data will be securely retained for 5 years. No participant will be identifiable in the data files.

What do you need to do to participate?
You and your child will need to complete both accompanying *Student* and *Parent Consent Forms*, and have them returned to the school's office or your child's roll-class teacher as soon as possible.

Further information
Following the completion of the study, Joseph Scott will return to the school and present the study's findings to the principal, teachers and staff. A summary of the findings will be

given to the principal and involved staff. It is suggested that the findings will be disseminated to students and their parents via a school newsletter or similar method. If you would like further information you can contact A/Prof David Lubans using the details below. Thank you for considering this invitation.

___________________ ____________________ ____________________ _________________

A/Prof David Lubans Prof Ron Plotnikoff Prof Philip Morgan Joseph Scott

A/Prof David Lubans Faculty of Education & Arts School of Education Phone: (02) 4921 2049 David.Lubans@newcastle.edu.au	**Prof Ron Plotnikoff** Faculty of Education & Arts School of Education Phone: (02) 4985 4465 Ron.Plotnikoff@newcastle.edu.au	**Prof Philip Morgan** Faculty of Education & Arts School of Education Phone: (02) 4921 7265 Philip.Morgan@newcastle.edu.au	**Joseph Scott** Faculty of Education & Arts School of Education Phone: 0431595272 Joseph.scott@newcastle.edu.au

This project has been approved by the University's Human Ethics Committee, Approval No. H-2011-0137. Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia (02) 4921 6333, or email Human-Ethics@newcastle.edu.au

Research Project: The Measurement of Physical Activity in Adolescents: Testing Objective Monitoring Protocols and Validation of Self-Reporting Measures

PARENT CONSENT FORM

Chief Investigator: A/Prof David Lubans
Associate Investigator: Prof Ron Plotnikoff
Associate Investigator: Prof Philip Morgan
Associate Investigator: Research Higher Degree student Joseph Scott

I have been given information about the research project identified above and have discussed it with my child. I understand that if I consent to my child participating in this project, he/she will participate in this study. I understand that my child's participation is entirely voluntary.
This will involve my child wearing a pedometer and an accelerometer (devises for measuring physical activity) for 7 days and completing the same physical activity questionnaire at three different times (the Oxford Physical Activity Questionnaire) and a Pedometry Behaviour Questionnaire once. Students will also be asked to self-report their height and weight (no physical measures will be taken). I understand that *if* my child is selected to be involved in a focus group (which is a small group discussion) they will only answer questions based on their perception/attitudes of the measuring process. I understand that an audio recording will be taken during the focus group and data obtained from this recording may subsequently be used in making changes to the questionnaires. I am also aware that my child will not be identified by name during the recording and should s/he like to withdraw any comments made during the recording, this will be noted by the researcher conducting the focus group and written transcripts of the recording will be amended.

I have had an opportunity to ask A/Prof Lubans questions about the research and my child's participation. I understand that my child's participation is voluntary and I am free to withdraw him/her from the research at any time. My refusal to his/her participation or withdrawal of consent will not affect my relationship with the University of Newcastle or my child's school. Withdrawal from this task will not result in any disciplinary action against my child, nor will it affect his/her academic grades, given that this is a purely voluntary research task.

By signing below, I am indicating consent for my child to participate in this research project conducted by A/Prof David Lubans, Prof Ron Plotnikoff, Prof Philip Morgan and Research Higher Degree student Joseph Scott as it has been described to us in the Information Statement, a copy of which I have retained.

Student name: ____

Parent/guardian name: ____

Contact phone number: (H) _____________________________________

Signature: ______________________________ **Date:** _________________

Please sign the completed consent form and return with your CHILD'S CONSENT FORM to their roll-call teacher or the school's office

Appendix 7: Student (participant) information and consent forms

Research Project: The Measurement of Physical Activity in Adolescents: Testing Objective Monitoring Protocols and Validation of Self-Reporting Measures

STUDENT INFORMATION SHEET

Dear Student,

Your school is invited to participate in a study being conducted by A/Prof David Lubans, Prof Ron Plotnikoff, Prof Philip Morgan and Research Higher Degree student Joseph Scott from the University of Newcastle.

Why is this research being done?
The measurement of physical activity is an important and challenging venture. Accurate measurement of physical activity is necessary to estimate how active young people are and to evaluate interventions to promote activity and identify the predictors of physical activity behaviour. By comparing existing measuring protocols and validating a series of physical activity questionnaires we are attempting to refine physical activity measurement.

Who can participate in this research?
Two Personal Development, Health and Physical Education (PDHPE) classes in years 9 or 10 will be invited to participate in the study. Students with pre-existing health issues and/or special needs can participate in the study if it does not impede their ability to wear a functional pedometer.

What is involved in this study?
If you agree to participate, you will take part in a study which will be conducted at school by a member of the research team. The study will involve you wearing a pedometer and an accelerometer (devises for measuring physical activity) for 7 days and completing a physical activity questionnaires three times and a pedometer questionnaire once. Students will also be asked to self-report their height and weight (no physical measures will be taken). These questionnaires will focus solely on your physical activity levels and behaviours that you exhibited whilst wearing a pedometer. A small number of students may also be selected to be involved in a focus group. As part of a focus group, you will then be asked questions by a member of the research team regarding your perceptions and attitudes of the measuring process. Discussion during the focus group will be recorded using a digital recorder. During the recording you will not be identified by name and are not required to answer a question if you do not wish to. Should you like to withdraw any comments personally made during the recording, this will be noted by the researcher conducting the focus group and written transcripts of the recording will be amended. Focus group questioning will occur only once in your normal Physical Education lesson on school grounds in a room allocated by the school and will run for no more the 30 minutes.

How much time will it take?
On day 1, the researchers will explain the study, provide each student with a pedometer and an accelerometer and then students will complete two brief physical activity questionnaires. (20 minutes). Students will then wear a pedometer and accelerometer for the next 7 days. On Day 8; students will their return pedometers and accelerometers complete the same physical activity questionnaires and answer questions regarding their perceptions of wearing the devices and (25 minutes). The following week students will be asked to complete the same physical activity questionnaires for a third time (10mins)

and a selection of students will be invited to participate in focus groups to explore students' perceptions and attitudes of the measuring process.

What choice do participants have?
The school principal has agreed to your school being involved in the study. However, participation in the study is entirely your choice. If consent to participate is provided, you can still choose to withdraw from the study at any time and will be free to discontinue participation in the assessments. A decision not to participate or discontinuation of involvement in the study will not jeopardise your relationships with the University of Newcastle or the school. Withdrawal from this task will not result in any disciplinary action, nor will it affect your academic grades, given that this is a purely voluntary research task.

What are the benefits and risks of participating?
Taking part in this research project will allow you to benefit from an increased awareness of the importance of physical activity and leading a healthy lifestyle. You will gain experience in physical activity measurement and an understanding of how research is conducted. There are no foreseeable risks and you can choose to withdraw from the study at any time.

How will the information collected be used?
Steps counts, questionnaire responses and audio recorded data obtained during the focus groups will be used to further refine the physical activity measuring protocols and validate existing physical activity questionnaires. This information may be used for journal publications and conference presentations and will contribute to Mr Joseph Scott research higher degree.

How will privacy be protected?
Any personal information provided by you will be confidential to the researchers. Any data collected from the focus group will be published in general terms and will not allow the identification of individuals or schools. Audio recorded data will be transcribed by a member of the research team and stored. All data will be securely retained for 5 years. No participant will be identifiable in the data files.

What do you need to do to participate?
You and your parent(s) will need to complete both accompanying *Student* and *Parent Consent Forms*, and return them to the School's office or your roll-class teacher as soon as possible. Your participation is entirely voluntary.

Further information
Following the completion of the study, Joseph Scott will return to the school and present the study's findings to the Principal, Teachers and staff. A summary of the findings will be given to the principal and involved staff. It is suggested that the findings will be disseminated to students and their parents via a school newsletter or similar method. If you would like further information you can contact A/Prof David Lubans using the details below. Thank you for considering this invitation.

____________________ ____________________ ____________________ __________________

A/Prof David Lubans Prof Ron Plotnikoff Prof Philip Morgan Joseph Scott

A/Prof David Lubans Faculty of Education & Arts School of Education Phone: (02) 4921 2049 David.Lubans@newcastle.edu.au	**Prof Ron Plotnikoff** Faculty of Education & Arts School of Education Phone: (02) 4985 4465 Ron.Plotnikoff@newcastle.edu.au	**Prof Philip Morgan** Faculty of Education & Arts School of Education Phone: (02) 4921 7265 Philip.Morgan@newcastle.edu.au	**Joseph Scott** Faculty of Education & Arts School of Education Phone: 0431595272 Joseph.scott@newcastle.edu.au

This project has been approved by the University's Human Ethics Committee, Approval No. H-2011-0137. Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia (02) 4921 6333, or email Human-Ethics@newcastle.edu.au

Research Project: The Measurement of Physical Activity in Adolescents: Testing Objective Monitoring Protocols and Validation of Self-Reporting Measures

STUDENT CONSENT FORM

Chief Investigator: A/Prof David Lubans
Associate Investigator: Prof Ron Plotnikoff
Associate Investigator: Prof Philip Morgan
Associate Investigator: Research Higher Degree student Joseph Scott

I have been given information about the research project identified above and have discussed it with my parent(s). I understand that if I consent to participating in this project, I will participate in the study that is called '*The measurement of physical activity in adolescents: testing objective monitoring protocols and validation of self-reporting measures'* I understand that my participation is entirely voluntary.
This will involve me wearing a pedometer and an accelerometer for 7 days and completing the same physical activity questionnaire at three different times (the Oxford Physical Activity Questionnaire) and a Pedometry Behaviour Questionnaire once. Students will also be asked to self-report their height and weight (no physical measures will be taken). I understand that *if* I am selected to be involved in a 'focus group' (which is a small group discussion) I will only answer questions based on my perceptions/attitudes of the measuring process. I understand that my answers will be recorded and maybe used in making changes to the questionnaires. I am also aware that I will not be identified by name during the recording and if I would like to withdraw any comments made during the recording this will be noted by the researcher conducting the focus group and written transcripts of the recording will be amended.

I have had an opportunity to ask A/Prof Lubans questions about the research and my participation. I understand that my participation is voluntary and I am free to withdraw from the research at any time. My refusal to participation or withdrawal of consent will not affect my relationship with the University of Newcastle or my school. Withdrawal from this task will not result in any disciplinary action against me, nor will it affect my academic grades, given that this is a purely voluntary research task.

By signing below I am indicating my consent to participate in this research project conducted by A/Prof David Lubans, Prof Ron Plotnikoff, Prof Philip Morgan and Research Higher Degree student Joseph Scott as it has been described to us in the Information Statement, a copy of which I have retained.

Student name: ____

Parent/guardian name: ____

Student contact number: (m) ____________________________________

Email: ____
(Only required if you don't have a mobile)

Signature: ______________________________ **Date:** _______________________

Please sign the completed consent form and return with your CHILD'S CONSENT FORM to their roll-call teacher or the school's office

Appendix 8: Accelerometer log sheet: This sheet was used by participants to log non-wear time of measuring devices (i.e., swimming, contact sports etc.)

ACTIVITY MONITOR (ACCELEROMETER) INFORMATION SHEET

What does the monitor do?

The monitor records all movement, so that when you watch television, play outside, or eat dinner, it records how much and how often you move your body.

Does the monitor hurt?

No. The monitor is attached to a soft elastic belt and worn under your clothes. You may be aware of the monitor when you first start to wear it, but it will not hurt.

When do you put your monitor ON?

- The monitor is to be put on as soon as you wake up each morning.
- You are to wear the monitor under your clothes over the right hip (not in the middle near their belly-button), making sure that it is the correct way up (The sticker on the top of the monitor should be facing upwards i.e. pointing towards the sky). The monitor should fit firmly so that the elastic belt can not bounce, but should not be uncomfortably tight.
- Write the time when the monitor is put on (see activity monitor log).
- The monitors are **not** water-proof, so please remember that the monitor is not to be worn in the shower, bath or when swimming or playing in aquatic areas.

When do you take OFF the monitor?

- The monitor should be taken off when you go to bed, or if there is a chance that the monitor could get wet (eg playing near water). Please note on the monitor log sheet any specific time periods that the monitor is taken off and why (e.g. 3.30-4.30pm on Wednesday – Swimming at the beach).
- The monitor is to be worn for all waking hours for all 8 days. At the end of each day please write the time the monitor is taken OFF (see activity monitor log).

What do I do at the end of the 8 days?

Please keep wearing your monitor until the researchers come and collect it from you at school on the 8th Day.

What if I damage or lose the monitor?

You will **not** have to pay for the monitor if you damage or lose it.

The monitors are expensive, so please take care of them. It is quite a sturdy piece of equipment, but will be damaged if thrown or forcefully dropped. You should not lose the monitor because it is securely fitted to a belt, and should not be removed except for during aquatic activities and sleeping.

ACCELEROMETER LOG SHEET

Name: …………………………………… **Monitor ID Number:** ……………………

School: ……………………………………

INSTRUCTIONS:

1. Please shade in the times that the activity monitor was ON your body.
2. During the times the monitor was taken OFF, please indicate what you were doing and the time the monitor was OFF (e.g. surfing at beach 3:30-4:30)
3. Please write down any time spent swimming, riding a bike, or playing on a trampoline underneath.
4. See the example on the left hand side of the page for how to complete the log.

EXAMPLE:

	Date	Monday 20/5		Day/Date	1.	2.	3.	4.
	12-1	Sleep		12-1				
	1-2	Sleep		1-2				
	2-3	Sleep		2-3				
	3-4	Sleep		3-4				
	4-5	Sleep		4-5				
AM	5-6	Sleep	AM	5-6				
	6-7	Sleep		6-7				
	7-8	**ON**		7-8				
	8-9	**BIKE RIDING**		8-9				
	9-10			9-10				
	10-11			10-11				
	11-12			11-12				
	12-1			12-1				
	1-2			1-2				
	2-3			2-3				
	3-4	**SWIMMING OFF**		3-4				
	4-5	**SHOWER OFF**		4-5				
PM	5-6	**ON**	**PM**	5-6				
	6-7			6-7				
	7-8			7-8				
	8-9			8-9				
	9-10	**BED OFF**		9-10				
	10-11	Sleep		10-11				
	11-12	Sleep		11-12				
Total time swimming for the day:								
Total time riding a bike for the day:								
Total time using a trampoline for the day:								

Assessment Protocols

	Day/Date	5.	6.	7.	8.
AM	12-1				
	1-2				
	2-3				
	3-4				
	4-5				
	5-6				
	6-7				
	7-8				
	8-9				
	9-10				
	10-11				
	11-12				
PM	12-1				
	1-2				
	2-3				
	3-4				
	4-5				
	5-6				
	6-7				
	7-8				
	8-9				
	9-10				
	10-11				
	11-12				
Total time swimming for the day:					
Total time riding a bike for the day:					
Total time using a trampoline for the day:					

###REMEMBER###

PEDOMETERS AND ACCELEROMETERS HAVE TO BE RETURNED ON DAY 8!!!

3

Appendix 9: Pedometer log books: This was used by the participants to record their daily step counts.

PEDOMETER INFORMATION SHEET

What does the monitor do?

The pedometer records all vertical movement. So basically, every time you take a step the pedometer senses an 'up' and 'down' movement it will record it a step.

Does the monitor hurt?

No. The monitor is attached to a soft elastic belt and worn under your clothes. You may be aware of the monitor when you first start to wear it, but it will not hurt.

When do you put your monitor ON?

- The monitor is to be put on as soon as you wake up each morning.
- You are to wear the monitor under your clothes over the right hip (not in the middle near their belly-button), making sure that it is the correct way up. The monitor should fit firmly so that the elastic belt cannot bounce, but should not be uncomfortably tight.
- The pedometer should be attached to the accelerometer belt.
- The monitors are **not** water-proof, so please remember that the monitor is not to be worn in the shower, bath or when swimming or playing in aquatic areas.

When do you take OFF the monitor?

- The monitor should be taken off when you go to bed, or if there is a chance that the monitor could get wet (e.g. playing near water).
- The monitor is to be worn for all waking hours for all 8 days. At the end of each day please write the time the monitor is taken OFF (on activity monitor log).

What do I do at the end of the 8 days?

Please keep wearing your monitor until the researchers come and collect it from you at school on the 8th Day.

What if I damage or lose the monitor?

You will **not** have to pay for the monitor if you damage or lose it.

The monitors are expensive, so please take care of them. It is quite a sturdy piece of equipment, but will be damaged if thrown or forcefully dropped. You should not lose the monitor because it is securely fitted to a belt, and should not be removed except for during aquatic activities and sleeping.

PEDOMETER LOG SHEET

Name: …………………………………… **School:** ……………………………………

INSTRUCTIONS:

- When you take off your pedometer at night to go to sleep write down your step count
- Also, write in the *day* and *date* next to your step count.

EXAMPLE:

DAY	DAY OF WEEK	DATE	STEP COUNT
1	Tuesday	15.9.11	6,540
2	Wednesday	16.9.11	8,971
3	Thursday	17.9.11	12,564
4	Friday	18.9.11	6,826
5	Saturday	19.9.11	14,879
6	Sunday	20.9.11	5,768
7	Monday	21.9.11	9,932
8	Tuesday	22.9.11	8,734

YOUR DAILY PEDOMETER LOG:

DAY	DAY OF WEEK	DATE	STEP COUNT
1			
2			
3			
4			
5			
6			
7			
8			

REMEMBER: PEDOMETERS AND ACCELEROMETERS HAVE TO BE RETURNED ON DAY 8!!!

Appendix 10: Oxford Physical Activity Questionnaire (OPAQ). Previous validated questionnaire in the adolescent population (Lubans, 2008)

Oxford Physical Activity Questionnaire (OPAQ)

Student Name: ____________________________

School: __________________________________

To protect your privacy this cover sheet will be removed and destroyed once

You've been allocated a study number.

A/Prof David Lubans	**Prof Ron Plotnikoff**	**Prof Philip Morgan**	**Joseph Scott**
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Oxford Physical Activity Questionnaire (OPAQ)

1) **Age:** _______

2) **Gender:** *please tick (✓)* □ Male □ Female

3) **Height:** ______cm **Weight:** ______kg

4) **In what country were you born?** *Please tick (✓)*
□ Australia □ Another country (Please specify):
____

5) **What is your cultural background?**
□ Australian □ Aboriginal □ Torres Strait Islander □ Asian □ European
□ Middle Eastern □ African □ Other: (please specify) ____________

6) **What language do you speak most at home?** *Please tick (✓)*
□ **English** □ **Another language - (please specify):**
____

7) **What is the postcode of the suburb you live in?** __ __ __ __

The purpose of this questionnaire is to estimate the amount of time you spent participating in physical activity over the past 7 days. This includes physical education, school sport and other moderate to vigorous physical activity you completed during the week and on the weekend.

Moderate to vigorous physical activity makes you breathe heavily and increases your heart rate. It includes all sports, exercise activities, games, swimming, running, skateboarding etc.

Please indicate the **ACTIVITY** and the **TIME** you spent doing the activity. There are a number of questions that will help you to remember, along with a list of common activities at the top of the next page. If you did not do any physical activity, please leave the table blank.

1) How do you usually travel to school? (*Please circle)*

Walk *Cycle* *Bus* *Car* *Other*

2) How long does each journey take? *(Write)* _______________ mins.

3) Over the past 7 days, on how many days did you walk or ride, scoot or skate to school? *(Please circle)*.

0 1 2 3 4 5 6

<u>Now, please record the following information on the timetable on the NEXT PAGE:</u>

4) List all the practical activities that you did in PE lessons over the past 7 days (e.g. football, hockey, dance, and gymnastics).
5) List all the activities that you did in school sport over the past 7 days (e.g. basketball, weight training, and golf).
6) List any sports or activities that you did before/after school or on weekends over the past 7 days (e.g. surfing, cricket and dance).
7) List any other physical activities that you did over the past 7 days that lasted 20 minutes or longer (e.g. you might have played soccer at recess or lunchtime).

Oxford Physical Activity Questionnaire (EXAMPLE)

Aerobics	Cricket	Golf	Inline skating	Running (jogging)	Surfing
Athletics	Cycling	Gymnastics	Lifesaving	Rugby league	Swimming
Austag	Dance (ballet)	Hockey	Martial arts	Rugby union	Tennis
Baseball	Dance (other)	Indoor soccer	Netball	Skateboarding	Touch football
Basketball	Dance (jazz)	Inline hockey	Rowing	Soccer	Volleyball

<table>
<tr><th colspan="15">Participation in physical activity during the last 7 days</th></tr>
<tr><th rowspan="2">Component</th><th colspan="2">Monday</th><th colspan="2">Tuesday</th><th colspan="2">Wednesday</th><th colspan="2">Thursday</th><th colspan="2">Friday</th><th colspan="2">Saturday</th><th colspan="2">Sunday</th></tr>
<tr><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td><td>Activity</td><td>Mins</td></tr>
<tr><td>Before school</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="6">Surfing</td><td rowspan="6">120</td><td rowspan="6">Touch football</td><td rowspan="6">60</td></tr>
<tr><td>Morning (including breaks)</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Dance(PE)</td><td>40</td><td></td><td></td></tr>
<tr><td>Lunch time</td><td></td><td></td><td>Basketball</td><td>45</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Afternoon (including breaks)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>After school</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Soccer</td><td>90</td></tr>
<tr><td>Evening</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="15">Note: Remember to include the number of minutes, examples have been have been provided for you.</td></tr>
</table>

Oxford Physical Activity Questionnaire

Aerobics	Cricket	Golf	Inline skating	Running (jogging)	Surfing
Athletics	Cycling	Gymnastics	Lifesaving	Rugby league	Swimming
Austag	Dance (ballet)	Hockey	Martial arts	Rugby union	Tennis
Baseball	Dance (other)	Indoor soccer	Netball	Skateboarding	Touch football
Basketball	Dance (jazz)	Inline hockey	Rowing	Soccer	Volleyball

Participation in physical activity during the last 7 days

Component	**Monday**		**Tuesday**		**Wednesday**		**Thursday**		**Friday**		**Saturday**		**Sunday**	
	Activity	Mins	Activity	Mins	Activity	Mins	Activity	Mins	Activity	Mins	Activity	Mins	Activity	Mins
Before school														
Morning (including breaks)														
Lunch time														
Afternoon (including breaks)														
After school														
Evening														

Note: Remember to include the activity and number of minutes.

Appendix 11: Single-item physical activity questionnaire: A single-item questionnaire for assessing physical activity.

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

THE SINGLE ITEM QUESTIONNAIRE

Student Name: ______________________________

School: ____________________________________

To protect your privacy this cover sheet will be removed and destroyed once

You've been allocated a study number.

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INSTUCTIONS:

To complete this questionnaire, answer the following question, by ticking the appropriate box.

QUESTION:

In the past week, on how many days have you done a total of 60 minutes or more of physical activity, which was enough to raise your breathing rate? This may include sport, exercise and brisk walking or cycling for recreation or to get to and from places? *Please tick only one box.*

No. of days	0	1	2	3	4	5	6	7
Tick one								

Appendix 12: Pedometry Behaviour Questionnaire (PBQ)

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

PEDOMETRY BEHAVIOUR QUESTIONNAIRE (PBQ)

STUDENT NAME: ………………………………..

SCHOOL: …………………….................

To protect your privacy this cover sheet will be removed and destroyed once you have been allocated a study number.

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INSTRUCTIONS:

- Please make sure your name is on the front page of the questionnaire. Your name will not be recorded and no-one except the researchers will see your answers.
- This is not a test. There are no right or wrong answers.
- When you complete the questionnaire please read back over your answers to ensure you have not missed any questions.
- There are three sections, please make sure you complete all three.

SECTION 1: Pedometer Behaviour

The following statements focus on how you wore a pedometer.

INSTRUCTIONS: *Circle **ONE** option for each statement*						
1.	When I forgot to write down my step count, I estimated my step count.	Never	Rarely	Sometimes	Often	Everyday
2.	Other than swimming, showering and sleeping, I wore my pedometer throughout the day.	Never	Rarely	Sometimes	Often	Everyday
3.	When wearing my pedometer I was more active than normal.	Never	Rarely	Sometimes	Often	Everyday
4.	I shook my pedometer to increase my step count.	Never	Rarely	Sometimes	Often	Everyday
5.	I purposely wrote down more steps than I actually did.	Never	Rarely	Sometimes	Often	Everyday

SECTION 2: Attitudes toward wearing pedometers

The following statements focus on how wearing a pedometer made you feel.

INSTRUCTIONS: *Circle **ONE** option for each statement*						
1.	I wanted to get a high step count to impress the researchers.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2.	I wanted to get a high step count to impress my friends and peers.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3.	I found that wearing the pedometer was uncomfortable.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4.	I found that wearing the pedometer was embarrassing.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5.	I found that wearing the pedometer was a waste of time.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

SECTION 3: Wearing Pedometers.		
INSTRUCTIONS: Please read the following questions and tick the appropriate box **(You can tick more than one box for each answer).**		
Question		Answer
1.	If you forgot to wear your pedometer, what did you do?	[ ] Didn't wear it that day [ ] Put it on later in the day [ ] Estimated my step count for the day [ ] Other:________________________________
2a.	Did you do more physical activity than normal when you were wearing your pedometer?	[ ] No [ ] A little more (less than 30min/day more) [ ] a fair bit more (30mins more) [ ] A lot more (greater than 30mins/day more)
2b.	In what ways did you increase your step count?	[ ] Did more exercise [ ] Shook my pedometer [ ] Gave my pedometer to someone else [ ] Wrote down more steps than I actually did [ ] I didn't [ ] Other___________________________________
3.	Who else wore your pedometer?	[ ] No-one [ ] Friend [ ] Boyfriend/girlfriend [ ] Brother or sister [ ] Parent [ ] A Pet
4.	Did you like wearing a pedometer?	[ ] Yes *(If you answered 'yes' you are finished the questionnaire)* [ ] No *(If you answered 'no' go onto question 4b)*
4b.	If you did you not like wearing a pedometer, what were your reasons?	[ ] I didn't want people to know how much activity I do [ ] It was uncomfortable [ ] It was embarrassing [ ] It was a hassle [ ] Other_________________________

THE END
THANK YOU FOR PARTICIPATING IN THIS QUESTIONNAIRE

Appendix 13: Accelerometry Behaviour Questionnaire (ABQ)

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

ACCELEROMETRY BEHAVIOUR QUESTIONNAIRE (ABQ)

SCHOOL: ....

To protect your privacy this cover sheet will be removed and destroyed once you have been allocated a study number.

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INSTRUCTIONS:

- Please make sure your name is on the front page of the questionnaire. Your name will not be recorded and no-one except the researchers will see your answers.
- This is not a test. There are no right or wrong answers.
- When you complete the questionnaire please read back over your answers to ensure you have not missed any questions.
- There are three sections, please make sure you complete all three.

SECTION 1: Accelerometer Behaviour

The following statements focus on how you wore the accelerometers.

INSTRUCTIONS: *Circle **ONE** option for each statement*						
1.	Other than swimming, showering and sleeping, I wore my accelerometers throughout the day.	Never	Rarely	Sometimes	Often	Everyday
2.	I wore wrist accelerometer more than my hip accelerometer.	Never	Rarely	Sometimes	Often	Everyday
3.	I wore hip accelerometer more than my wrist accelerometer.	Never	Rarely	Sometimes	Often	Everyday
4.	When wearing the accelerometers, I was more active than normal.	Never	Rarely	Sometimes	Often	Everyday
5.	I shook my accelerometers to increase my physical activity level	Never	Rarely	Sometimes	Often	Everyday

SECTION 2: Attitudes toward wearing Accelerometers

The following statements focus on how wearing the accelerometers made you feel.

INSTRUCTIONS: *Circle **ONE** option for each statement*						
The next 3 questions are in relation to the WRIST accelerometer.						
1.	I liked wearing the wrist accelerometer.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2.	I found that wearing the accelerometer on my wrist was uncomfortable.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3.	I found that wearing the wrist accelerometer was embarrassing.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The next 3 questions are in relation to the HIP accelerometer.						
4.	I liked wearing the hip accelerometer.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5.	I found that wearing the accelerometer on my hip was uncomfortable.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6.	I found that wearing the hip accelerometer was embarrassing.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

SECTION 3: Wearing Accelerometers.

INSTRUCTIONS: Please read the following questions and tick the appropriate box **(You can tick more than one box for each answer).**

Question		Answer
1.	If you forgot to wear the accelerometers, what did you do?	[ ] Didn't wear it that day [ ] Put it on later in the day [ ] Other:______________________________
2a.	Did you do more physical activity than normal when you were wearing the accelerometers?	[ ] No [ ] A little more (less than 30min/day more) [ ] a fair bit more (30mins more) [ ] A lot more (greater than 30mins/day more)
2b.	In what ways did you increase your physical activity level?	[ ] Did more exercise [ ] Shook my accelerometer [ ] Gave my accelerometer to someone else [ ] I didn't [ ] Other_________________________________
3.	Who else wore your accelerometers?	[ ] No-one [ ] Friend [ ] Boyfriend/girlfriend [ ] Brother or sister [ ] Parent [ ] A Pet
4.	Did you like wearing accelerometers?	[ ] Yes *(If you answered 'yes' you are finished the questionnaire)* [ ] No *(If you answered 'no' go onto question 4b)*
4b.	If you did you not like wearing the accelerometers, what were your reasons?	[ ] I didn't want people to know how much activity I do [ ] It was uncomfortable [ ] It was embarrassing [ ] It was a hassle [ ] Other______________________

THE END
THANK YOU FOR PARTICIPATING IN THIS QUESTIONNAIRE

Appendix 14: Focus-group questions

Focus group questions

Focus groups participants will be stratified into groups depending on their 7-day physical activity levels as measured by pedometers and accelerometers These focus groups will be numbered from 1-6 (Each group will not be named so that students so that do not know why they have been selected and will assume that it is random selection. Interviews will be recorded and later transcribed. Participants will be categorised as follows:

1. *High-active boys' group*: Participants within this focus group will be boys who have achieved an average of 60 minutes/day in MVPA over their monitoring period.
2. *High-active girls' group:* Participants within this focus group will be girls who have achieved an average of 60 minutes/day in MVPA over their monitoring period.
3. *Middle-active boys' group:* Participants within this focus group will be boys who have achieved an average of 30-60 minutes/day in MVPA over their monitoring period.
4. *Middle active girls group*: Participants within this focus group will be girls who have achieved an average of 30-60 minutes/day in MVPA over their monitoring period.
5. *Low-active boys group:* Participants within this focus group will be boys who have achieved an average of less than 30 minutes/day in MVPA over their monitoring period.
6. *Low-active girls' group*: Participants within this focus group will be girls who have achieved an average of less than 30 minutes/day in MVPA over their monitoring period.

ATTITUDINAL

1. Tell me about wearing a pedometer?
2. Did you feel that you had to get a high step count to impress the researchers, teachers or your friends? Why or why not?
3. What were some of the reasons for attempting to increase your step counts?
4. Did you think that most people are honest or dishonest about their step count?

5. Do you think that trying to find physical activity levels with pedometers is a waste of time? Why or Why not?

BEHAVIOURAL

1. Can you give some reasons that some of the other students may have removed the pedometers over the 7 days of measurement?
2. Did you do more exercise than normal when wearing a pedometer? Why or why not?
3. Did you attempt to increase your step count in anyway? If so, how?
4. What were the other students doing? Do you think they changed their behaviours?
5. Did you let anyone else wear your pedometer? Why/why not