

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

Thesis presented for the degree of

DOCTOR OF PHILOSOPHY

In the department of Human Biology

UCT/MRC Research Unit for ESSM

Faculty of Health Sciences

University of Cape Town

Steps that count!

The use of pedometry for physical activity and health promotion in South Africa

Julian Pillay

PLLJUL004

In collaboration with:

Department of Public and Occupational Health
EMGO+ Institute for Health and Care research
VU University Medical Center, Amsterdam, the Netherlands

**Supervisors: Prof. EV. Lambert; Dr TL Kolbe-Alexander; Prof W van
Mechelen; Dr KI Proper**

May 2013

DECLARATION

This research has not been previously accepted for any degree and is not being currently submitted in candidature for any degree.

.....

JD Pillay

07 May 2013

University of Cape Town

To my mum
For all her struggles

University of Cape Town

ACKNOWLEDGEMENTS

Many people, some unknowingly, have contributed towards bringing to fruition my greatest academic endeavour to date, the completion of my PhD journey. Although the contributions are of a different nature and extent, I am equally grateful to each person as each contribution, however small, has assisted in bringing this process to its natural conclusion. I therefore acknowledge and express gratitude to the following people for their support and contribution during this process:-

Those that participated in my study - some because you were really interested in participating, others because you were my friends, students, family and wanted to be of assistance to me; others just because of the incentives - Thanks to all of you. You made it happen!

My supervisors-Dr Tracy Lynn Kolbe-Alexander, Estelle Victoria Lambert, Willem van Mechelen and Karin Proper - who created a wealth of opportunity for me and for always being supportive of my ambitions and endeavours. Thank you for your input and constructive critique. I look forward to our future collaborations as academics and friends.

Tracy, I am indeed grateful for all of the funds you have made available to me and constantly re-assuring me that I will get there.

Vicki, your intelligence and way of thinking is a part of your skill set that I would love to acquire.

Karin, thank you for your quick responses and constructive advice, as well as the positive comments about my work that kept motivating and reassuring me.

Willem, you are a gifted academic and I am grateful that our paths crossed. I am not sure what good I have done in my life to have been blessed with your friendship and mentorship. Thank you for all of the opportunities you have offered me and also for the great hospitality that you provided during my visits to the Netherlands. Your prompt response to all of my correspondence whether it was work related or social, is greatly appreciated and valued.

I have enjoyed abundant generosity from my funders - DUT (Research office, International Education and Partnerships office), NRF (Thuthuka), SANPAD and SAVUSA. Without your committed contribution this walk would have been a lot more challenging to have endured and concluded.

My mum, *Punitha*, who is responsible for the beginning of my life and my life's journey; for prophesying the spirit of David (which I am proud to have as my middle name) into my life - a spirit of faith, intellect, strength and uncommon favour - and for continuing to do so.

Mohammed, Neil, Yanita, Denise, Madelaine, Neezaam, Trevino and Lance (my Cape Town support group). Thank you for your support and friendship during this time and always. Madelaine, thank you especially for your kindness and eager and unconditional assistance when my work required that I spend extended periods in Cape Town.

Allen Johnathan, a mentor, father and friend. Thank you for the support, encouragement and advice during this time, and always. Thank you also for the language editorial assistance. I will have to take some English lessons from you.

My good friend, Leon: Thank you for reminding me that I needed to enjoy (and not rush) the process in order to really appreciate and value the end when it arrived.

Milli, my dear, dear friend: Thank you for your support and motivation, even before the idea to embark on this venture was conceived. Thank you also for all those articles that you willingly mailed to me whenever I could not access them quickly enough in South Africa - your Fulbright scholarship has served me well, too. Hopefully we will write a paper together, soon.

Nirusha Lachman, my former work colleague and friend. Thank you for the inspiration and motivation to embark on a PhD. I look forward to writing many anatomy education papers with you.

My work colleagues - Nalini and Nombeko- Thank you for your motivation, inspiration and support; for allowing me into your office whenever I felt brain-dead and needed a breather and to be re-energised.

Nalini, thank you, more importantly, for your friendship.

Nombeko, your great sense of humour always gave me a pep-up. You have proved that laughter is indeed the best medicine in any downhill moment.

Razia Kharwa, my Head of Department: I have been blessed to have had you as my HOD during this time. Thank you for allowing me the freedom to explore every opportunity that presented itself to me.

I hope to offer you similar support, in whatever capacity, as you advance further in academia.

My fellow anatomist and friend, Fazila Ally: Thank you for your friendship. More importantly, thank you for offering me temporary relief during my research visits away from KZN.

I wish you every success as you embark on your PhD.

My precious aunts - Radha, for minding me as a child and teaching me discipline - a key tool in allowing me to follow through and complete this chapter of my career; Kookie, for constantly reminding me of the inspiration I am to your children and in so doing prompting me to strive towards on-going achievement.

Amanda - my cousin, my daughter, my sister and my friend. Thank you for loving me unconditionally; for understanding the demands that this project has placed on me resulting in me not giving you as much time and energy as I would have liked to have given you. Thank you for still being so grateful for the little that I have provided you that you see as a lot.

I look forward to your graduation too, and I hope that I can inspire and motivate you further.

My late Grandmother and my late aunt Saloshini whose light and love continue to shine upon my life. It is unfortunate that you are not here to share this glorious moment with me, but you are with me, in spirit. As clichéd as that sounds, I do believe it.

My students for allowing me the opportunity to impart to them the greatest gift that can be given to anyone - that of knowledge. Without you, the burning desire to achieve a PhD would have never ignited.

A special thanks to Danella Middleton, a former student whom I taught and who has subsequently provided me unconditional assistance in the latter two years of this project. Your passion and enthusiasm towards any task that you are entrusted with, and the fact that you strive for excellence in the execution of the task is indeed remarkable. Thank you also to Duncan Jack for his assistance with some of the parts of this research - another great former student of mine that I am blessed to have been offered assistance by.

The statistical input and advice and assistance from Tonya Esterhuizen, Deepak Singh, Riekie De Vet, Tobias Berg and Jos Twisk.

Joske Nauta, for all the administrative assistance and more importantly, your friendship during my visits to VUmc, Amsterdam. Thank you also for all the tourist suggestions/advice and the Google maps. I am sorry that you didn't manage to acquire a taste for my favourite South African treat, Biltong, but at least you enjoyed the spicy, roasted corn.

Discovery Health (RSA) for allowing me access to corporate wellness events in KwaZulu-Natal. A special thanks to Lizette Jooste and Craig Nossel for facilitating this process.

Virgin Life Care for allowing me the use of the “step-test” and providing the required training. A special thanks to Amanda Claasens and Catherine Viljoen in this regard.

The teachers in my life - Mrs Naicker (my favourite primary school teacher- I cannot even remember her initials- it’s been a while!);

Dr Stephen Knight (my master’s supervisor and course-coordinator);

Denise and Sharon (my piano tutors- I am not that musical hence I needed two teachers) - Denise, I am really sorry that I could not do a PhD on you, as you would have liked, but the study just would not have had enough statistical power. Thank you for also giving me a great gift in teaching me to play the piano;

Jenny (my swimming instructor);

Sabrina (my Italian teacher);

Vicki, Tracy, Willem, Karin (my PhD supervisors and mentors);

My mum, my aunts, my late Grandmother, the list goes on.

Thank you for always making me believe in me.

The great scientists that have preceded me and the master researchers of the past, whose academic works have lit within me a passion to learn and achieve more.

My loyal companion, Vicki (my golden cocker spaniel). Thank you for being a true companion in the latter stages of my PhD walk. Thank you for keeping me company,

sitting in your favourite spot in my office and giving me something beautiful to look at each time I looked away from my computer. I pray that I will enjoy many years of your companionship and true loyalty.

Finally, and most importantly, my sincerest and heartfelt gratitude to the Lord almighty for the uncommon favour you have bestowed on me in creating all the right opportunities at the right time; for allowing me to excel, not all the time, but when it mattered the most and most of all for the assurance of success through your declared words:-

"I know the plans I have for you, plans to prosper you and not to harm you, plans to give you hope and a future."

Jeremiah 29:11

ABSTRACT

The association between physical inactivity and the increased risk of many clinical conditions has been well documented and is currently a major global public health challenge. Walking has been reported as the most common and easily accessible form of physical activity and therefore an important activity to prescribe and assess. Pedometers have been demonstrated as a practical tool for measurement and motivation of ambulatory physical activity, typically providing information on volume of steps/day. Recent developments in steps/day research have, however, emphasised the importance of intensity-based steps as part of steps/day recommendations. Such steps/day recommendations are also directed towards current physical activity guidelines, so as to provide further options for achieving guidelines. To complement these developments in steps/day recommendations, technological advancements in pedometry afford the opportunity to provide information on intensity-based steps/day. We therefore use this application to provide further insight into the association between pedometer-based physical activity and fitness and health outcomes. Particular reference is made to intensity-based steps/day, through a series of studies.

An explorative study (Chapter 2) provides information on pedometer-determined physical activity patterns, with reference to clinical, anthropometric and fitness measures, in a convenience sample of adults (N=70; 35 men, 35 women; 32±8years). The study highlights the importance of intensity-based steps/day and raises pertinent questions around intensity-based steps/day recommendations and the relationship between these recommendations and current physical activity guidelines. This informed a subsequent study (Chapter 3) which aimed to address

some of these issues. In this study, a convenience sample of men and women (N=58; 34 men, 24 women; 31.7 ± 7.7 years) underwent a series of metronome-regulated walking trials (ranging from 60 steps/minute-120 steps/minute). Using steps/minute and heart rate data, during these walking trials, a steps/minute rate for moderate intensity physical activity was predicted. The analysis of self-paced brisk walking, in terms of steps/minute, was compared to that of moderate intensity physical activity. Findings showed that the average steps/minute rate for self-paced brisk walking was 118 ± 9 steps/minute (men- 116 ± 9 steps/minute; women- 121 ± 8 steps/minute; $P=0.022$). The predicted steps/minute rate for moderate intensity physical activity was calculated to be 122 ± 37 steps/minute (men- 127 ± 36 steps/minute; women- 116 ± 39 steps/minute; $P<0.99$). We found similarity between the predicted steps/minute rate for moderate intensity physical activity and that of self-paced brisk walking ($P=0.452$), even after adjusting for age, gender and aerobic fitness. A further outcome of this study therefore supports current messages that use the term “brisk” walking as a reference for moderate intensity physical activity.

Chapter 4 presents cross-sectional pedometer-based data of a South African, employed adult population (N=312, 147 men, 165 women; 37 ± 9 yrs). In our analyses, a steps/minute rate ≥ 100 steps/minute and for a minimum duration of 10 consecutive minutes was applied as a minimum reference for moderate intensity physical activity. In so doing, our analysis made reference to documented literature (such as steps/minute) as well as alignment to current physical activity guidelines (i.e. minimum duration of moderate intensity physical activity bouts). The study additionally provides information on ambulatory physical activity patterns in an employed South African, adult population group, presenting for health risk assessment. Findings of the study showed that the average steps/day accumulated

were $6,574 \pm 3,541$ steps/day (men- $6,476 \pm 4,076$; women- $5,769 \pm 2,759$; $P < 0.003$). Further findings indicated that total steps/day and average daily aerobic time were inversely associated with clinical measures such as percentage body fat, body mass index, waist circumference and systolic blood pressure ($P < 0.05$) in the expected direction. An analysis of covariance (adjusted for age, gender and total steps/day) showed a similar relationship between aerobic time categories and health outcomes.

A further analysis, in this study (Chapter 4), compared the mediation effect of percentage body fat, body mass index and waist circumference independently on the association between steps and health outcomes. Of the 3 measures used to estimate body fat, percentage body fat emerged as the strongest mediator in the relationship between steps and health outcomes, in all of the associations evaluated. Body mass index appeared to be the weakest mediator.

In keeping with the central theme of intensity-based steps, and its relation to current guidelines, Chapter 5 describes the association between self-reported physical activity and pedometer-measured ambulatory physical activity. In this study, pedometer-data was grouped into different steps/day and aerobic time categories and particular reference to current guidelines was made. This allowed for comparisons between self-reported and pedometer-determined ambulatory physical activity to be made, in relation to estimates of current guidelines. Findings showed that of a total of 312 participants' self-reported data, those meeting guidelines ($n=63$) accumulated significantly more steps/day than those not meeting guidelines (8753 ± 4251 steps/day versus 6022 ± 3114 steps/day, respectively; $P < 0.001$). A similar finding was noted when comparing moderate intensity steps/day with those meeting/not meeting guidelines ($1,772 \pm 2,020$ steps/day versus $421 \pm 1,140$

steps/day, respectively; $P < 0.0001$). Our analyses also identified that more than half of the group meeting guidelines on the basis of self-reported, did not meet guidelines, based on pedometer-measured ambulatory data. It is important to note that the self-report measure includes all types of activity, in different domains, whereas pedometer-based measures relate specifically to ambulation. Implications of comparisons between self-reported physical activity and pedometer-measured ambulatory physical activity are further discussed in Chapter 8.

As an application of some of our previous findings, a 10-week work-site pedometer-based study ($N=22$), *Steps that count!*, (Chapter 6) was conducted as a pilot (i.e. feasibility) intervention to inform the development and design of a future randomised controlled trial to be administered in an employed, adult population.

A questionnaire on participants' perception of the intervention was completed as part of the intervention follow-up measures. The value of the pedometer serving as a useful motivational aid, and a reminder to increase steps/day, was a factor highlighted by most participants. Additionally, the participants expressed an increased awareness of the need for engaging in physical activity, and supported pedometer-based interventions as a strategy to motivate for increased ambulatory physical activity. Our findings also showed that the steps/day increase was greater in the intervention group than the control group ($996 \pm 1,748$ steps/day versus 97 ± 750 steps/day; $P=0.06$). Similarly, modest but non-significant improvements were noted in all clinical measures. The findings of the pilot intervention have been applied to the development of a protocol for a large-scale randomised controlled trial.

Based on a minimum improvement of 1,000 steps/day, as obtained in the pilot study, a sample size of approximately 85 participants in the intervention and control groups, respectively, was established as the required number to be included in this future

trial. This would ensure 80% statistical power, with a P-value set at <0.05 . In order to account for the loss to follow up, as well as the possibility of performing sub-group analyses, we recommend a minimum of 150 participants in both the intervention and control groups, respectively.

Chapter 7 outlines the rationale behind, and the development of, a randomised controlled trial protocol aimed at improving ambulatory physical activity through pedometer use. The study combines the use of pedometers with regular, individualised, email-based feedback.

Through this series of formative studies, we focused on intensity-based steps, and not just on step volume, such that the outcomes of this research can be used to supplement and improve physical activity and exercise prescription. The research has additionally provided more objective insight into the ambulatory physical activity patterns of the South African employed population in relation to fitness and health.

CONTENTS

	Page number
<u>CHAPTER 1:</u>	01
General introduction and outline of thesis	
<u>CHAPTER 2:</u>	35
The association between the number and intensity of steps accumulated and fitness and health measures	
<u>CHAPTER 3:</u>	57
Physical activity recommendations, brisk walking and steps per minute- how do they relate?	
<u>CHAPTER 4:</u>	75
A pedometer-based cross-sectional study in an employed South African population	
<u>CHAPTER 5:</u>	98
Pedometer-measured and self-reported physical activity, in relation to current guidelines and ambulatory physical activity	
<u>CHAPTER 6:</u>	112
<i>Steps that count!</i> A pilot feasibility study of a pedometer-based health promotion intervention in an employed, South African population	
<u>CHAPTER 7:</u>	132
The development of a pedometer-based health promotion intervention, <i>Steps that count!</i> , in an employed, health insured South African population	

	Page number
<u>CHAPTER 8:</u>	148
General discussion and conclusion	
 <u>REFERENCE LIST</u>	 166
 <u>APPENDICES</u>	
<i>Appendix A: Ethics approval</i>	176
<i>Appendix B: Participant Information Sheet</i>	179
<i>Appendix C: Informed Consent</i>	187
<i>Appendix D: Modified Physical Activity Readiness Questionnaire</i>	193
<i>Appendix E: Self-reported Physical Activity Questionnaire</i>	194
<i>Appendix F: Uploading pedometer data</i>	198
<i>Appendix G: Feedback information provided to participants</i>	199
<i>(Feasibility study)</i>	
<i>Appendix H: Motivational messages provided to participants</i>	200
<i>Appendix I: Pedometer intervention feedback questionnaire</i>	205
<i>Appendix J: Feedback information provided to participants</i>	209
<i>(Randomised controlled trial)</i>	
 <u>ABOUT THE AUTHOR</u>	 210

LIST OF TABLES

	Page number
Table 2.1: Fitness, health and ambulatory characteristics of participants	43
Table 2.2: Correlation (ρ) between health measures and total steps, aerobic steps, intensity and time per day	44
Table 2.3: Fitness, health and ambulatory characteristics of participants by group	45
Table 3.1: Clinical and ambulatory characteristics of participants	63
Table 4.1: General characteristics of participants	82
Table 4.2: Biometric and clinical measures by step per day categories	83
Table 4.3: Biometric and clinical measures based on daily aerobic step time categories	85

	Page number
Table 4.4:	87
Mediation effect of percentage body fat, body mass index and waist circumference on the association between daily steps/aerobic time and clinical measures	
Table 5.1:	106
The association between pedometer and self-reported data in relation to physical activity guidelines	
Table 6.1:	122
Descriptive baseline characteristics of participants	
Table 6.2:	124
Net change of participants' characteristics at follow-up	

LIST OF FIGURES

	Page number
Figure 2.1: Step Test Protocol- Virgin Life Care™	40
Figure 3.1 a) Percentage of maximum age-predicted heart rate of each trial b) Steps per minute rate of each trial	65
Figure 3.2: Step per minute rate and percentage heart rate of self-paced brisk walk	66
Figure 5.1: Steps per day in relation to physical activity guidelines- self-reported (A) and pedometer-determined (B)	104
Figure 6.1: Flow of the study design (pilot intervention)	118
Figure 7.1: Flow of the study design (randomised controlled trial)	142

LIST OF ABBREVIATIONS

Ancova- Analysis of covariance
Anova- Analysis of variance
BC- Blood glucose
BG- Blood cholesterol
BMI- Body mass index
BP- Blood pressure
C' – C-prime
DBP - Diastolic blood pressure
HR- Heart rate
Kcal/day - Kilocalories per day
METS - Metabolic equivalents
Minutes/day – minutes per day
% - Percent
%BF - Percentage body fat
%HRM - Percentage of maximum heart rate
RCT – Randomised controlled trial
Steps/day - Steps per day
Steps/minute - Steps per minute
SBP - Systolic blood pressure
U.S. – United States
WC - Waist circumference
WHO - World Health Organisation

LIST OF PUBLICATIONS AND PRESENTATIONS

2005 Durban Institute of Technology Institutional Research Day: [oral presentation]

Awarded “Best Masters Presentation”.

Topic: An Analysis and Evaluation of the Child survival Project in the uThukela District of KwaZulu-Natal

Pillay JD, Knight S

Published: *Southern African Journal of Epidemiology and Public Health* 2010, 25(2): 22

2008 South African Society of Clinical and Sports Medicine Annual Conference (Cape Town)/ International Society for Behavioural Nutrition and Physical Activity (ISBNPA) Annual Conference (Banff, Canada): [oral and poster presentation, respectively]

Topic: Are point-of-decision prompts in a sports science and medicine centre effective in changing the prevalence of stair usage?-A preliminary study

Pillay JD, Carstens M, Achmat M, Kolbe-Alexander TL, Lambert EV

Published: *South African Journal of Sports Medicine*, 2009, 21(2):58

2009 International Society for Behavioural Nutrition and Physical Activity (ISBNPA) Annual Conference (Lisbon, Portugal): [poster presentation]

Topic: Steps that count- The association between the number and intensity of steps accumulated and health and fitness measures

Pillay JD, Kolbe-Alexander TL, van Mechelen W, Lambert EV

Published: *Journal of Physical Activity and Health*, [in press]

2010 International Society for Behavioural Nutrition and Physical Activity (ISBNPA)
Annual Conference (Minnesota, USA): [poster presentation]

Topic: Steps that count: Physical activity recommendations, brisk walking and
steps per minute- How do they relate?

Pillay JD, Kolbe-Alexander TL, Proper KI, van Mechelen W, Lambert EV

Published: *Journal of Physical Activity and Health* [in press]

2012 Working on wellness (WOW): A worksite health promotion intervention
programme

Kolbe-Alexander TL, Proper KI, Lambert EV, Van Wier MF, Pillay JD, Nossel
C, Adonis L, van Mechelen W

Published: *BMC Public Health* 2012, 12:372

2012 Steps that count: The development of a pedometer-based health promotion
intervention in an employed, health insured South African population

Pillay JD, Kolbe-Alexander TL, Proper KI, Lambert EV, van Mechelen W

Published: *BMC Public Health* 2012, 12:880

2012 Steps that count: A pedometer-based, cross-sectional study in an employed
South African population

Pillay JD, van der Ploeg H, van Stralen M, Kolbe-Alexander TL, Tomaz S, van
Mechelen W, Lambert EV

In submission: *Journal of Physical Activity and Health*

2012 Steps that count: Pedometer-measured and self-reported physical activity, in relation to current guidelines and ambulatory physical activity

Pillay JD, Kolbe-Alexander TL, Tomaz S, van Mechelen W, Lambert EV

In submission: Journal of Physical Activity and Health

2012 Steps that count!: A pilot feasibility study of a pedometer-based health promotion intervention in an employed, South African population

Pillay JD, Kolbe-Alexander TL, Proper KI, van Mechelen W, Lambert EV

In submission: South African Journal of Sports Medicine

University of Cape Town

CHAPTER 1

General Introduction

This chapter presents a background on the use of pedometers for objective measurement of ambulatory physical activity, and for self-monitoring of, and motivation for, physical activity.

Particular reference is made to consider intensity-based recommendations for walking, within the context of current physical activity guidelines and technological advancements in pedometry.

The chapter ends with an overview of the outline of the dissertation.

INTRODUCTION

Physical activity, defined as “any bodily movement produced by contraction of skeletal muscle that increases energy expenditure” ¹, has been shown to provide significant protective effects against several chronic diseases²⁻⁸. These diseases include clinical conditions such as coronary heart disease, hypertension, non-insulin-dependent diabetes mellitus, osteoporosis, and among others colonic cancer ²⁻⁸.

Most studies suggest that there is a dose-response relationship between physical activity and associated health benefits ^{1-3,9}. This dose-response effect refers to the relationship between higher levels of physical activity or a relative increase in the levels of physical activity (dose) and the improvements in the levels of a defined health parameter (response) ¹. The dose of physical activity is prescribed as mode (type of activity), intensity, duration and frequency (sessions per week) ¹. The response to physical activity relates to the improved health outcomes and overall well-being achieved through regular physical activity ¹.

The World Health Organisation (WHO) physical activity guidelines recommend that individuals accumulate at least 150 minutes of moderate intensity physical activity per week (or equivalent), in bouts of at least 10 consecutive minutes in duration ⁸. Such a recommendation is identified to result in a reduction in risk for all-cause mortality and disease-specific morbidity and mortality ⁸. This dose-response effect encompasses components of physical activity including: mode, intensity, duration and frequency and the expected response of improved health and well-being ^{10,11}.

Walking has been reported as the most common mode of physical activity in both developed and developing countries ^{10,12-15}. This is, in part, due to the fact that walking is an inexpensive and easily accessible activity for a large proportion of the general population ¹³ and across age groups ¹⁰. Furthermore, there are fewer physical, social and psychological barriers associated with walking than other more traditional forms of exercise ¹⁶.

By collecting objective data on patterns of ambulatory physical activity, researchers and practitioners can develop strategies to advise the public on how best to improve physical activity levels as well as their health ¹⁷. This is important for surveillance, screening, programme evaluation and intervention in order to develop appropriate and feasible approaches to facilitate improved physical activity ^{18,19}. Such approaches can be directed towards producing different options for improving ambulatory physical activity, whilst simultaneously relating to current guidelines.

MEASUREMENT OF PHYSICAL ACTIVITY

Physical activity levels are often measured and monitored in order to assess health behaviours and their association with morbidity and mortality rates ²⁰. The accurate measurement of physical activity is also required to establish current levels and changes within a population, and to assess the effectiveness of interventions designed to increase physical activity ²⁰.

Different measurement techniques available can be grouped in different categories. These categories include direct observation, self-report (questionnaires and activity diaries/logs), physiological markers (heart rate, body temperature, ventilation),

motion sensors (pedometers, accelerometers), and indirect calorimetry (doubly labelled water) ^{21,22}.

Self-reported (indirect) measures of physical activity using interviews, surveys, questionnaires and diaries/logs have been used to collect physical activity data in populations or sub-groups. These measures are used more frequently because of their practicality, including the low cost, low participant burden and general acceptance ²³.

Although self-reported data can provide useful insights into the physical activity levels of populations or sub-groups, this data has the tendency to overestimate or underestimate true physical activity energy expenditure and rates of inactivity ²⁰.

Furthermore, issues around recall and differential interpretations of terms, present an evident bias ²⁴. For example light, moderate and vigorous activity, floor effects (the lowest score available is too high for some respondents), and a lack of sensitivity to ambulatory activity or walking are often apparent ²⁴.

Self-reported measures are also usually unable to capture the absolute level of physical activity ²¹ and are therefore typically considered a subjective measure.

Self-reported measures, such as time use surveys, have the ability to provide detailed information on physical activity ²⁵. Such information can accordingly be used to estimate levels of energy expenditure ²⁵. Issues around recall may, nevertheless still pose a threat to its accuracy.

As self-reported methods possess several limitations in terms of their reliability and validity ²⁶, objective or direct measures of physical activity are commonly used in addition to, or in place of self-reported measures ²⁷. Objective measures have the potential to provide more precise estimates of energy expenditure and may reduce/eliminate many of the limitations of recall and response bias evident in indirect measures ²⁶.

There is a particularly increasing interest in the objective monitoring of daily physical activity using electronic motion sensors, which includes accelerometers and pedometers ²⁴. Both motion sensors are small, light-weight, unobtrusive instruments that are typically worn comfortably at the waist and detect and quantify movement. The accelerometer records “activity counts” (raw or pure movement data) that are the product of frequency and intensity (inferred from velocity) of movement sampled at set intervals or epochs (e.g. over one minute) ²⁴. The results are then either displayed as an accumulated total or, more often, uploaded for computerised display/feedback. In contrast, the pedometer is much simpler in design and often requires minimal additional software or expertise to access or interpret data ²⁴, particularly valuable in ambulatory activity and research.

Despite the advantages of using direct methods, these types of measures are time and cost intensive and often limited in their ability to be applied to large settings ²⁴. Such measures may also require specialised training and the physical proximity of the participant for data collection ²⁴. Furthermore, pedometers typically cannot extrapolate information on energy expenditure. More modern pedometers may, however, provide estimates of energy expenditure, by factoring

in aspects such as age and gender to volume, duration and intensity of ambulation²⁸.

Using pedometers to measure and quantify ambulatory physical activity have, nonetheless, been validated by several studies as a reliable and accurate measurement instrument of ambulatory physical activity²⁹⁻³³. In terms of practicality, pedometers therefore, offer a good solution for a low cost, objective monitoring tool of ambulatory physical activity²⁹⁻³¹.

CURRENT PHYSICAL ACTIVITY GUIDELINES IN RELATION TO PEDOMETER-BASED STEPS PER DAY RECOMMENDATIONS FOR HEALTHY ADULTS

Current physical activity recommendations incorporate elements of frequency, duration and intensity of physical activity. For example, the United States (US) Surgeon General's recommendation prescribes 30 minutes of moderate-vigorous physical activity on at least five days per week¹⁰. Similarly, the World Health Organisation's global recommendations on physical activity for health suggests at least 150 minutes of moderate intensity physical activity per week, in minimum bouts of 10 minutes⁸.

Researchers have complemented physical activity guidelines by providing further options for achieving recommended guidelines. Murphy, et al have shown that accumulating 30 minutes of activity in bouts of 10 minutes does lead to a significant improvement in aerobic fitness³⁴. The study further demonstrated that a reduction in skin-fold measures for body fat was evident³⁴. Similarly, Coleman, et al showed that accumulating the 30 minutes of physical activity in bouts of 5 minutes may be

enough to show some improvements in cardiovascular health and body composition

35 .

Global physical activity trends, nevertheless, show that less than 40 percent (%) of adults are physically active. For example, Hansen et al found approximately one in five people meeting current physical activity guidelines (N=3267) ³⁶. In a recent report of current physical activity levels in 122 countries, that provided an estimate of 88.9% of the world's population, only 31.4% (95% Confidence Interval: 31.2-31.4) were classified as active ³⁷. A slightly higher value of 38.0% (95% Confidence Interval: 37.6–38.4) was found in the African continent ³⁷. This, however, related to vigorous intensity physical activity on at least 3 or more days per week ³⁷.

Researchers have attempted establishing the association between current physical activity guidelines and steps per day (steps/day) recommendations. For example, Miller and Brown demonstrated the association between the 10,000 steps/day recommendation and the 30 minutes of moderate intensity physical activity per day, in an adult Australian population ²⁷. The study involved a total of 185 adults that completed a 7-day pedometer wear and a survey on patterns of physical activity, thereafter ²⁷. A mean amount of approximately 10,000 steps/day for women and about 9,000 for men were reported in those meeting guidelines²⁷. Similarly, Strycker et al compared steps/day with self-reported physical activity data, in a population-based youth sample (N=367) and post-menopausal women with type 2 diabetes (N=270) ³⁸. The study found low, but significant associations between steps/day counts and self-reported data in both sample groups ³⁸.

Research has, more recently been directed towards incorporating other elements of current recommendations, such as intensity and duration of physical activity, into steps/day messages^{30,39-43}. For example, in 2005, Tudor-Locke and colleagues reported a study involving participants (N=50, ages 18-39 years) that performed three 6-minute bouts of walking at different treadmill speeds⁴⁰. In this study, the relationship between steps and metabolic equivalents (METs), calculated using steady-state oxygen uptake), across all speeds, were quantified⁴⁰. The study concluded that 96-107 steps per minute (steps/minute) represents a minimum threshold for moderate-intensity walking (“aerobic steps”)⁴⁰.

Marshall et al corroborated the findings of Tudor-Locke et al by performing a similar study involving four 6-minute walking bouts on a level treadmill (N=97; mean age=32)⁴². The study determined that a range of 100-110 steps/minute equates to moderate intensity physical activity in healthy adults⁴².

More recently, Abel and colleagues performed a study on 19 participants of a mean age of 29 years⁴³. Oxygen consumption was measured at rest and during 10 minutes of treadmill walking at 6 standardised running speeds⁴³. The study found that men and women walking at a moderate intensity had a step rate of 94 steps/minute and 99 steps/minute, respectively⁴³.

Recent studies have also shown that 30 minutes of moderate-vigorous walking corresponds to a total of between 3,000 and 4,000 steps^{30,39-41}. This translates to approximately 100-133 steps/minute. Welk et al, in the earliest of such findings performed a pedometer-based study on 31 adults of a mean age of 31 years and 26

years in men (n=17) and women (n=14), respectively ³⁰. In the study, participants completed three 1-mile trials of walking/jogging under both track and treadmill conditions ³⁰. The study concluded that approximately 3,800-4,000 steps is sufficient to meet current guidelines of 30 minutes of moderate intensity physical activity ³⁰. This translates to an approximate step rate of 127-133 steps/minute.

Most of these findings incorporate elements of volume, duration and intensity of step/day so as to provide some congruency with current guidelines ⁴⁴.

In general, most of these studies were, however limited to treadmill-based walking and the estimation of energy expenditure. The application of alternative methodological approaches, combined with those in the literature can offer a strong body of evidence to support the development of a step rate recommendation.

THE APPLICATION OF PEDOMETRY IN PUBLIC HEALTH

The emergence of pedometers in physical activity health promotion initiatives is believed to be of Japanese origin and dating back to the 1960's ⁴⁴⁻⁴⁶. During this time, pedometers entered the commercial market under the name "*manpo-kei*" which translates to "10,000 steps meter" ⁴⁶. Local walking clubs promoted the use of pedometers and encouraged their members to walk at least 10,000 steps/day ⁴⁶. It is therefore assumed that the "10,000 steps/day" recommendation and the emergence of pedometers originated at the same time, to assess physical activity and increase walking behaviours ^{39,45}.

According to Hatano, 10,000 steps/day is approximately equal to an energy expenditure of 300-400 kilocalories per day (kcal/day)⁴⁶. This is double the energy expenditure of 150 kcal/day as commonly estimated in public health recommendations^{2,47}. The discrepancy between the two is presumed to be due to the fact that the former is a daily recommendation that includes all activity, and the latter to be “over and above an undisclosed minimal level of daily activity”³⁹.

The changing societal trends, with particular reference to baseline levels of physical activity, typically low intensity physical activity, recognises the need to revisit traditional steps/day guidelines⁴⁴. As described, the 10,000 steps/day recommendation, for example, has largely been based on a baseline level physical activity, which evidently may have changed over the years. It is, therefore important that steps/day recommendations consider such changes so as to ensure harmony with existing physical activity guidelines⁴⁴. In so doing, such recommendations will complement guidelines rather than create further confusion and disagreement⁴⁴.

Whilst a value of 10,000 steps/day has been a reasonable estimate for healthy adults to attain¹², there are conflicting views as to whether people who accumulate 10,000 steps/day meet the guideline of 30 minutes of moderate-vigorous intensity physical activity. Similarly, it is questionable as to whether those who meet the 30 minutes guideline achieve a minimum of 10,000 steps/day.

Welk and colleagues demonstrated that people who recall achieving a minimum of 30 minutes of moderate intensity physical activity on any specific day, generally accumulated at least 10,000 steps/day³⁰. The study, however, mainly included

young individuals (an approximate average age of 29 years) who were recruited from a physical activity research centre, which maybe likely to have influenced the results.

Miller and Brown demonstrated the association between the 10,000 steps/day recommendation and the 30 minutes of moderate intensity physical activity guideline in an adult Australian population, ²⁷ described earlier.

Wilde et al in their study (described earlier) further reported that less than 50% of women did not achieve the 10,000 steps/day target, even when prescribed 30-minutes of walking ⁴¹. Steps/day did, however, increase by approximately 3,000 steps/day, to reach 10,000 steps/day, when a 30-minute, self-timed walk was included ⁴¹.

Although these studies generally imply some association between the 10,000 steps/day guideline and 30 minutes of moderate intensity physical activity, there are implications that intensity-based steps is a contributing factor towards achieving the 10,000 steps/day target.

Despite the evidence of studies described, that indicate an association between 10,000 steps/day and current guidelines, studies have also shown contrasting results. For example, Strycker et al found low, but significant associations between steps/day and self-reported data ³⁸, as described earlier. Miller and Brown, however demonstrated that only approximately 10% of those achieving 10,000 steps/day did not achieve physical activity guidelines ²⁷. The study also showed that nearly 40% of men that met guidelines did not achieve 10,000 steps/day ²⁷.

The conflicting findings around 10,000 steps/day and current physical activity guidelines suggest that steps/day recommendations be revisited, in the context of current guidelines and, more importantly intensity-based ambulatory physical activity. This is particularly relevant in view of the notion that current levels of baseline physical activity (low intensity physical activity) may have changed, over time ⁴⁴.

Additionally, the recent release of the United States Physical Activity Guidelines ⁴⁸ which suggest that “some physical activity is better than none”, makes particular reference towards an emphasis on moderate-vigorous physical activity ⁴⁸. This creates a platform for an expanded, yet still compatible, step-based goal that considers recommendations for moderate intensity physical activity ⁴⁴.

CHARACTERISTICS OF PEDOMETERS

There is a wide variety of available commercial pedometers. Most pedometers are small, inexpensive and unobtrusive (in terms of their attachment on the body) devices that offer an easily understandable output to the user ²⁹⁻³¹.

As walking is the most commonly encouraged form of physical activity, the use of pedometers in capturing information on walking behaviour, in terms of steps taken, is widely accepted ⁴⁹. The ability of pedometers to provide information on patterns of physical activity, particularly intensity and duration of intensity-based steps, is an area of increasing development ⁴⁹.

Reliability and validity of pedometers for predicting daily steps

Accurate and reliable measurement and monitoring of physical activity behaviours and their attributes is considered an important part of health promotion and practice⁵⁰. Validity refers to an instrument assessing what it is intended to assess, typically against some “gold standard” criterion, which may better represent or measure the aspect of interest⁵⁰.

Pedometers have been recognised and accepted as instruments with a high validity in measuring ambulatory physical activity, typically volume-based steps/day⁵¹. They are, however not as reliable at classifying some common physical activities such as swimming and cycling⁵⁰. Caution is therefore warranted when making comparisons of pedometer-based physical activity data to other measurement tools that consider modes of physical activity other than ambulation. Furthermore, pedometers are usually unable to measure total energy expenditure, which typically forms the basis for defining physical activity intensity⁵⁰.

Reliability refers to the consistency of a measure, which would classify people’s physical activity levels in the same way, if repeated⁵². Tudor-Locke and colleagues reported that several statistical techniques may be appropriate in identifying the minimum number of days of pedometer-wear required to reliably predict weekly physical activity⁵³. These statistical techniques include co-efficient of variance, analysis of variance, intra-class correlations and regression analyses⁵³. For example, in their study of 90 participants, wearing a pedometer for 7 days, a 32% mean co-efficient of variance was noted⁵³. Analysis of variance confirmed that differences in the week were significant, but primarily limited to Sunday⁵³. The regression analysis and intra-class correlation similarly showed Sunday to be the

weakest predictor of daily steps⁵³. Similar studies of this nature, have since been performed and, in general, seem to support the viewpoint that at least 3 days of pedometer wear can provide a reliable average estimate of daily steps, although additional days increase reliability⁵⁴⁻⁵⁶. Most studies further concur with the viewpoint that steps accumulated on a Sunday are significantly different from all other days of the week^{54,56}.

Measurement mechanism of pedometers

Traditionally, a horizontal spring-suspended pendulum within the pedometer is displaced with hip vertical motion. The up and down movement translates to an electrical signal, which records as step. Usually, a force sensitivity threshold is established in the design, such that a step is recorded only upon reaching the manufacture-determined threshold and consequently deflecting the lever arm sufficiently to complete the electronic circuit⁴⁹.

The pedometer is designed to tally steps accumulated and display this information on a digital screen. However, the sensitivity thresholds used may vary between instruments (brands and models), resulting in varying levels of accuracy of steps data⁴⁹. For example, a pre-set threshold may capture certain hip movements as steps when they are not⁴⁹. Similarly, structural characteristics of the hip area may result in steps not reaching the desired threshold to be classified as a step⁴⁹. These structural characteristics include factors related to obesity of individuals, unstable positioning of the pedometer at the hip area or even a very slow walking speed⁴⁹.

Structural characteristics, as described earlier, limit the consistency of defining a step and can reduce the ability to compare studies using different pedometer brands and models ⁴⁹. Most comparisons between study groups/populations are, however, based on a pre-determined reliability of the respective brand (usually an 80% minimum reliability) ⁴⁹.

To compensate for some of the limitations identified, recent advancements in technology have produced pedometers that include a piezoelectric accelerometer mechanism to detect acceleration by way of generating a sine wave corresponding to vertical accelerations of the hip. A count of the sine waves is recorded as steps taken. The magnitude of bending of the piezoelectric element is more sensitive than the pendulum mechanism that requires sufficient displacement of the pendulum in order to record a step ⁵⁷.

Crouter et al examined the appropriateness of spring-levered versus piezoelectric pedometers in a group of overweight and obese adults ⁵⁸. It was reported in their study that higher levels of accuracy were obtained using the piezoelectric pedometer compared with the spring-levered model ⁵⁸. Similarly, Melanson et al demonstrated that piezoelectric pedometers more accurately counted steps at slower walking speeds than spring-levered pedometers ⁵⁹.

More recent advances in pedometers include devices that have two piezoelectric senses that use multiple-position sensing technology ⁵⁷. This advancement allows for alternate mounting positions to the hip area, such as the pants pocket, the chest shirt pocket, mid-back, around the neck and at various waist-mounted positions ⁵⁷. Such

advancements have been indicated to improve the accuracy of measuring steps, for example in obese individuals⁵⁷.

To support the technological mechanical advancements in pedometry, studies have demonstrated the level of reliability of pedometer data using certain brands and models of pedometer in various mounting positions, walking conditions and speeds^{57,58,60}. For example, Holbrook et al, in a study on 47 young healthy and overweight adults (24±4.4 years), examined the reliability and validity of two brands of the Omron pedometers⁶⁰. Different mounting positions, through a range of prescribed walking conditions, were used in this study⁶⁰. With the exception of the backpack position, the pedometers indicated accurate step counts at various positions (including different waist-mounted and pocket positions) and at different speeds (including slow, moderate and very brisk walking)⁶⁰.

Hasson et al performed a similar study, to validate the Omron HJ-111 pedometer, on 92 participants, of different body mass index categories⁵⁷. The study similarly showed that, in general, pedometer placement and body mass index groups had little effect on validity of this brand and model of pedometers⁵⁷.

Further to this, pedometers may also provide information on intensity of steps²⁸. As this is a fairly recent innovation within pedometry, studies evaluating the accuracy and reliability in this regard, to our knowledge, have not been conducted.

The Omron HJ720ITC pedometer

The Omron HJ720 ITC (Omron Corp., Kyoto, Japan) is an example of a piezoelectric pedometer that provides information on intensity of steps taken as well as a memory function that recalls previous data. The validity and reliability of this brand and model of pedometers has been studied at various mounting positions under prescribed and self-paced walking conditions with both healthy and overweight adults^{32,53}. Such studies have promoted its application as an accurate measure of step counts^{44,60}.

A valuable feature of the pedometer is that the information captured by the pedometer can be uploaded, electronically. The electronic display presents information as a visual display (bar graph) and further includes a 43 day recall with the ability to summarise information by weekly and monthly categories. A further benefit of this brand of pedometers is its' ability to provide an hourly representation of steps data.

Information provided on the pedometer display, for immediate viewing, includes daily steps information such as the total number of steps accumulated²⁸. Additionally, the number of "manufacturer-defined aerobic steps", duration (in minutes) of these steps, distance (in kilometres) completed and calories (kilocalories) expended are displayed²⁸. These "manufacturer-defined aerobic steps" (≥ 60 steps/minute, minimum duration of 1-minute) within the total steps/day record is therefore provided²⁸. Consequently, total time spent accumulating such steps (in minutes per day (minutes/day)) are provided as aerobic time²⁸.

Whilst the validity and reliability of this brand and model of pedometers have been studied, the outcomes relate more specifically in terms of the pedometer's ability to accurately measure steps, and at various mounting positions ^{44,60}. The appropriateness of cut-offs used for classifying the "manufacturer-defined aerobic steps, however, raises concern when contextualised with recent steps/minute recommendations for moderate intensity physical activity ^{40,42,43}.

The added features of pedometers (such as the piezoelectric mechanisms, ability to capture intensity-based steps) are, nevertheless, useful to researchers ⁴⁹. Evaluating the impact of such additional features on individual behaviour may, therefore enhance current literature. This will contribute towards facilitating maximum benefits of such advancements in pedometry. Such research can contribute towards ensuring optimal use of the more modern pedometers in physical activity programmes, for increased public health impact. Additionally, the application of more recent steps-based recommendations that consider intensity of steps/day may be appropriately applied, within the context of pedometry.

THE USE OF PEDOMETERS AS AN OBJECTIVE ALTERNATIVE TO SELF-REPORTED PHYSICAL ACTIVITY DATA

Studies on the extent of agreement between indirect and more objective measures of physical activity have become an aspect of interest in recent years. A systematic review, conducted in 2008, compared self-reported and objective measures for assessing physical activity levels in observational and experimental studies of adult populations ²⁰. The review reported on studies, primarily accelerometer-based, from 1984-2007 and only used studies with units of measurement that were the same for

both the self-reported and direct measures²⁰. Percentage mean difference was used as the main outcomes of this analysis²⁰. The review summarised that overall, there were no clear trends in the over-reporting, nor under-reporting, of physical activity by self-reported methods when compared to direct methods²⁰. Some of the results, however, suggest that the agreement between self-report and objective measures of physical activity are likely to differ depending on the type of method used and, often, the gender of the population studied²⁰. As the studies in this review used different measurement units (e.g. kilocalories, METs/day, MET-minutes/day), pooled estimates and confidence intervals could not be determined²⁰.

Most studies that have compared self-reported physical activity to objective measures have been largely accelerometer-based²⁰. This is essentially due to the fact that accelerometers not only provide information on ambulatory physical activity, but information on intensity, frequency and duration of movements related to physical activity⁶¹. Information obtained from accelerometers, additionally have the potential to be translated to estimates of energy expenditure⁶².

Studies have attempted examining the specific relationships and agreement between accelerometers and pedometers, in free-living conditions. Tudor-Locke and colleagues, in 2002, reported one of the first studies in this regard⁶³. Using the ActiGraph accelerometer and the Yamax pedometer, steps/day values were compared, in a convenience sample of adults (N=52; mean age=38; mean body mass index=26kg/m²)⁶³. These participants were recruited to examine the validity of the International Physical Activity Questionnaire in South Carolina⁶³. A mean difference of 1,845±2,116 steps/day was noted (accelerometer>pedometer; t=6.29,

$P < 0.0001$)⁶³. The study reported, that although there were significant differences noted, these may be due to differences in sensitivity thresholds and/or placement of the instrument⁶³.

More recently, Behrens and Dinger reported results from similar comparisons in two free-living sample groups⁶⁴. The ActiGraph accelerometer and the Accusplit Eagle 120 pedometer, reported in the study to be amongst the most accurate pedometers available to assess steps, were used for these comparison⁶⁴. The first sample, that included participants between the ages of 18 and 30 years ($N=99$), showed a mean difference of 1,643 steps/day over the 7-day wear⁶⁴. The second sample, that included participants between the ages of 25 and 60 years ($N=74$), showed a mean difference of 2,199 steps/day over the 7-day wear⁶⁴. There were strong correlations noted in both the first sample ($r=0.85$, $P < 0.01$) and the second sample ($r=0.87$, $P < 0.01$)⁶⁴. The results additionally indicated that the accelerometer consistently recorded more steps than the pedometer, and reported this differences to be associated with sensitivity thresholds between the devices⁶⁴. The study nevertheless concluded agreement in steps/day values between the two devices⁶⁴.

Few studies^{27,38} have attempted demonstrating the association between pedometer-measured ambulatory physical activity and self-reported physical activity. Miller and Brown demonstrated the association by using the 10,000 steps/day recommendation and the 30 minutes of moderate intensity physical activity per day guideline, for comparisons²⁷. Further details have been presented earlier.

In a similar study, Strycker et al compared steps/day with self-reported physical activity data³⁸, as described earlier. These studies were, however limited to volume-based steps/day information for comparisons and were unable draw associations between intensity-based steps/day and current guidelines.

Recent advancements in pedometry create the opportunity for its use in providing more detailed information on physical activity patterns, than simply record a tally of steps/day, albeit that it is limited to ambulatory physical activity. For example, their added ability to provide information on intensity-based steps²⁸ may provide a more objective alternative to, or complement, self-reported approaches that typically rely on recall. Using pedometers for such a purpose would also be less costly than instruments such as accelerometers, used for providing more objective measures of ambulatory physical activity.

THE USE OF PEDOMETERS AS A MEASUREMENT TOOL, IN DETERMINING THE ASSOCIATION BETWEEN AMBULATORY PHYSICAL ACTIVITY AND HEALTH MEASURES

Studies that have used pedometers as an instrument of measure in determining the association between ambulatory physical activity and various clinical and health measures date as far back as the early 90's^{17,65 66,67}.

Tyon et al, in 1992, was one of the first researchers that compared pedometer data to a clinical measures, such as body mass index and percentage body fat⁶⁷. The study, however, demonstrated pedometer output in terms of distance travelled per hour, implying that all steps taken were of the same stride length⁶⁷.

McClung, in 2000, reported the association between pedometer-measured steps/day and body mass index in a sample of 209 participants, primarily with knee or hip replacements ⁶⁶. In this study, it was reported that a higher body mass index was associated with lower steps/day values ⁶⁶.

One of the earliest reporting on the association between steps/day and more than one body composition variable was documented by Tudor-Locke et al, in 2001 ⁶⁵. The study described the association between steps/day, and body mass index and percentage body fat among a group of 109 (41 men and 68 women) healthy adults living in South Carolina ⁶⁵. Using steps/day as a continuous variable, the study showed an inverse correlation between steps/day and both body mass index and percentage body fat ⁶⁵. Tertiles for steps/day, as a measure of ambulatory physical activity, showed that nearly half (41%) the participants in the lowest (below the 25th percentile of distribution) physical activity tertile ($\leq 5,267$ steps/day) were also classified as obese ⁶⁵. Only 11% of those in the highest (above the 75th percentile of distribution) physical activity tertile ($\geq 9,357$ steps/day) were shown to be obese ⁶⁵. Similarly, 57% of participants in the highest tertile of physical activity were classified as normal weight compared with 30% in the lowest tertile of physical activity ⁶⁵.

Chan et al, in 2003, performed a cross-sectional study on the relationship between pedometer-determined ambulatory physical activity and components of the metabolic syndrome (through self-reported measures) ¹⁷. The study also compared pedometer-determined ambulatory physical activity to general health indicators such as body mass index, waist circumference and blood pressure, in a Canadian working population of 182 participants ¹⁷. The results of the study showed that fewer

steps/day were associated with increased body mass index, waist circumference, diastolic blood pressure and components of the metabolic syndrome (hypertension, hypercholesterolemia, heart disease, or type 2 diabetes) ¹⁷.

“Colorado on the move”, the first-ever population-based survey of walking reported in 2005, was conducted with 1098 individuals in the US state of Colorado ⁶⁸. The study reported an average of 6,804 steps/day and also showed that obese individuals (body mass index ≥ 30 kg.m⁻²) walked about 2,000 fewer steps/day than normal-weight individuals ⁶⁸.

In general, pedometer-based cross-sectional studies have shown that people who walk more tend to have a lower body mass than those who walk less ⁶⁸⁻⁷³. Nevertheless, the decrease in steps/day population estimates, in more recent years (discussed previously), warrants the need for exploring further options for improving ambulatory physical activity.

The evolution of pedometry affords the potential to explore its ability to obtain information on patterns of ambulatory physical activity. For example, information on intensity of sustained ambulatory physical activity that can be extrapolated from pedometer data may be correlated to clinical and health measures. In so doing, associations between clinical measures can be correlated with volume, duration and intensity of steps/day. Such advancements, in the context of pedometry, may provide useful information to support current guidelines through pedometer-based recommendations.

THE USE OF PEDOMETERS FOR SELF-MONITORING AND MOTIVATING FOR CHANGING PHYSICAL ACTIVITY BEHAVIOUR

Over the last few decades, there has been a public health shift from a focus on exercise intended to develop physical fitness to an emphasis on promoting moderate intensity lifestyle physical activity ⁷⁴. Consequently, ambulatory physical activity intended to improve health outcomes ⁷⁴, has promoted the emergence of pedometers as a useful self-monitoring tool and a potential motivational aid for increasing physical activity.

As discussed earlier, the concurrent use of pedometers and the 10,000 steps/day message has, over the years, been used as a motivating tool and a steps/day goal, respectively. The application of the 10,000 steps/day message has, consequently been adopted and evaluated in several health promotion initiatives. For example, “Canada on the Move”, a 12-month health promotion initiative promoting the 10,000 steps/day goal ⁷⁵ reported a 2.3% (95% confidence interval: 1.9-2.9%) higher prevalence of sufficient walking in those that were aware of the campaign (32.4%) than those that were not aware of the campaign (30.0%).

The “10, 000 Steps Rockhampton Project” ⁷⁶, a health promotion initiative, evaluated the effect of the 10,000 steps/day goal in Rockhampton, Australia. The study subsequently compared pedometer-determined ambulatory physical activity levels to a comparable community (Mackay) that had limited exposure to this message. An interesting finding was that, although ambulatory physical activity levels did not significantly increase in the project, the downward trend in physical activity seen in

the comparison community (48.3% to 41.9% active) was not evident in Rockhampton⁷⁶.

The European-based “10,000 steps Ghent” community intervention for nearly 230,000 residents in Ghent, Belgium, reported an increase in daily steps by an average of 896 steps/day ($P < 0.001$) in a sub-sample of 440 adults, after one year of the intervention⁷⁷. However, only 8% of participants achieved the 10,000 steps/day goal, compared with no increase in the comparison community⁷⁷.

Whilst pedometer-based interventions have traditionally supported and encouraged the 10,000 steps/day goal⁴⁶, several interventions that have promoted the 10,000 steps/day goal have had limited success in reaching this goal⁷⁸. It must be noted, however, that most of these interventions provided minimal or no additional support, over and above providing pedometers to complement the 10,000 steps/day goal. These studies, nevertheless, demonstrated a significant increase in physical activity⁷⁸ and therefore imply that pedometer-based programmes are useful predictors for change in ambulatory physical activity.

Researchers have since suggested that the 10,000 steps/day goal may be unrealistically high⁷⁹. Consequently, more recent research has been directed towards providing alternate options such as 3,000 steps in 30 minutes or 1,000 steps in 10 minutes, at least three times a day^{39,42,79}. These studies have largely been methodological studies to contextualise steps/day information with current physical activity guidelines. Information on interventions that have adopted such messages is, however, limited due to the recent emergence of such messages.

Evaluating the effects of pedometer-based programmes that incorporate intensity-based steps recommendations will therefore provide a useful addition to current literature.

THE ASSOCIATION BETWEEN PEDOMETER-BASED INTERVENTIONS AND HEALTH OUTCOMES

A systematic review on pedometer-based interventions between 1966 and 2006, evaluated the association between changes in ambulatory physical activity and health outcomes amongst outpatient adults⁷⁸. The studies documented in the review included randomised controlled trials, in which the intervention group was provided with a pedometer and a diverse range of support measures⁷⁸. These included physical activity goals (steps-based and non-step-based) and, in some cases, rehabilitation supervision⁷⁸. Control groups generally did not receive a pedometer but were provided with all other support offered to the intervention group⁷⁸. In some studies, a pedometer was also provided to the control group but were requested to maintain their usual physical activity levels⁷⁸.

Analysing a total of 18 studies (mean intervention duration of 18 weeks), the review reported that participants decreased their body mass index by 0.38 from baseline ($P=0.03$)⁷⁸. The decrease was associated with factors such as older age ($P=0.001$), having a step goal ($P=0.04$) and interventions of longer duration ($P=0.07$)⁷⁸. No significant associations were established between baseline steps/day, change in steps/day, gender, diet counselling or body mass index at the beginning of the intervention⁷⁸.

Similarly, intervention participants from 12 of the studies presented in the review significantly decreased their systolic blood pressure by an average of 3.8mmHg ($P<0.001$)⁷⁸. This decrease was associated with a higher systolic blood pressure at baseline ($P=0.009$) and change in steps/day ($P=0.08$)⁷⁸. No significant associations were found with factors such as age, change in body mass index, setting a step goal or the duration of intervention⁷⁸.

Using a total of 7 studies from the review, no significant improvements in serum lipid levels or fasting serum glucose concentrations was found⁷⁸. The serum lipid and glucose levels were, however, reported to be fairly normal at baseline and was implied to be the reason for a lack of significance established⁷⁸.

The review provided the first published synthesis of documented studies on the effectiveness of pedometer. In general, the review indicated that the use of pedometers were associated with significant increases in physical activity and improvements in clinical measures⁷⁸.

Richardson and colleagues, similarly performed a meta-analysis of pedometer-based interventions and their effects on weight loss⁸⁰. The review included a total of 9 randomised controlled trials and prospective cohort studies ranging from 15-106 participants, 73% of whom were women and 27%, men⁸⁰. The duration of the intervention ranged from 4 weeks to 1 year, with a median duration of 16 weeks⁸⁰. Most of the studies included some behavioural counselling, usually in relation to step goals⁸⁰.

The pooled estimate of mean weight change was reported as -1.27kg (95% confidence interval: -1.85kg to -0.70kg) and an average loss of 0.05kg per week during the intervention ⁸⁰. The review demonstrated that, although pedometer-based interventions result in modest weight loss, the increased step counts, ranging from less than 2,000 steps/day to more than 4,000 steps per day, confer health benefits associated with the increase in physical activity ⁸⁰, as similarly concluded in the studies, described above.

A growing amount of physical activity research has been directed towards comparisons in outcomes (such as clinical measures) between interventions prescribing the 10,000 steps/day versus alternative goal-settings to the 10,000 steps/day recommendation or not setting a goal at all ⁷⁸. Studies show that very small and insignificant improvements are achieved in pedometer-based interventions that do not provide steps/day targets/goals.

For example, Bravata et al, through a systematic review reported in 2007, demonstrated the modest improvement in steps/day through minimal contact pedometer-based interventions ⁷⁸. Analysing the outcomes of four studies meeting the criteria for inclusion in the review, a mean increase of 686 steps/day (95% confidence interval: -1,621 steps/day -2,994 steps/day; P=0.60) was noted ⁷⁸.

The review further showed that setting a step goal resulted in higher increases in ambulatory physical activity over baseline, than not setting a step goal ⁷⁸. Analysing a total of 8 studies, a mean increase of 2,998 steps/day (95% confidence interval: 1,646 steps/day - 4,350 steps/day; P<0.001) was noted when a 10,000 steps/day goal was set ⁷⁸. Similarly, analysing the data of 16 studies, a mean increase of 2,363

steps/day (95% confidence interval: 1,789 steps/day - 2,936 steps/day; $P < 0.001$) was noted when an alternative step goal was used ⁷⁸.

The type of goal set may, therefore, be an area of increasing importance. Sidman et al showed little difference between participants given a target of 10,000 steps/day and those given alternative goals ⁸¹. The intervention involved inactive women between the ages of 20 and 65 years and found that despite the fact that most participants given a target of 10,000 steps/day did not achieve this goal, their steps/day increase was similar to those given more modest, alternative goals such as progressive steps goals or time-based goals ⁸¹.

Given the similar increases in ambulatory physical activity among those given a 10,000 steps/day goal and those given alternate goals, research establishing the relative benefits of setting alternate goals, within the context of pedometry, will enhance current literature. Directing us to such alternatives, recent methodological studies have provided intensity-based thresholds for moderate intensity physical activity, such as "3000 steps in 30 minutes" ^{30, 42} or 1,000 steps in 10 minute bouts at least three times a day ⁴².

The application and evaluation of pedometer-based programmes that incorporate such messages, will therefore support current methodological findings and create a platform for further application enhancement in practice.

EXTENT OF ADDITIONAL SUPPORT STRATEGIES WITHIN PEDOMETER-BASED INTERVENTIONS

Pedometer-based interventions have historically involved minimal contact and focused primarily on outcomes⁸². As a consequence of this, many interventions have been shown to produce modest improvements in physical activity⁸³⁻⁸⁶. Studies that provide information concerning process evaluation (i.e. why and how pedometers work to motivate physical activity) have become increasingly valuable in identifying factors that may contribute to the success of such interventions⁸².

Heesch et al, in 2005, were among the first researchers that have reported on participant experiences in a 6-week, minimal contact, pedometer-based intervention programme for women striving to achieve self-selected step goals⁸⁷. In this study, contact with researchers was limited to data collection sessions at pre-intervention and post-intervention, and receipt of weekly e-mails containing strategies for increasing ambulatory physical activity. Focus group findings indicated that pedometers provided a motivating tool for increasing awareness of individual physical activity and thereby providing an opportunity for goal-setting. Suggested programme improvements included assistance with goal-setting, strategies for overcoming barriers, feedback on progress relative to other participants and shared experiences/walking partnerships with other participants⁸⁷.

Lauzon et al, in 2008, contributed further by providing a pedometer-based intervention, called the "Prince Edward Island First Step Program (PEI-FSP)" in Canada⁸². The study incorporated on-site group meetings into a workplace pedometer programme and demonstrated both physical and attitudinal

improvements⁸². The major themes that emerged from this investigation concurred with many of those reported by Heesch et al⁸⁷. Most notably, themes related to increased awareness of, and motivation for, physical activity emerged⁸².

The evaluation of pedometer-based interventions, that provide varying levels and extent of support, can contribute towards establishing a balance between support required during interventions and physical activity improvements. Such an outcome would have implications on determining the minimum resources required to support a successful intervention.

AIMS OF THE THESIS

The studies described in this thesis attempt to provide insight into the association between ambulatory physical activity, and fitness and health outcomes in the adult population, from a dose-response perspective. In so doing, the thesis will also provide information on ambulatory physical activity patterns in a South African population group and relate these results to self-reported measures and current international trends, respectively. In addition, the thesis will administer and evaluate a 10-week pedometer-based feasibility study aimed at increasing ambulatory physical activity amongst employed adults, through individualised email-based pedometer feedback.

The outcomes of the studies described in this thesis can be used to supplement and improve physical activity and exercise prescription such as steps/day recommendations, with a strong emphasis on intensity of steps. These outcomes will

contribute towards providing clearer insight into pedometer-based ambulatory physical activity so that more sustainable health programmes can be implemented.

Finally, using the outcomes of a feasibility study conducted, a work-site, pedometer-based intervention protocol will be developed to be administered as a future randomised controlled trial, in an adult, employed population.

STRUCTURE OF THE THESIS

The introductory chapter provides an overview of physical activity within the context of current guidelines. This chapter further presents information around the emergence of pedometers and the role of pedometers in health promotion in terms of its use as a measurement, self-monitoring and motivational tool with reference to current physical activity guidelines and intensity-based ambulatory physical activity, in particular.

Chapter 2 determines the association between pedometer-determined ambulatory physical activity and fitness and health measures in a convenience sample of adults. We hypothesise a linear relationship between the number and intensity of steps accumulated per day and fitness and health measures.

In Chapter 3, we determine, using heart rate monitors and regulated timing, the appropriate steps/minute rate that corresponds to moderate intensity physical activity. We further compare the steps/minute rate of moderate intensity physical activity to that of self-paced brisk walking. There are two hypotheses to the study described in this chapter:

Hypothesis 1: A steps/minute rate of approximately 100 steps/minute, relates closely to moderate intensity physical activity;

Hypothesis 2: The steps/minute rate for moderate intensity physical activity relates closely to the steps/minute rate of self-paced brisk walking.

Chapter 4 presents the results of a cross-sectional, pedometer-based study establishing the association between objectively measured ambulatory physical activity and health measures in an adult, employed South African population. A linear relationship between total steps/day and improved health outcomes is hypothesised. We further hypothesise a linear relationship between aerobic steps and improved health outcomes.

A further analysis, in this study (Chapter 4), compares the mediation effect of percentage body fat, body mass index and waist circumference independently on the association between steps and health outcomes. We hypothesise a significant mediation effect of percentage body fat, body mass index and waist circumference in the association between steps (total steps/day and aerobic steps/day) and clinical measures (blood pressure, blood cholesterol and blood glucose).

The potential use of pedometers to provide a more direct measure of physical activity patterns than self-reported approaches is evaluated in Chapter 5. We aim to demonstrate the association between self-reported physical activity and pedometer-measured ambulatory physical activity in a South African, employed adult population group.

We hypothesise that self-reported physical activity over-reports physical activity.

Chapter 6 presents the analysis and evaluation of a pedometer-based pilot feasibility study, conducted in an employed adult group. The study informs the development, design and recommended sample size (i.e. the protocol) of a future pedometer-based intervention (randomised controlled trial) aimed at improving ambulatory physical activity in the employed adult population.

Hypothesis: The addition of a pedometer, supplemented by regular, emailed feedback and general motivational messages is an effective strategy for increasing steps/day in an employed, adult group.

The protocol design of the randomised controlled trial, *Steps that count!*, is presented in chapter 7, as an outcome of our overall findings and a recommendation for a future intervention programme.

The main findings of the studies, followed by a reflection on the methodological considerations concerning the results of each study are discussed in chapter 8. This chapter also discusses the implications for public health and directions for future research and practice.

CHAPTER 2

The association between the number and intensity of steps accumulated and fitness and health measures

Accepted in part: Journal of Physical Activity and Health (June 2012) [in press]

Authors: Julian D Pillay, Tracy L Kolbe-Alexander, Willem van Mechelen, Estelle V Lambert

(Elements of the original paper have been condensed in certain areas to avoid duplication from the previous chapter and referenced accordingly.)

INTRODUCTION

Walking is an accessible mode of activity and therefore may be easily translated into physical activity recommendations, especially for adoption by inactive adults^{40,88,89}. The benefits of walking have been demonstrated by many studies^{78,80,90,91}. Despite the significant health benefits of walking, the overall prevalence of walking for health is only 8%-15% in adults⁹².

Pedometer-based studies have shown that 30 minutes of moderate-vigorous walking equates to between 3,100 and 4,000 steps^{39,41,42}, even when considering factors such as stride length and body mass index as a potential confounder^{93,94}. Studies on the extent to which walking contributes to meeting current guidelines, however, largely describe the volume of physical activity, typically steps/day^{95,96}. Little consideration has been placed on intensity-based steps/day, the health benefits of which have been reported to be substantively dependent on⁹⁷.

The impact of intensity-based walking recommendations is therefore an emerging area of research. Further information on volume and intensity of physical activity patterns, within the context of steps/day, will add to the current understanding of the dose-response effects of walking. This can provide the basis for current and future steps/day recommendations to complement current physical activity guidelines.

We therefore aim to determine the relationship between the volume and intensity of steps/day and aerobic fitness and health status.

METHODS

A convenience sample of 70 adults (35 men and 35 women), between the ages of 21 and 49 years, completed the study. The participants were recruited through advertisements placed at a tertiary academic institution, as well as via word of mouth.

Ethical considerations

Ethics approval for the study was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town, Republic of South Africa (REC REF: 172/2005) (Appendix A). Prior to the study the participants were provided with a Participant's Information Sheet detailing purpose, aims, procedures, requirements and potential risks of the study (Appendix B). An Informed Consent Form was thereafter signed (Appendix C).

Inclusion and exclusion criteria:

All individuals willing to participate in the study were considered for participation. Other inclusion criteria included: being between the age of 21 years (inclusive) and 50 years (exclusive) and; willingness to wear a blinded pedometer, during wakeful hours, for the duration of the study.

Employees were excluded for the following reasons: pregnancy; diagnosis or treatment of cancer; any other condition that could impact on physical activity; non-compliance to the pedometer wear and; participating in non-ambulatory physical activity (such as swimming and cycling) that may not be captured or be inaccurate through the pedometer reading.

Pre-participation screening:

The Physical Activity Readiness Questionnaire ⁹⁸ (Appendix D) was administered to all participants prior to participation. This conforms to the recommendations for cardiovascular screening, staffing and emergency policies at health/fitness facilities ⁹⁹.

Measures

The following measures were taken prior to commencement of the study:

Anthropometry:

Anthropometric measures were completed (upon return of the pedometer and prior to the commencement of the aerobic fitness assessment) in an indoor setting. Participants, during their initial visit (during which information on the study was provided and the Physical Activity Readiness Questionnaire completed) were requested to abstain from eating/drinking within 4 hours of the subsequent visit. They were requested to avoid exercising within 12 hours of the visit. Additionally, participants were requested to void (urinate) completely prior to the visit and abstain from any alcoholic drinks within 48 hours of the visit. They were also requested to avoid taking any diuretics prior to the visit, unless instructed by a physician.

Body height was measured in centimetres, using a height chart as the vertical distance from the floor to the vertex of the head. The participant stood barefoot with heels, buttocks and head in contact with the wall and arms at their side.

Waist circumference was measured (in centimetres) using a tape measure around the skin.

Body weight was measured using an electronic scale (Beurer® PS 06), allowing only a single layer of clothing. The values were rounded to the nearest 100g.

Body mass index was computed as weight (in kg)/height (in meters) squared.

The Futrex 6 100 (Futrex Inc., Gaithersburg, MD, USA) method of near-infrared reactance was used to measure percentage body fat. This measure is based on the principles of light absorption and reflection, where body fat absorbs the light and muscle reflects it ¹⁰⁰. The pre-programmed equation takes into account the participant's age, body height and gender, and then calculates the individual's percentage body fat ¹⁰⁰.

Blood Pressure

Blood pressure was recorded (in mmHg) using a sphygmomanometer after the participant remained relaxed for 5 minutes. Two readings were taken, approximately 5 minutes apart. An average of the two readings was recorded. If the two readings obtained were markedly different from each other (>5mmHg), a third reading was taken. The average of the two nearest readings was used.

Estimated maximal oxygen uptake

Aerobic fitness was derived from the heart rate response (recorded by a Suunto™ heart rate monitor) based on a 12-minute intermittent step test. This test comprised four incremental workloads for 2 minutes at a time on a stationary, 25cm high step, separated by a one-minute rest period between each bout. The intensity of each workload was regulated by an audible metronome (80, 96, 112 and 120 steps/minute, respectively). The final rest period lasted 1-minute and the heart rate

response to exercise was regressed to predict peak METs at age-predicted maximum heart rate.

Maximal oxygen uptake (ml/kg/min) was, thereafter, estimated using the following equation: $44.891 - (\text{age} * 0.262) - (\text{gender} * 0.855) + (\text{peak METS} * 0.994) + (\text{maximum reported MET hours/week of activity} * 0.163)$ ¹⁰¹. This test has been shown to explain 76% of the variance in actual measured maximal oxygen consumption¹⁰¹.

The test was conducted after the participants had worn the pedometer for five consecutive days (minimum of 10 waking hours per day), so that the outcome of the test did not play a role in altering ambulatory physical activity during pedometer wear.

Figure 2.1 illustrates the 12-minute step test.

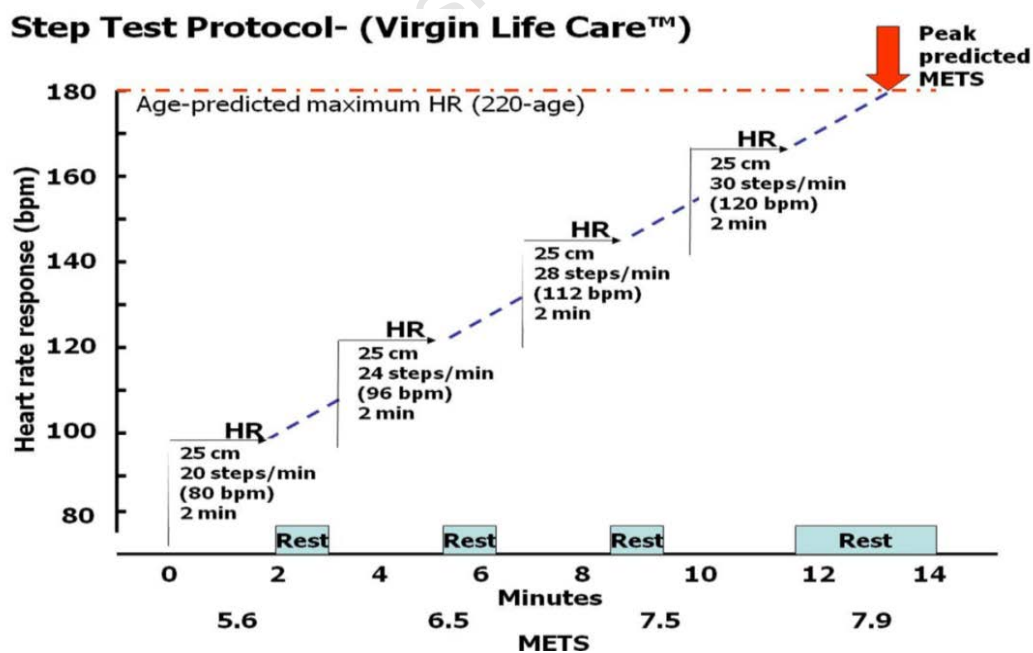


Figure 2.1: Step Test Protocol- Virgin Life Care™

Pedometer wear

Participants were requested to wear the Omron HJ 750 ITC pedometer for 5 consecutive days, attached to the left or right hip, as worn in most studies ²⁴.

The pedometer screen was covered to reduce the likelihood of participants observing their daily steps, which may have influenced habitual levels of physical activity and subsequently daily steps accumulation during the study. Participants were asked to wear the pedometer throughout the day and to follow their usual routine of daily activities and remove the pedometer only when bathing or showering.

Participants were also informed that their daily results would be made available to them at the end of the study.

Data recording

The pedometer data was uploaded electronically by the researcher according to the Omron Health Management Manager software protocol ²⁸. Details of the type of information provided by the pedometer output have been described in chapter 1.

Statistical analyses

The data were analysed using STATISTICA version 8 (StatSoft Inc., Tulsa, OK, USA) and statistical significance was set at $P < 0.05$. The relationship between average number of steps/day and blood pressure, percentage body fat, body mass index, waist circumference and estimated maximal oxygen uptake was assessed using Pearson-Product-Moment Correlation analysis.

To differentiate between total steps/day, and the intensity on health and fitness outcomes, participants were grouped according to the number and intensity of steps: LOW (<5,000 steps/day, irrespective of intensity), HIGH-LOW (\geq 5,000 steps/day with no aerobic activity) and HIGH-HIGH (\geq 5,000 steps/day with aerobic activity).

The 5,000 steps/day cut-off is based on current physical activity classifications that categorise those accumulating less than 5,000 steps/day as inactive^{40,102}.

Analyses of co-variance (ANCOVA), adjusting for age, gender and total steps/day, were used to compare groups, with Bonferonni post-hoc analyses, to determine the between group effect of these categories for blood pressure, percentage body fat, body mass index, waist circumference and estimated maximal oxygen uptake.

RESULTS

Of the 78 participants that volunteered to participate in the study, 77 participants returned the pedometer and completed the fitness test. After uploading pedometer data, 7 of the participants (3 men and 5 women) were identified as not having worn the pedometer for at least three consecutive days or for a minimum of 10 hours per day and were excluded from the analysis.

The final analysis sample therefore included 70 participants (35 men and 35 women, 32 ± 8 yrs). Table 1.1 illustrates the clinical and ambulatory characteristics of the study group.

Table 2.1 Fitness, health and ambulatory characteristics of participants (N=70)

Variable	Men	Women	Total
Age (years)	33.1±7.9	31.6±7.7	32.3±7.8
Body mass index (kg/m ²)	25.3±3.2	23.9±4.5	24.6±3.9
Percentage body fat (%)	20.9±8.1	23.3±9.6	22.1±8.9
Waist circumference (cm)	86.7±9.6	75.9±9.8	81.3±11.1**
Systolic blood pressure (mmHg)	125.8±12.6	120.1±7.3	122.9±10.6*
Diastolic blood pressure (mmHg)	83.3±8.8	81.7±8.6	82.5±8.7
Estimated VO ₂ max (ml/kg/min)	41.9±7.6	35.8±8.8	38.8±8.7**
Pedometer data (steps/day)	6,424±2,208	6,616±2,427	6,520±2,306
Daily aerobic time (minutes/day)	14.4±7.4	17.4±10.7	16.2±9.6
(n=42, participants who accumulated any aerobic steps)			

Note: Values are means ± standard deviation

*indicates statistical significance (P<0.05), ** (P < 0.003) between men and women

The mean daily steps accumulated was 6,520±2,306 steps/day for the total sample (N=70). The intra-individual co-efficient of variation of steps/day, was 39.2±17.3%.

Forty-two participants accumulated steps classified by the pedometer as “aerobic” (≥60 steps/minute for 1-minute or more). Of the participants accumulating “aerobic” steps (n=42), the mean daily aerobic steps accumulated averaged to 1,816±938 steps/day and the average intensity and duration of these steps were 118±9 steps/minute and 16.2±9.5 minutes, respectively.

Table 2.2 illustrates the association between health measures and total volume of steps (i.e. both aerobic and non-aerobic combined), aerobic steps only, aerobic intensity and aerobic time accumulated daily.

Table 2.2 Correlation (rho) between health measures and total steps, aerobic steps, intensity and time per day (N=70)

Variable	Total steps (steps/day)	Aerobic steps (steps/day)	Aerobic time (minutes/day)	Aerobic intensity (steps/min)
Percentage Body Fat (%)	-0.38**	-0.45**	-0.37**	-0.48**
Body mass index (kg/m ²)	-0.28*	-0.31*	-0.24*	-0.32*
Waist circumference (cm)	-0.41**	-0.38**	-0.31**	-0.44**
Systolic blood pressure (mmHg)	-0.25*	-0.31*	-0.31*	-0.28*
Diastolic blood pressure (mmHg)	-0.10	-0.15	-0.20	-0.16
Estimated maximal oxygen (ml/kg/min)	0.27*	0.23	0.17	0.29*

Note: Values indicate rho values; asterisk indicates statistical significance (* P<0.05, **P < 0.01)

Total steps/day, aerobic intensity and aerobic time were significantly negatively correlated to percentage body fat ($P<0.003$), body mass index ($P<0.03$), waist circumference ($P<0.005$) and systolic blood pressure ($P<0.01$) respectively, for the overall group. Similarly, a positive correlation was found between total steps/day and aerobic intensity and estimated maximal oxygen uptake ($P<0.03$ and $P<0.02$, respectively).

Diastolic blood pressure was not significantly correlated to any measure of steps.

In the groups accumulating $\geq 5,000$ steps/day (HIGH-HIGH and HIGH-LOW groups), statistically significant differences in the total steps/day were observed ($7,839 \pm 1,952$ in HIGH-HIGH group and $6,353 \pm 949$ in HIGH-LOW group respectively; $P<0.001$).

In the subsequent analyses of between-group differences for fitness and health outcomes, adjustments were therefore made for age and gender, as well as total steps/day.

Table 2.3 illustrates between group effects of health measures (age and gender-adjusted).

Table 2.3: Fitness, health and ambulatory characteristics of participants by group (means adjusted for age and gender, \pm standard deviations).

Variable	Low (N=18)	High-Low (N=13)	High-High (N=39)
Percentage Body Fat (%)	30.1 \pm 6.7 ^a	23.5 \pm 6.8 ^b	17.9 \pm 6.8 ^c
Body mass index (kg/m ²)	26.8 \pm 3.5 ^a	24.4 \pm 3.5 ^{ab}	23.6 \pm 3.5 ^b
Waist circumference (cm)	87.2 \pm 8.7 ^a	84.5 \pm 8.9 ^a	77.5 \pm 8.9 ^c
Systolic blood pressure (mmHg)	127.1 \pm 10.2 ^a	125.7 \pm 10.3 ^{ab}	120.1 \pm 10.3 ^b
Diastolic blood pressure (mmHg)	82.8 \pm 8.8	86.1 \pm 8.9	81.2 \pm 8.9
Estimated maximal oxygen uptake(ml/kg/min)	35.4 \pm 6.8 ^a	36.2 \pm 7.0 ^{ab}	41.3 \pm 7.0 ^b
Pedometer data (steps/day)	3,705 \pm 1,540 ^a	6,176 \pm 1,540 ^b	7,935 \pm 1,564 ^c

Note: Values represent mean \pm standard deviation
percentage body fat ^avs^b, P<0.03, percentage body fat and waist circumference, ^avs^c, P<0.002

There were significant differences in percentage body fat between all three groups, after adjusting for age and gender (P<0.001), irrespective of whether or not results were adjusted for total steps/day. Percentage body fat was lowest in those in the HIGH-HIGH group, followed by the HIGH-LOW group and then, the LOW group.

Waist circumference was, similarly, significantly lower in the HIGH-HIGH group, compared to the other groups (P<0.001). This effect remained even after adjusting for differences in total steps/day.

Estimated maximal oxygen uptake was only significantly different between the LOW group and the HIGH-HIGH group ($P < 0.01$). After adjusting for total steps/day, these results were, however, no longer significant. This indicates that estimated maximal oxygen uptake is not independent of total steps/day, despite differences in intensity. The between-group differences for estimated maximal oxygen uptake may, therefore, relate more to the total volume than intensity of steps/day. Comparable results were found for blood pressure and body mass index.

DISCUSSION

The results of this study support the existing evidence linking steps/day to fitness and health outcomes. The study additionally provides evidence that body composition may be influenced by not only total steps/day, but also by the intensity at which they are accumulated. Intensity of steps may, therefore, be a factor directly contributing to the attainment of better fitness and health outcomes, or indirectly by increasing the total volume of steps/day.

Exercise prescription and/or steps/day recommendations may benefit from being framed within the context of intensity, thus corroborating recent accelerometer-based studies^{63,103}.

The mean steps/day of $6,520 \pm 2,306$ suggest that our sample group fell slightly below the lower end of the range of steps/day data in healthy, younger adults (7,000-13,000 steps/day)⁴⁰. Limitations of our study may have contributed to the low steps/day data obtained, which we have highlighted under the limitations of this study (Chapter 2, page 51). Our data was, however consistent with the observation

that individuals accumulating <5,000 steps/day are more likely to be classified as inactive¹⁰² and obese⁶⁵.

Additional findings showed that the mean number of aerobic steps/day in the HIGH-HIGH group was 1,816±938 steps/day (accumulated over 16.2±9.5 minutes/day) at an approximate average intensity of 118±9 steps/minute. Our findings were higher than the steps/minute ranges identified for moderate-intensity walking in recent studies under controlled settings^{40,42,43}. The steps/minute rate obtained, however, provides useful information on the intensity of ambulatory physical activity accumulated by individuals under free-living conditions.

Participants accumulating 5,000 steps/day or more, which included some sustained walking, showed lower percentage body fat, waist circumference and a higher estimated maximal oxygen uptake when compared to those who walked less than 5,000 steps/day. Similar findings were shown when those accumulating 5,000 steps/day or more, with some sustained walking, were compared to those who walked more than 5,000 steps/day but at low intensities and/or short bouts. The association between intensity of steps/day and health and fitness parameters persisted even after adjusting for differences in total steps/day.

In a recent literature review, Choi et al¹⁰⁴ alluded to the viewpoint that there is a daily deficit of approximately 4,000 steps/day which must be gained from more sustained, intensity-based activities. The result of the current study, which demonstrates the possible benefit of intensity-based walking, supports the viewpoint

that the addition of intensity-based steps to daily physical activity does contribute to improved clinical outcomes.

The intra-individual co-efficient of variation (represented as a percentage) in steps/day was 39.2 ± 17.3 . An intra-individual co-efficient of variation less than or equal to 10% has been recommended as an indication of adequate repeatability^{105,106}. However, Schonhofer et al reported an intra-individual co-efficient of variation of steps/day of 17-18% in patients with chronic obstructive pulmonary disease¹⁰⁷ and Tudor-Locke et al reported an intra-individual co-efficient of variation of steps/day of 32.7% in adult participants³⁹. Tudor-Locke et al also reported that the individual with the lowest co-efficient of variation (6.3%) took $1,466 \pm 92$ steps/day and the individual with the highest co-efficient of variation (87.9%) took 695 ± 610 steps/day³⁹.

Most pedometer-based studies support the contention around day-to-day consistency of walking behaviour^{39,105-107}. The results obtained in our study support the viewpoint that daily walking behaviour is often not consistent^{17,34-36}. The implications of this may infer that average daily steps be viewed with caution and, more importantly, within the context of daily variability. Several studies have, nonetheless, provided guidelines on the minimum number of days required to predict reliable average daily steps/day estimates, as discussed in Chapter 1.

Association between steps per day and body measures

Studies have shown that people meeting the 10,000 steps/day target are more frequently classified as normal weight and those individuals with values less than

5,000 steps/day are more frequently classified as obese⁶⁵. Studies have also shown a distinct relationship between pedometer data and body composition variables in the expected direction^{17,65,66,108}.

Tudor-Locke et al⁶⁵, for example, through an accelerometer-based study measured time spent in various intensity categories, showed a decreasing gradient across all body mass index categories. Our study, in establishing a mean percentage body fat of 17.9%, 23.5% and 30.1% in the HIGH-HIGH, HIGH-LOW and LOW groups, respectively, confirms the linear, and positive, relationship between physical activity and percentage body fat.

The results we report on waist circumference (mean waist circumference of 77.5cm, 84.5cm and 87.2cm noted in the HIGH-HIGH, HIGH-LOW and LOW groups, respectively) demonstrate a significant association between physical activity and waist circumference. Our results further demonstrate the benefit of the accumulation of volume and intensity of steps in maintaining a waist circumference within the accepted range, as suggested by the National Institutes of Health¹⁰⁹.

A lower mean systolic blood pressure observed in the HIGH-HIGH group when compared to the HIGH-LOW and LOW groups, respectively demonstrates the value of ambulatory physical activity that is at least of moderate intensity. The mean values obtained in all of the three groups were, however, within the accepted clinical range of 110-140mmHg⁴⁷. Similarly, no clinical significance was noted for diastolic blood pressure between the groups as the mean values were within the accepted 70-90mmHg range⁴⁷ for all 3 groups.

Chan et al ¹⁷ reported a comparable finding in 2003, where a low inverse correlation between diastolic blood pressure and steps/day was detected ¹⁷. A stronger inverse correlation between systolic blood pressure and steps/day that was nearly significant (P=0.0648), was, however, noted ¹⁷. The result obtained in this (Chan et al) study, however, only demonstrated the association between volume of steps/day and blood pressure and did not consider intensity of steps accumulated.

Totsika et al ¹¹⁰ demonstrated a similar effect, in a 9 month diet and physical activity modification intervention in patients at risk of type 2 diabetes, where systolic blood pressure improved (P≤0.006) but diastolic blood pressure did not change significantly (P=0.06).

Association between steps per day and estimated maximal oxygen uptake

It is widely accepted that physical activity contributes to improved aerobic fitness and longevity ^{111,112}. Such evidence points to the fact that aerobic fitness is an important predictor of longevity. There is, however, limited evidence on the association between steps/day and aerobic fitness.

The results of this study show a positive relationship between estimated maximal oxygen uptake and steps accumulated, with the HIGH-HIGH group attaining the highest estimated maximal oxygen uptake and the LOW group, the lowest.

Steps per day versus the 30-minute recommendation of moderate intensity physical activity

The improved clinical ranges seen in the HIGH-HIGH group of our study supports current literature on the importance of volume and intensity of ambulatory physical activity^{3,113}. This outcome points toward a similar direction as that documented by Wilde et al⁴¹ in establishing that the addition of intensity based steps/day contributed towards achieving the 10,000 steps/day recommendation and the consequent improvement in clinical measures.

In relation to current guidelines that recommend 30 minutes moderate-vigorous physical activity at least five times a week¹⁰⁵, Wilde et al reported that women increased their average physical activity from 7,220 steps/day to 10,030 steps/day when they included a 30-minute, self-timed walk⁴¹. Such findings direct us further to the value of incorporating intensity based steps, into daily physical activity. Not only will such recommendations contribute towards achieving the 10,000 steps/day recommendation, but also relates closely to current physical activity guidelines.

Notwithstanding this viewpoint, a recent accelerometer-based study by Cook et al¹¹⁴, in an adult population of rural black South African women, showed the health benefits of a high number of low intensity steps accumulated (mean>9,000 steps/day). In the study, a reduced risk of obesity by 34% at 7,500 steps/day, 52% at 10,000 steps/day and 62% at 12,500 steps/day were observed, when compared with achieving <5,000 steps/day¹¹⁴. The ambulatory levels seen in this study are very different from our study, which observed a mean value of 6,520 steps/day.

The pronounced risk reduction (more acceptable clinical and anthropometric ranges) in the $\geq 5,000$ steps/day categories in both studies, nonetheless, remains a notable observation.

Categorisation of aerobic steps

Omron has proprietary software which categorises “aerobic” steps as ≥ 60 steps/minute for a minimum duration of 1 minute, as described in Chapter 1. This categorisation is substantially different from the recommended steps/minute rates for moderate intensity physical activity, by recent studies conducted. (Information on these studies has been provided in Chapter 1). The Omron classification of “aerobic steps” has, however, allowed for the differentiation of steps based on some level of intensity and duration.

By no means do we suggest or assume that 60 steps/minute is an equivalent proxy for moderate intensity physical activity. Rather, this categorisation has allowed us to extrapolate more refined intensity and duration-based steps data typically not available through traditional pedometers.

Previous studies on intensity of physical activity have been limited to accelerometry^{28,63,103}. The sub-categorisation of steps/day, according to a base-line level of intensity and duration, is therefore a useful addition to pedometry. Appropriate intensity-based steps/day and/or steps/minute recommendations in relation to moderate intensity physical activity may be a valuable enhancement to pedometry, and current documented literature.

Strengths of the study

The research undertaken adds to the relatively limited pedometer-based research that differentiates walking according to a baseline level of intensity and duration. In a sample of people accumulating an approximate average of 6,500 steps/day, this categorisation has helped identify more sustained daily steps. Further information on intensity and volume specific to these bouts of physical activity were extrapolated, thereafter.

Such findings are useful in establishing associations between sustained ambulatory physical activity and health and fitness measures. It must be noted however, that in the sub-analysis of the HIGH-HIGH group, the intensity of steps was 118 ± 9 steps/minute accumulated for an average duration of 16.2 ± 9.5 minutes/day. The results obtained therefore support the recommendations made by Marshall and colleagues⁴² that concluded comparable, but slightly lower steps/minute rate findings for aerobic ambulation. The demonstration of this effect under free-living conditions provides a useful addition to current literature.

This is also among the first pedometer-based studies to be conducted in the Republic of South Africa within an urban context. This, therefore, provides useful information on physical activity patterns and a starting point to further pedometer-based research studies.

Limitations

The relatively small sample size and the potential selection bias, inherent in any convenience sample, limit the external validity of the study. As the study is presented as a pilot study, no power calculation has been carried out. Thus the results cannot be generalised to the entire population. This necessitates the need for similar but larger studies to confirm present findings. The outcomes of the study can also be used to perform an appropriate power calculation for future studies of this nature which can be carried out in a similar context.

The use of a near infrared reactive device as a measure of percentage body fat may be viewed as a limitation. Furthermore, most published percentage body fat ranges have been based on empirically set limits, population percentiles and z-scores and subject to potential limitations¹¹⁵. Percentage body fat was, however, used as an additional measure to body mass index and the results of both measures were analysed and reported separately.

The categorisation of aerobic steps as ≥ 60 steps/minute by this pedometer is substantively lower than those recommended by recent studies^{40,42,43}. Furthermore, the pedometer does not reflect any moderate-high intensity steps as aerobic steps if sustained for anything less than 1-minute in duration. This (≥ 60 steps/minute; 1-minute or more) classification does provide some level of differentiation in the type and duration of steps accumulated throughout the day.

The low steps/day volume noted in our study ($6,520 \pm 2,306$) may be related to the paucity of the data obtained (i.e. 3-consecutive days of pedometer-wear, minimum

wear-time of 10 hours) and to the sensitivity of the Omron pedometer is categorising appropriate movement as steps. This, is however in keeping with the literature alluded to in Chapter 1 on studies that make reference to such cut-offs being appropriately used to reasonably estimate daily ambulatory physical activity⁵⁴⁻⁵⁶ and the reliability of the Omron pedometer at reliably categorising and calculating steps accumulated^{116,117}.

CONCLUSIONS AND RECOMMENDATIONS

Our findings highlight the association between the volume and intensity of steps/day and health and fitness measures. Such findings support the viewpoint that pedometer-determined ambulatory physical activity is of practical importance in establishing more precise, population-specific indices. The association between specific health outcomes and both the number and intensity of steps/day study is also demonstrated.

The possibility of expanding and modifying the current study into a large-scale study is recommended and can be explored further.

As part of our conclusion and recommendations, we performed a power calculation to provide an estimated sample size for a study of this nature. The estimated sample size established was a minimum of 176 men and women, respectively. The calculation was based on an expected negative association between pedometer-derived steps/day and measures such as blood pressure, blood cholesterol and blood glucose, of a magnitude of $r = -0.21$, with confidence intervals between -0.29 and 0.00 ¹¹⁸.

The limitation around the cut-off used for moderate intensity physical activity (as per the pedometer) raises the issue around the recommended steps/minute rate for moderate intensity physical activity. Our finding of 118 ± 9 steps/minute, accumulated for an average duration of 16.2 ± 9.5 minutes/day, in the group that accumulated intensity-based steps, further raises the question around intensity-based step goals. Future research in this regard, using alternative methodological approaches to the previous studies ^{39,42,43} would contribute further towards enhancing current documented research.

University of Cape Town

CHAPTER 3

Physical activity recommendations, brisk walking and steps per minute- how do they relate?

Accepted in part: Journal of Physical Activity and Health (October 2012) [in press]

Authors: Julian D Pillay, Tracy L Kolbe-Alexander, Karin I Proper, Willem van Mechelen, Estelle V Lambert

(Elements of the original paper have been condensed in certain areas to avoid duplication from previous chapters and referred to/referenced accordingly. Some aspects included in the introduction and discussion of this chapter may, however, be repeated from previous chapters so as to maintain the integrity of the original paper)

INTRODUCTION

Walking for fitness has been promoted, in part, by the growing popularity of pedometers and several pedometer-linked health promotion initiatives ^{119,68, 76,77} (discussed in Chapter 1).

Traditionally, steps/day messages have recommended the accumulation of 10,000 steps/day in healthy adults (discussed in Chapter 1). A systematic review of 32 empirical studies suggests that relatively healthy adults take between 7,000-13,000 steps/day ⁷⁸. Tudor-Locke and Myers ⁷⁹ have suggested that 10,000 steps/day is unrealistically high for low-active or inactive adults and may contribute to low programme adherence. Furthermore, messages to the population promoting 10,000 steps/day have paid little emphasis on the importance of intensity.

Findings from Chapter 2 indicated that the approximate intensity of steps, in those participants' accumulating aerobic activity, were at an average intensity of 118±9 steps/minute. We acknowledge the limitations around the accuracy of this estimate, based on the manner in which these estimates were obtained (discussed in Chapter 2).

The question of intensity of steps has, nevertheless, been identified as a pertinent aspect emerging from the study (Chapter 2).

In keeping with research within the context of intensity-based steps, Tudor-Locke & Bassett ³⁹ suggest that when prescribing a 30-minute walk as a way to meet physical activity guidelines, it is important to recommend walking at a "brisk" pace.

To date, few studies have empirically validated a steps/minute rate associated with moderate intensity physical activity and/or self-paced brisk walking.

Tudor-Locke and colleagues determined that 96-107 steps/minute represent a minimum threshold for moderate-intensity walking⁴⁰. This has been corroborated by Marshall et al⁴² who found a range of between 100-110 steps/minute⁴² for healthy adults, and Abel et al⁴³, who found that men and women walking at a moderate intensity had a step rate of 94 steps/minute and 99 steps/minute, respectively. Further details on these studies have been described in Chapter 1.

Studies have also shown that 30 minutes of moderate-vigorous walking corresponds to a total of between 3,100 and 4,000 steps^{30,39,41,120}.

In relation to current advancements in step recommendations, that pay particular attention to intensity of steps accumulated, further investigation around this aspect is relevant. Moreover, guidelines for physical activity have traditionally been duration and intensity-based (such as 30 minutes/day of moderate-to-vigorous physical activity at least five times a week⁴⁷). A steps/minute and/or an intensity-based steps/day recommendation may, therefore provide further options for meeting current guidelines.

The aims of the present study were, therefore, to determine the steps/minute rate corresponding to self-paced brisk walking; to predict a steps/minute rate for moderate intensity physical activity and; to compare these findings.

METHODS

A convenience sample of 61 adults (35 men and 26 women) between the ages of 21 and 49 years volunteered to participate in the study. The participants were recruited through advertisements placed at 2 tertiary academic institutions as well as by word of mouth.

The study was approved by the Faculty of Health Sciences Research Ethics Committee (REC REF: 172/2005) (Appendix A) of the University of Cape Town and all participants signed an Informed Consent Form before participation (Appendix C).

Pre-participation screening:

The Physical Activity Readiness Questionnaire ⁹⁸ (Appendix D), described in Chapter 2 (Methods), was administered to all participants at the initial visit.

Inclusion and exclusion criteria:

The inclusion and exclusion criteria were the same, as described in Chapter 2.

Clinical measurements:

Clinical measures such as body height, body weight, waist circumference and body mass index were measured as described in Chapter 2 (Methods section).

The Omron Body Composition Monitor (BF500) was used to measure percentage body fat and is based on the principles of bioelectrical impedance ¹²¹.

Blood pressure was recorded (in mmHg) using a digital blood pressure monitor (Medactive™ UA-631) after the participant remained relaxed for 5 minutes.

Maximal oxygen uptake was estimated using a sub-maximal test, described in the methods section of Chapter 2.

Walking trials

On a separate day, participants were requested to wear a pedometer (Omron™ HJ 720 ITC) on the left and/or right hip and a Suunto™ T6 heart rate monitor around the lower chest area to record heart rate data during six walking trials.

In the first walking session, each participant was required to walk for 10 minutes at a self-paced “brisk” pace on an indoor track, timed by the researcher. Participants were requested to walk at a pace that they considered “brisk” and would be able to maintain for 30 minutes.

For the subsequent walks, the participant’s pace was externally regulated by a clearly audible metronome which was set at 60, 80, 100, 110 and 120 steps/minute (in random order). The electronic monitoring of the heart rate ensured that each participant reached a steady state heart rate (that was maintained for at least 2 minutes) before terminating the respective trial. The electronic monitoring also ensured that the participant recovered completely (i.e. returned to resting heart rate or within 10% of resting heart rate, thereof) before the subsequent trial.

Pedometer readings were recorded at the start and end of each session to determine the total steps taken during the trial. This information was used to determine the precise steps/minute rate of each trial undertaken by the participant.

A sub-sample of participants (n=29), during the trials, wore the pedometer on both the left and right hips to validate the reliability of this brand and model of pedometers, based on typical mounting positions.

The intra-individual co-efficient of variation in steps/minute in each trial ranged from 96.6% to 99.2%.

Statistical Analyses

The data were analysed using STATISTICA version 8 (StatSoft Inc., Tulsa, OK, USA) and statistical significance was set at $P < 0.05$. Repeated measures analysis of variance (ANOVA) was used to compare heart rate data in each of the walking trials, as a percentage of age-predicted maximum heart rate (%HRM).

Regression analysis was used to predict a steps/minute rate for moderate intensity physical activity using the various trials conducted. The prediction was based on the use of heart rate data, i.e. the steps/minute rate at which the participant would reach 60% of their maximum age-predicted heart rate.

In the regression analysis, fitness emerged as a primary factor contributing to a difference in results. The data was therefore subsequently grouped by aerobic fitness (using the estimated maximum oxygen uptake established from the fitness test) and stratified into upper, middle and lower tertiles.

A multivariate analysis was subsequently used to determine factors which contributed to the variance in the stepping rate corresponding to moderate intensity physical activity.

A *post hoc* Tukey HSD test was used to determine the trial/s that was/were similar to the self-paced brisk walk (based on percentage of maximum heart rate).

RESULTS

Of the 61 participants that volunteered to participate in the study, 2 could not complete the fitness test (due to exceeding their age-predicted maximum heart rate) and 1 did not return for the walking trials. The final analysis sample, therefore, included 58 participants (34 men and 24 women, mean age 31.7 ± 7.7 years).

Table 3.1 provides descriptive statistics of the study group.

Table 3.1: Clinical and ambulatory characteristics of participants (N=58)

Variable	Men (n=34)	Women (n=24)	Total (N=58)
Age (years)	30.4±7.9	33.7±7.1	31.7±7.68
Body mass index (kg/m ²)	27.4±3.9	25.4±6.2	26.5±5.04
Percentage body fat (%)	23.3±7.6	28.4±12.7	25.4±10.2*
Waist circumference (cm)	91.3±11.0	81.5±15.8	87.2±13.9
Systolic blood pressure (mmHg)	126.3±12.6	114.0±16.2	121.2±15.3
Diastolic blood pressure (mmHg)	82.6±9.4	79.7±13.2	81.4±11.1*
Estimated maximal oxygen uptake (ml/kg/min)	49.1±11.4	36.5±9.5	43.9±13.4*

Note: Values are means ± standard deviation

*indicates statistical significance ($P < 0.01$) between men and women

Other than percentage body fat ($P=0.002$) and diastolic blood pressure ($P<0.04$), there was no statistically significant difference in clinical measures between men and women.

Walking trials

Repeated measures analysis of variance showed a significant difference ($P<0.0001$) in age-predicted maximum heart rate across the different trials. A *post hoc* Tukey HSD test revealed that the intensity of the self-paced brisk walk (based on percentage of maximum age-predicted heart rate) was similar to that of the 120 steps/minute trial ($P=0.08$). Furthermore, the self-paced “brisk” walk and the 120 steps/minute trial were the only two trials in which the mean percentage of maximum heart rate was $\geq 60\%$ of maximum age-predicted heart rate, indicating that the walking pace of these two trials correlated closely with moderate intensity physical activity.

Figure 3.1a illustrates the overall relative heart rate response for each of the trials.

Figure 3.1b illustrates the mean steps/minute rate of each trial.

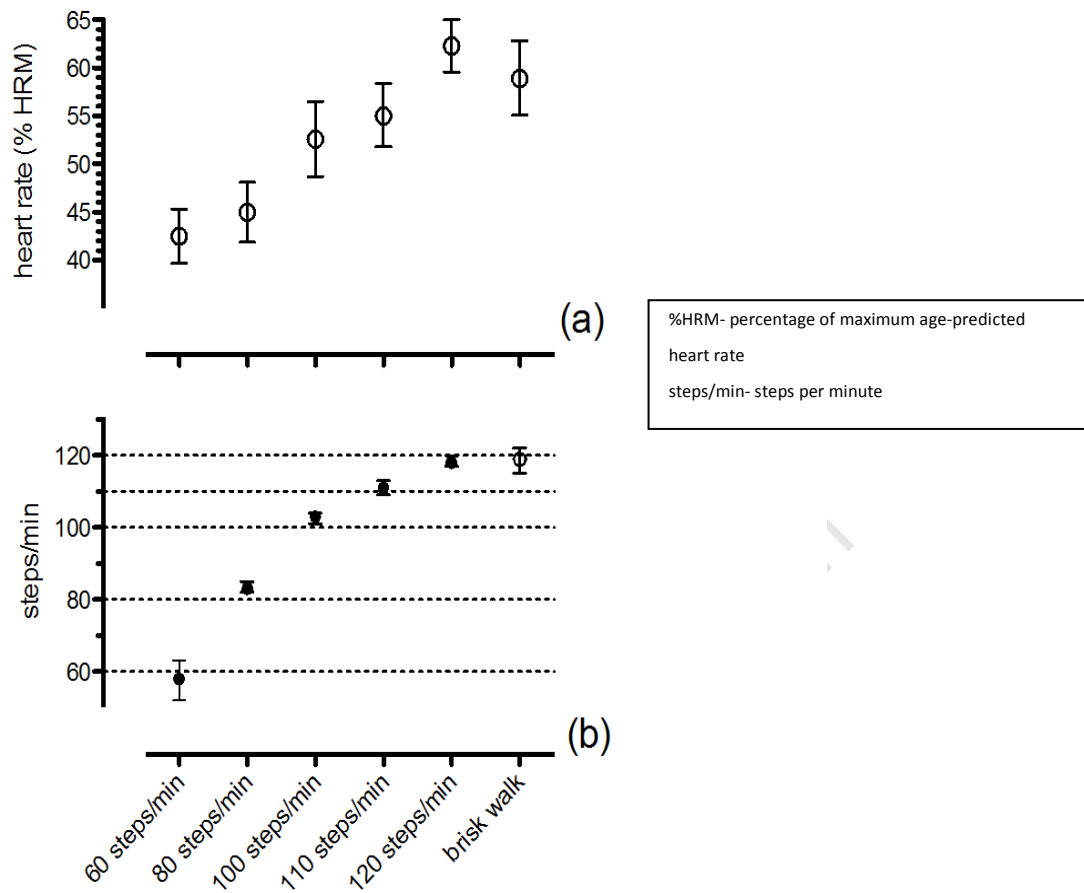


Figure 3.1 a) Percentage of maximum age-predicted heart rate of each trial
b) Steps per minute rate of each trial

Analysis of self-paced brisk walk

The mean steps/minute rate of the self-paced brisk walk was 118±9 steps/minute. When categorised by gender, the mean steps/minute rate was 116±9 steps/minute and 121±8 steps/minute for men and women, respectively (P=0.022).

We subsequently analysed the stepping rates of the self-paced brisk walk by tertiles of fitness (using estimated maximal oxygen uptake). The results obtained showed no

statistical difference in the stepping rate of self-paced brisk walking between the fitness groups, even after adjusting for differences in age and gender.

Figure 3:2 illustrates the steps/min rate and the heart rate response of the self-paced brisk walk in relation to aerobic fitness (tertile stratification).

Analysis of the relative heart rate response during self-paced brisk walking showed a statistically significant difference between fitness tertiles. Those participants in the highest tertile walked at a significantly lower relative intensity compared to those in the lowest fitness tertile ($P=0.008$). However, after adjusting for differences in age and gender, these between-group effects were no longer significant.

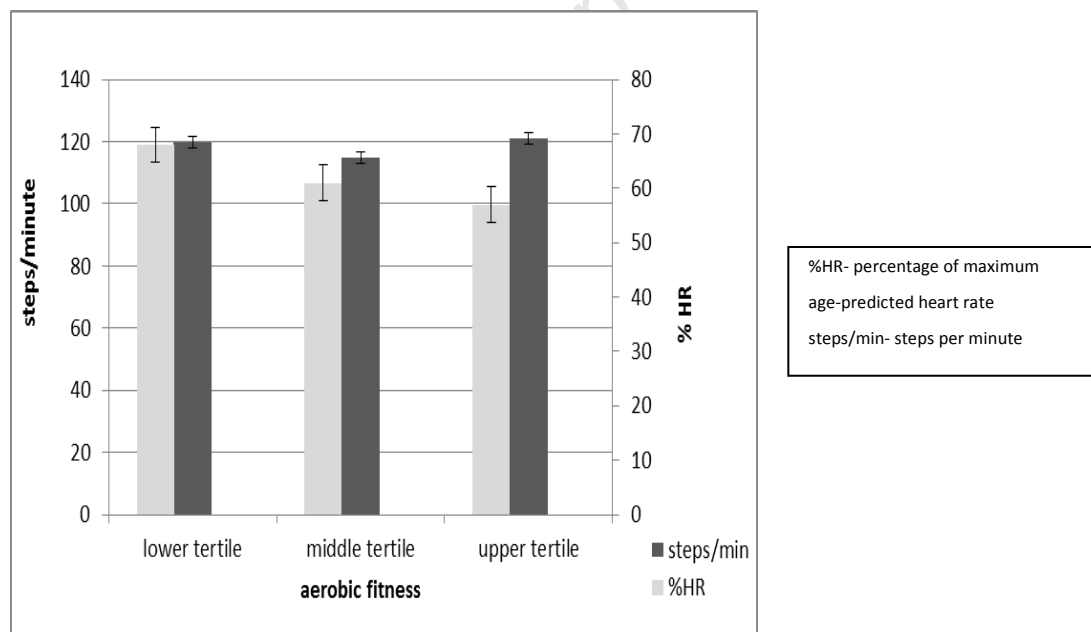


Figure 3.2: Step per minute rate and percentage heart rate of self-paced brisk walk

Steps per minute rate corresponding to moderate physical activity

The predicted stepping rate (using the steps/minute rates and the heart rate data of the different walking trials) that corresponded to 60% of the maximum age-predicted heart rate was 122 ± 37 steps/minute. When categorised by gender, the mean steps/minute rate was 127 ± 36 steps/minute and 116 ± 39 steps/minute for men and women, respectively ($P=0.99$). The subsequent analysis by tertiles of fitness showed the predicted stepping rate for moderate intensity physical activity. The stepping rate for those persons in the highest fitness tertile was significantly higher than both the middle and lowest tertiles ($P<0.003$), even after adjusting for age and gender.

Comparison of self-paced brisk walk to predicted steps/minute rate for moderate physical activity

The stepping rate for the self-paced brisk walk was similar to that of the predicted stepping rate corresponding to moderate intensity physical activity ($P=0.452$), even at different levels of aerobic fitness. A multivariate analysis identifying determinants of the predicted steps/minute for moderate intensity physical activity showed that age, gender and aerobic fitness (estimated maximal oxygen uptake) contributes to the variance in predicted steps/minute rate for moderate intensity physical activity.

DISCUSSION

Our findings confirm that self-paced brisk walking relates closely to moderate intensity physical activity and is similar to the predicted steps/minute rate for moderate intensity physical activity.

The term “brisk” walking, has often been used in directing public health messages to describe moderate intensity physical activity, ranging between 60–70% of the age-predicted maximum heart rate ¹²². The confirmation that self-paced brisk walking relates closely to moderate intensity physical activity is important for exercise prescription. Over-estimation or under-estimation of moderate intensity physical activity may affect adherence to physical activity regimens and potentially impact negatively on the effect gained from participation in physical activity ¹²³.

Those walking much faster than the recommended rate for moderate intensity physical activity, for example, might perceive brisk walking to be too intense. They may, therefore not maintain their pace, or more importantly the recommended duration of such bouts of physical activity. Consequently, those who fall below the recommended stepping rate for moderate intensity physical activity may not benefit from the positive effects of walking. The value of brisk walking may, accordingly, be less effective.

A steps/minute rate relevant to moderate intensity physical activity may, therefore, be a useful starting point and the basis on which to improve walking speed steadily. Studies continue to emerge in this regard, using different methodologies and measurement tools ^{40,42,43}. These studies have been described in greater detail in Chapter 1.

Similar studies have also attempted establishing steps/minute rates for moderate intensity physical activity, taking into account anthropometric measures, such as stride length^{93,94}.

As conducted in previous studies, our study involved walking trials at different walking speeds. A less laboratory-based method of performing the walking trials, through metronome-regulated walking trials on an indoor track was applied, as an alternate methodology. We were, however, unable to determine an absolute measure of oxygen uptake to predict energy expenditure corresponding to moderate intensity physical activity (as used in the Abel et al study⁴³, recently published).

Freedson and Miller provide some limitations to the use of heart rate measures as an estimate of physical activity intensity, and particularly relate these limitations to age, gender and aerobic fitness³¹.

Whilst our findings report age, gender and aerobic fitness in the study group, the estimation of energy expenditure corresponding to moderate intensity physical activity, using a relative measure of heart rate intensity is identified as a primary limitation of this study.

The steps/minute rate obtained in our study (122±37 steps/minute), notwithstanding the large standard deviation, was however, higher than the steps/minute rates recommended by recent studies^{42-44,109}. These studies have, in general, established that moderate intensity physical activity translates to approximately 100-110 steps/minute^{40,42,43,120}.

Further to this, Marshall et al ⁴² suggested that the guide of 3,000 steps in 30 minutes or accumulated in three bouts of 10 minutes, which similarly can be translated to 1,000 steps in 10 minutes, may be an “easy-to-remember” and “an-easy-to-measure” recommendation that can be used as a physical activity promotion heuristic rather than a precise criterion ⁴².

The inclination of convenience sampling attracting those that are more physically active and who might be assumed to have a higher level of aerobic fitness is apparent. Consequently such participants would require a higher steps/minute rate to reach the heart rate threshold for moderate intensity physical activity.

We attempted to address this issue in our results by analysing and reporting according to tertiles of aerobic fitness. Nonetheless, the steps/minute rate identified for moderate intensity physical activity is an overall estimate for the study group and may be evidently increased by a large aerobically fit proportion of the group.

Our findings show no significant difference in both the heart rate response and the stepping rate of self-paced brisk walking between the fitness tertiles, even after adjusting for differences in age and gender. This suggests that individuals walk, during self-paced brisk walking, at an appropriate steps/minute rate for moderate intensity physical activity, independent of aerobic fitness.

A significant difference in the predicted stepping rate for moderate intensity physical activity in those persons within the highest fitness tertile, when compared to both the middle and lowest tertiles was, however, found. This is an expected finding, as people with higher estimated maximal oxygen uptake scores would consequently

need to engage in more vigorous activity, such as a higher steps/minute walking rate, in order to reach the targeted heart rate for moderate intensity physical activity. It is, however, interesting to note that no differences in stepping rates, or heart rate intensities were observed during self-paced brisk walking, across the tertiles of aerobic fitness.

A further factor that often plays a role in the association between physical activity intensity and oxygen uptake is gender¹²³. Due to the limited number of participants, it was not possible to present data stratified according to both aerobic fitness and gender. We therefore presented our results according to tertiles of aerobic fitness, but covaried for gender, so that the effect of gender is accounted for. The equation to estimate maximal oxygen uptake as an estimate of aerobic fitness used in this study includes gender and age in the calculation (described in the methodology).

Further to identifying the stepping rate of self-paced brisk walking in an adult group and predicting a steps/minute rate for moderate intensity physical activity, a further interesting finding was noted. There was a close similarity observed between the steps/minute rate of the self-paced brisk walk and the predicted steps/minute rate for moderate intensity physical activity. This supports current physical activity messages that use the term “brisk walking” as a reference for engaging in moderate intensity physical activity³⁹.

Strengths of the study

This is one of the first studies to determine the approximate steps/minute rate of self-paced brisk walking in a healthy adult group. A recent study has demonstrated

patterns of physical activity during free-living conditions using accelerometer data ¹²⁰. No study, to our knowledge has analysed self-paced brisk walking measured in steps/minute.

The use of an external regulating device (audible metronome) to regulate walking intensity, has allowed us to analyse walking behaviour under more free-living conditions. Previous studies determining steps/minute rates for moderate intensity physical activity have usually involved participants walking on a treadmill at speeds that were steadily increased ^{40,42}. Other studies have engaged participants in specific intensity-based walking trials ⁴³ and correlating the heart rate data obtained to the relevant steps/minute rates.

From a practical perspective, the methodology of our study may be easily applied (and modified to overcome some of the limitations) in future studies as a less controlled proxy for free-living walking. In particular, the use of an absolute measure of moderate intensity physical activity rather than a relative measure may provide more accurate heart rate estimates for moderate intensity physical activity rather than an age-predicted targeted heart rate.

The study additionally demonstrates the relationship between the steps/minute rate of self-paced brisk walking and a predicted steps/minute rate for moderate intensity physical activity.

Our results consequently support the adoption of the term “brisk walking” as an estimate for moderate intensity physical activity in public health messages and guidelines, based on steps/minute data.

Limitations

The trials were carried out on a flat surface and as such, no distinction could be made between walking at different gradients and walking surfaces, which may not always represent actual conditions of exercise. In addition, using an estimated targeted heart rate instead of a more direct measure during the various trials was a further limitation.

The relatively small sample size (N=58) obtained in this study necessitates future research aimed at a larger, more representative study sample, particularly in terms of age, gender and aerobic fitness.

The potential selection bias inherent in any convenience sample, particularly if related to physical activity, is noted. As such, convenience sampling may attract those that are more physically active and therefore have better aerobic fitness than the general population. We attempted addressing this issue in our results by separating our analysis into aerobically fit and un-fit groups alike. We could not further stratify according to gender due to the limited size of the study group. This limitation does necessitate similar studies in other groups, and more importantly in a more representative sample group.

CONCLUSION AND RECOMMENDATIONS

The study provides a useful alternative method of determining the steps/minute rate for moderate intensity physical activity and self-paced brisk walking, respectively. We add a further dimension to current literature in determining the average steps/minute rate obtained for self-paced brisk walking in healthy adults. The relationship between self-paced brisk walking and moderate intensity physical activity is also demonstrated, that can be adopted to complement current physical activity guidelines^{11,47}.

Due to the limitations identified around some methodological issues, we recommend that our findings be evaluated in the light of recent studies of a similar objective^{40,42,43,120}. Consequently, aspects of the methodologies can be applied and modified to provide more accurate estimates in future studies.

Additionally, the application of a steps/minute rate for moderate intensity physical activity in larger cross-sectional studies may provide more direct estimates of physical activity. This will be particularly relevant in the context of moderate intensity physical activity as well as current guidelines. Such an application may be useful in supporting intensity-based steps/day recommendations as an additional strategy/option for achieving current physical activity guidelines.

CHAPTER 4

A pedometer-based, cross-sectional study in an employed South African population.

In submission: Journal of Physical Activity and Health

Authors: Julian D Pillay, Hidde van der Ploeg, Maartje van Stralen, Tracy L Kolbe-Alexander, Karin I Proper, Simone Tomaz, Willem van Mechelen, Estelle V Lambert

INTRODUCTION

In the context of walking and steps/day recommendations, recent studies have been directed towards the application of intensity-based steps, such as a steps/minute rate, for moderate intensity physical activity. For example, studies have shown that 30 minutes of moderate-vigorous walking equates to between 3,100 and 4,000 steps^{41,42,93}, even when considering factors such as stride length and body mass index in their recommendations^{93,94}.

Such studies have accordingly emphasised the significance of intensity-based steps/day recommendations as an emerging area of research. Further to this, Chapters 2 and 3 make reference to intensity-based step recommendations and in particular, an appropriate steps/minute rate for moderate intensity physical activity.

Information on ambulatory physical activity patterns, in the context of steps/day and in particular intensity-based steps, will therefore add to the current understanding of the dose-response effects of walking. Studies of this nature, conducted in large population groups, may provide useful estimates of ambulatory physical activity. This application may be valuable in supporting intensity-based steps/day recommendations as an additional strategy/option for attaining current physical activity guidelines.

The aim of this study was, therefore to determine the association between the volume and intensity of daily steps accumulated, and health measures (such as body mass index, blood pressure, blood glucose, blood cholesterol) in a South African employed adult group. The study also explores the extent to which differences in body composition (percentage body fat, body mass index and waist circumference)

may mediate the association between steps/day and clinical outcomes (blood pressure, blood cholesterol and blood glucose).

METHODS

The study was a cross-sectional study, among South African employed adults.

Participant recruitment

A convenience sample of participants was recruited through an invitation email sent out to employees, or following the completion of a health risk screening hosted at the corporate organisation. The corporate organisations mainly comprised health insured, white-collared workers. The range of work performed by the employees varied considerably (from secretarial/administrative to senior management roles). The physical activity levels required by, and performed in most of these jobs were however, low in general. This information was provided by the relevant questionnaire responses (Appendix E: Section 4-Physical activity assessment).

Upon completion of the informed consent form (Appendix C), participants were provided with a blinded pedometer to wear, as described in the methods section of Chapter 2.

Inclusion and exclusion criteria:

Employees attending the health screening event and/or willing to participate in the study were eligible for inclusion. Other inclusion and exclusion criteria have been described in Chapter 2 (Methods).

Ethical considerations and informed consent

The study was approved by the Faculty of Health Sciences Research Ethics Committee (REC REF: 348/2008) (Appendix A) of the University of Cape Town. Permission was also obtained from the corporate organisation to provide an on-site health screening event and invite employees to participate in the study. Employees were, at the health screening event, provided with a Participant Information Sheet (Appendix B) detailing the purpose, aims, procedures, requirements and potential risks of the study. They were thereafter required to sign an Informed Consent Form (Appendix C).

Clinical measures:

The clinical measures recorded, including body height, body weight, waist circumference, percentage body fat and blood pressure, have been described in Chapter 2 (methods section). Finger prick blood cholesterol and blood glucose were also taken.

Pedometer

Participants were requested to wear the Omron HJ 750 ITC pedometer, according to the protocol described in Chapter 2 (methods sections). A 5-consecutive-day protocol was decided as the number of days the participants will be requested wear the pedometer to provide a good indication of weekly physical activity. This would increase probability of obtaining at least 3 consecutive days of pedometer data, as a minimum criterion for inclusion in the data analyses.

Data recording

The pedometer data was uploaded electronically by the researcher according to the Omron Health Management Manager software protocol ²⁸. Feedback on pedometer data was communicated to the participant when the pedometer was being returned. Information relating to the feedback provided to participants has been described in Chapter 2 (Methods section).

With particular reference to intensity-based steps, recently documented literature on intensity-based steps/day ^{40,42} suggests a minimum of 100 steps/minute to be a reliable estimate of, and target for, moderate intensity physical activity. The findings of the studies described in Chapters 2 and 3, respectively, further make reference to this estimate, as a reliable indicator of moderate intensity physical activity.

The 100 steps/minute rate for moderate intensity physical activity, consequently, informed the refinement of “aerobic” steps by the pedometer’s classification, to an estimate more relevant to current literature, in our subsequent analysis. Current literature also suggests that the accumulation of moderate intensity physical activity in bouts of at least 10 minutes to be acceptable in contributing towards meeting current physical activity guidelines ⁸.

We thus limited our intensity-based analysis to bouts of 10 consecutive minutes or more and at a minimum average intensity of 100 steps/minute using the graphical display of pedometer results. “Manufacturer-defined aerobic steps” were used as a basis for separating sustained steps (≥ 60 steps/minute; duration ≥ 1 minute) and this category of steps were further stratified according to whether these steps were sustained for at least 10 minutes. We then determined the average intensity of these bouts (using the total number of steps and duration information). Only if the steps

accumulated were at a minimum average intensity of 100 steps/minute was this bout categorised as “aerobic steps”

The data was further sub-grouped according to intensity-based categories i.e. “no aerobic activity”, “low aerobic activity” (1-21 minutes/day of aerobic activity) and “high aerobic activity” (≥ 21 minutes/day of aerobic activity). The 21 minutes/day of aerobic activity sub-group relates to current physical activity guidelines of 150 minutes of moderate intensity physical activity per week ⁸. The guideline of accumulating a minimum of 150 minutes per week of moderate intensity physical activity ^{8,10,11} was translated to an average daily approximation of 21 minutes, thereby still relating to current physical activity guidelines.

Statistical analyses

The data were analysed using STATISTICA version 8 (StatSoft Inc., Tulsa, OK, USA) and statistical significance was set at $P < 0.05$. General characteristics of the study group were summarised using descriptive statistics and additionally categorised by gender, with the P-value determined.

The data was subsequently grouped according to steps/day and aerobic time categories, respectively. An analysis of co-variance (ANCOVA), adjusting for age, gender and total steps/day was used to compare groups based on volume and intensity-based steps categories. A post-hoc Bonferroni test was used to determine between group effects, where relevant.

The mediation effect of percentage body fat, body mass index and waist circumference on the association between both steps/day and aerobic time on clinical outcomes (systolic blood pressure, diastolic blood pressure, blood cholesterol and blood glucose) was examined. Our mediation analysis was informed by the product-of-coefficient test, which essentially consists of four steps¹²⁴. As a first step, we determined the total effect (c path) of the independent variable (e.g. steps/day) on the outcome variable (e.g. systolic blood pressure). We thereafter determined the association between the independent variable (e.g. steps/day) and the potential mediator (e.g. percentage body fat), calculated as the “a-coefficient”. Thirdly, the association between the potential mediator and the outcome variable was assessed (b-coefficient), controlled for the independent variable (c’ coefficient). The c-prime (c’) path is the direct effect of the independent variable on the outcome variable, adjusted for the mediator. Finally, the mediated effects of the independent variable on the outcome variable through the proposed mediator was determined by multiplying the a- and b coefficient (a*b coefficient). We also calculated the percentage mediation of the potential mediator ($a*b/c$) to assess the percentage of the effect of the independent variable on the outcome variable that could be explained by the mediator.

The bootstrapping statistical approach using 1,000 bootstrap re-samples was used, with the SPSS script of Preacher, Rucker and Hayes¹²⁵ to calculate the bias corrected confidence intervals around the mediated and direct associations¹²⁵.

RESULTS

Participant characteristics

Of the 366 participants who volunteered to participate in the study, 312 participants (147 men and 165 women, 37±9yrs) completed the pedometer wear for a minimum of 3 consecutive days, with at least 10 hours per day of wear, and were included in the analysis. Seventy-two participants had completed pedometer wear for 3 consecutive days, 109 for 4 consecutive days and 131 for 5 or more consecutive days. Eighty-nine participants had worn the pedometer for at least one weekend day and 40 participants for both weekend days.

The mean steps/day accumulated in men and women were 7,476±4,076 steps/day and 5,769±2,759 steps/day, respectively.

Table 4.1 presents characteristics of the study group.

Table 4.1: General Characteristics of participants

Variable	Total	N	Men	n	Women	n
Age (years)	37.4±9.3*	312	38.1±9.9	147	36.8±8.8	165
Height (m)	1.68±0.1**	311	1.7±0.1	146	1.6±0.1	165
Weight (kg)	76.4±16.8	312	81.1±15.2	144	72.2±17.1	165
Body mass index (kg/m ²)	26.9±5.7*	304	27.0±4.9	139	26.8±6.4	165
% body fat (%)	30.0±10.7**	244	26.8±8.8	121	33.2±11.5	123
Waist circumference (cm)	85.8±13.3	302	88.7±12.1	137	83.4±13.8	165
Systolic blood pressure (mmHg)	120.9±14.5	296	125.5±13.3	131	117.3±14.4	165
Diastolic blood pressure (mmHg)	79.6±11.7	296	81.1±12.0	131	78.4±11.3	165
Blood cholesterol (mmol/L)	3.9±1.1	250	3.8±0.9	106	4.0±1.2	144
Blood glucose (mmol/L)	4.9±1.8	243	4.9±1.4	100	4.9±2.1	143
Pedometer data (total steps/day)	6574±3541**	312	7476±4076	147	5769±2759	165

Average daily aerobic steps (steps/day)	694±1465**	312	947±1771	147	468±1081	165
Average daily aerobic time (minutes/day)	5.7±12.0**	312	7.8±14.6	147	3.8±8.7	165

Note: Values are means ± standard deviation

*indicates statistical significance (P<0.05), ** (P<0.003) between men and women

The data were subsequently grouped according to four volume-based categories based on current steps/day classifications⁸⁸: “<5,000 steps/day”; “5,000-7,499 steps/day”; “7,500-9,999 steps/day” and “≥ 10,000 steps/day” (Table 4.2).

Table 4.2: Biometric and clinical measures by step per day categories

Variable	N	<5,000	n	5,000-7,499	n	7,500-9,999	n	≥10,000	n
Weight (kg)	309	78.9±19.0	112	75.4±15.5	99	74.7±17.2	60	73.8±11.1	38
BMI (kg/m ²)	304	28.1±7.1	110	26.5±5.1	98	25.7±4.6	59	26.1±3.6	37
% BF (%)	244	34.7±12.5 ^B	97	28.7±8.3 ^A	80	24.4±7.2 ^A	38	25.6±7.7 ^A	29
WC (cm)	302	89.9±15.3 ^B	111	84.8±12.8 ^A	99	81.3±10.4 ^A	56	83.0±8.6 ^A	36
SBP(mmHg)	296	122.2±15.5	111	122.1±15.0	99	117.9±12.6	55	117.8±11.1	31
DBP (mmHg)	296	81.9±10.1	111	80.0±13.1	99	76.1±11.0	55	76.4±11.5	31
BC (mmol/L)	250	4.1±1.1	99	3.9±1.2	75	3.7±0.8	47	3.6±0.8	29
BG(mmol/L)	243	5.4±2.5 ^B	98	4.5±1.1 ^A	71	4.4±1.0 ^A	45	4.8±1.0 ^A	29

Note: Values represent mean ± standard deviation, adjusted for age, gender and average daily aerobic steps

Means with a different letter superscript indicate statistical significance between groups (P<0.05)

BMI- body mass index

%BF- percentage body fat

WC- waist circumference

SBP- systolic blood pressure

DBP- diastolic blood pressure

BC- blood cholesterol

BG- blood glucose

A total of 112 participants (35.9%) accumulated an average of <5,000 steps/day, typically classified as inactive⁴⁰. Only 41 participants (13.1%) achieved an average of ≥10,000 steps/day, typically classified as “moderately active”⁴⁰. Within the

“moderately active” group, most of the participants (73%) also accumulated aerobic steps.

Significant differences were evident between some biometric and clinical outcomes in those participants in the <5,000 steps/day category, when compared to the other steps/day categories, as indicated in Table 4.2. For example, when adjusted for age and gender, no statistically significant differences were noted between the groups in body weight, body mass index, systolic blood pressure, diastolic blood pressure and blood cholesterol ($P<0.05$).

The <5,000 steps/day group was, however significantly different from all other groups ($P<0.05$) in percentage body fat, waist circumference and blood glucose, only.

The same effects persisted when adjusting for age, gender and daily aerobic steps (so as to establish the independent effect of volume of steps/day).

Table 4.3 presents our data according to intensity-based categories, i.e. “no aerobic activity”; “low aerobic activity” and “high aerobic activity”.

Table 4.3: Biometric and clinical measures based on daily aerobic step time categories

Variable	N	No aerobic time	N	1-21 minutes/day	n	≥21 minutes/day	n
Weight (kg)	309	76.7±17.5	209	76.8±15.4	66	73.6±15.2	34
BMI (kg/m ²)	304	27.1±6.1	207	26.9±5.1	63	25.6±4.6	34
% BF (%)	244	32.2±11.6 ^B	168	26.2±6.6 ^A	49	23.7±5.7 ^A	27
WC (cm)	302	86.9±14.0	207	84.0±11.9	63	82.5±10.6	32
SBP(mmHg)	296	121.8±15.0	204	119.4±12.7	60	118.4±13.9	32
DBP (mmHg)	296	80.9±11.4 ^B	204	77.4±10.9 ^A	60	75.2±13.3 ^A	32
BC (mmol/L)	250	4.0±1.1	183	3.8±0.9	42	3.7±0.8	25
BG(mmol/L)	243	5.0±2.1	180	4.5±0.9	39	4.7±1.8	24

Note: Values represent mean ± standard deviation, adjusted for age and gender and total steps/day
Means with a different letter superscript indicate statistical significance between groups (P<0.05)

BMI- body mass index

%BF- percentage body fat

WC- waist circumference

SBP- systolic blood pressure

DBP- diastolic blood pressure

BC- blood cholesterol

BG- blood glucose

Of the total sample, 102 participants (32.7%) accumulated aerobic steps. However, only 35 participants (11.2%) of the total study group accumulated aerobic steps for a minimum duration of 21 minutes/day.

No statistically significant differences were noted in body weight, body mass index, waist circumference, systolic blood pressure, blood glucose and blood cholesterol across the categories (P<0.05). With regards to percentage body fat and diastolic blood pressure, however, the “no aerobic activity” group was significantly different from the other 2 groups (P<0.05), as indicated in Table 4.3.

When adjusted for age, gender and total steps/day, none of the measures emerged as statistically significant between the groups ($P < 0.05$).

A subsequent analysis investigated the mediation effect of variables related to body fat measures, i.e. percentage body fat, body mass index and waist circumference, on the association between volume and intensity-based steps/day and clinical outcomes (systolic blood pressure, diastolic blood pressure, blood cholesterol and blood glucose).

Table 4.4 presents a summary of the results.

University of Cape Town

Table 4.4: Mediation effect of percentage body fat, body mass index and waist circumference on the association between total daily steps/aerobic time and clinical measures

Mediator	Independent variable	Outcome Variable	c path (SE)	a path (SE)	b path (SE)	c' path (SE)	ab path (95% CI)	% mediation
Percentage body fat	Total steps (steps/day)	SBP (mmHg)(n=233)	-2,70(0,94)	-3,61(0,67)	0,33(0,94)	-1,50(0,98)	-1,19(-2,46;-0,53)	44
		DBP(mmHg)(n=233)	-2,75(0,78)	-3,61(0,67)	0,28(0,08)	-1,76(0,81)	-0,99(-1,63;-0,49)	36
		BC (mmol/L)(n=195)	-0,18(0,08)	-3,44(0,74)	0,02(0,01)	-0,11(0,08)	-0,07(-0,16;-0,0006)	38
		BG (mmol/L)(n=189)	-0,31(0,14)	-3,37(0,74)	0,04(0,01)	-0,19(0,15)	-0,13(-0,35;-0,,24)	42
	Aerobic time (minutes/day)	SBP (mmHg)(n=233)	-3,71(1,37)	-4,39(0,98)	0,34(0,09)	-2,22(1,39)	-1,48(-2,72;-0,70)	60
		DBP (mmHg)(n=233)	-4,34(1,12)	-4,39(0,98)	0,27(0,07)	-3,14(1,14)	-1,19(-1,98;-0,67)	27
		BC (mmol/L)(n=195)	-0,18(0,13)	-4,00(1,17)	0,02(0,01)	-0,09(0,13)	-0,08(-0,19;-0,01)	44
		BG (mmol/L)(n=189)	-0,30(0,23)	-4,13(1,20)	0,04(0,01)	-0,13(0,23)	0,17(-0,46;-0,04)	57
Body mass index	Total steps (steps/day)	SBP (mmHg)(n=290)	-2,38(0,84)	-1,04(0,34)	0,60(0,14)	-1,75(0,82)	-0,63(-1,31;-0,20)	26
		DBP(mmHg)(n=290)	-2,61(0,69)	-1,04(0,34)	0,51(0,11)	-2,08(0,68)	-0,53(-0,95;-0,20)	20
		BC (mmol/L)(n=247)	-0,16(0,07)	-0,71(0,38)	0,01(0,01)	-0,15(0,07)	-0,009(-0,05;0,005)	06
		BG (mmol/L)(n=240)	-0,27(0,12)	-0,77(0,38)	0,07(0,02)	-0,27(0,12)	-0,05(-0,17;-0,007)	19
	Aerobic time (minutes/day)	SBP (mmHg)(n=290)	-2,81(1,17)	-0,67(0,50)	0,63(0,14)	-2,38(1,17)	-0,43(-1,18;0,10)	15
		DBP (mmHg)(n=290)	-3,40(0,10)	-0,67(0,50)	0,54(0,11)	-3,03(0,96)	-0,36(-0,87;0,09)	11
		BC (mmol/L)(n=247)	-0,12(0,11)	-0,38(0,57)	0,02(0,01)	-0,12(0,11)	-0,01(-0,05;0,01)	08
		BG (mmol/L)(n=240)	-0,25(-0,18)	-0,37(0,60)	0,07(0,02)	-0,22(0,18)	-0,03(-0,14;0,04)	12

Table 4.4/continued

Mediator	Independent variable	Outcome Variable	c path (SE)	a path (SE)	b path (SE)	c' path (SE)	ab path (95% CI)	% mediation
Waist circumference	Total steps (steps/day)	SBP (mmHg)(n=292)	-2,60(0,83)	-3,91(0,76)	0,34(0,06)	-1,26(0,82)	-1,34(-2,21;-0,76)	52
		DBP(mmHg)(n=292)	-2,90(0,67)	-3,91(0,76)	0,27(0,05)	-1,83(0,67)	-1,05(-1,65;-0,60)	36
		BC (mmol/L)(n=243)	-0,15(0,07)	-3,43(0,83)	0,01(0,01)	-0,12(0,07)	-0,03(-0,09;0,001)	20
		BG (mmol/L)(n=236)	-0,30(0,12)	-3,34(0,84)	0,03(0,01)	-0,20(0,12)	-0,10(-0,19;-0,05)	33
	Aerobic time (minutes/day)	SBP (mmHg)(n=292)	-3,30(1,21)	-3,24(1,14)	0,35(0,06)	-2,15(1,16)	-1,14(-2,07;-0,46)	35
		DBP (mmHg)(n=292)	-3,91(0,99)	-3,24(1,14)	0,28(0,05)	-2,99(0,95)	-0,91(-1,62;-0,36)	23
		BC (mmol/L)(n=243)	-0,12(0,11)	-3,01(1,31)	0,01(0,01)	-0,01(0,11)	-0,03(-0,10;-0,0002)	25
		BG (mmol/L)(n=236)	-0,25(0,19)	-3,31(1,33)	0,03(0,01)	-0,14(0,19)	-0,11(-0,24;-0,03)	44

c= total effect of the independent variables (i.e. steps/day and aerobic time) on the outcome variable (i.e SBP, DBP, BC, BG),

a= association between the independent variable (e.g. steps/day) and the potential mediator (e.g. percentage body fat)

b= association between the potential mediator and the outcome variable was assessed, controlled for the independent variable

c'= direct effect of the independent variable on the outcome variable was determined

ab= indirect effects of the independent variable on the outcome variable through the proposed mediator

% mediation= percentage mediation of the potential mediator (a*b/c)

SE: Standard error

values represented in bold indicate significant associations

SBP- systolic blood pressure

DBP- diastolic blood pressure

BC- blood cholesterol

BG- blood glucose

Total steps/day was associated with all clinical outcomes, i.e. systolic blood pressure, diastolic blood pressure, blood cholesterol and blood glucose. Aerobic steps/day appeared to be associated with systolic blood pressure and diastolic blood pressure. Total steps/day and aerobic steps/day were negatively associated with percentage body fat and waist circumference. With regards to body mass index, only total steps/day was negatively associated it. No association was evident between aerobic steps/day and body mass index.

Our results show that the mediators (percentage body fat, waist circumference and body mass index) were all associated with the clinical measures (systolic blood pressure, diastolic blood pressure, blood cholesterol and blood glucose).

Percentage body fat was the strongest mediator (27-60% mediation, in associations of statistical significance) in the association between steps (steps/day and aerobic activity) and clinical measures. Waist circumference also mediated most of the associations between steps and clinical measures, although providing a less strong extent of mediation (23-52% mediation, in associations of statistical significance) than percentage body fat. Body mass index was evidently a less convincing mediator in the associations presented (19-26% mediation, in association where statistical significance was found).

DISCUSSION

The findings of this study support the existing evidence linking volume and intensity of steps/day to fitness and health outcomes^{55,78,80}. Exercise prescription and/or steps/day recommendations may be enhanced if framed within the context of volume, intensity and duration of intensity-based steps, as corroborated by our earlier findings (Chapters 2 and 3).

In support of our findings, reference to 3,000 steps in 30 minutes was made as an overall guideline that incorporates volume, duration and intensity of steps/day. Recent studies have also shown that 30 minutes of moderate-vigorous walking corresponds to a total of between 3,000 and 4,000 steps^{30,39-41}. The use of 3,000 steps in 30 minutes is, however suggested as a heuristic value and taken over and above habitual activity levels.

The mean steps/day of $6,574 \pm 3,541$ suggest that our sample group fell below the lower end of 7,000-13,000 steps/day for healthy, younger adults⁸⁸. Our data was, nevertheless, consistent with the observation that individuals accumulating <5,000 steps/day are more likely to be classified as obese⁶⁵. Significant differences were also found between most biometric and clinical outcomes in those participants in the <5,000 steps/day category, when compared to the other steps/day categories. As recently confirmed⁴⁴, total daily values less than 5,000 steps/day may be an appropriate index for inactivity and its associated risk with health consequences, such as obesity.

Additional findings were that 102 participants (32.7%) accumulated aerobic steps (≥ 100 steps/min for a minimum duration of 10-minutes/day). Only 35 participants (11.2%), however, accumulated aerobic steps for an average of at least 21 minutes/day, as a proxy for current guidelines that make reference to moderate intensity physical activity. This suggests that only approximately one-third of our study group accumulated some moderate intensity physical activity relevant to current guidelines⁸, with respect to ambulatory physical activity⁸.

Our findings are similar to recent studies reported. For example, in a report on current physical activity levels in 122 countries, that provided an estimate of 88.9% of the world's population, 31.4% (95% Confidence Interval: 31.2-31.4) were classified as active³⁷. A higher value of 38.0% (95% Confidence Interval: 37.6–38.4) was found on the African continent³⁷. This related to vigorous intensity physical activity on at least 3 or more days per week, seen as a more reliable and valid estimate from standardised self-reported instruments than moderate intensity physical activity³⁷.

Whilst our study group may not be truly representative of the South African adult population, the results do support the viewpoint that globally, most adults are currently not meeting physical activity guidelines³⁷.

Association between steps per day and anthropometric measures

Research has shown that people meeting the 10,000 steps/day target are more frequently classified as normal weight and those individuals with values less than 5,000 steps/day are more frequently classified as obese⁶⁵. In addition, a distinct

relationship between steps/day and body composition variables in the expected direction^{17,48,65,66,108} has been previously reported, as discussed in Chapter 1.

In general, we did not find significant associations in clinical outcomes between participants accumulating more than 10,000 steps/day versus those accumulating 7,500-9,999 steps/day or even 5,000-7,499 steps/day. There was, however, significance between the <5,000 steps/day group and the other 3 groups in most of the clinical outcomes. Even after adjusting for age, gender and aerobic steps (so as to establish the true effect of volume of steps/day), this effect still prevailed. This points towards the conclusion that steps/day recommendations may need to consider intensity-based steps.

Steps per day in relation to moderate intensity physical activity and current physical activity guidelines

The categorisation of our pedometer data into intensity-based categories, described in the methodology, so as to relate to current physical activity guidelines, showed conflicting findings. After adjusting for age and gender, only percentage body fat and diastolic blood pressure were significantly different between the “no aerobic activity” and the “low aerobic activity” groups. A similar finding was observed when comparisons between the “no aerobic activity” and the “high aerobic activity” groups were made. No other between-group effects were noted. This may direct us to the notion that “some physical activity is better than none”⁴⁸. However, when adjusted for age, gender and total steps/day (to establish the independent effect of intensity), none of the variables emerged as significantly different between the three groups.

The interplay between volume and intensity of daily steps may imply an integrated effect of volume and intensity of steps/day on health outcomes. As such, applying volume and intensity steps/day targets may be crucial in future pedometer-based messages than volume or intensity-based messages alone. This suggests that the addition of intensity based steps/day may contribute towards achieving the 10,000 steps/day recommendation^{3,113}. Furthermore, the implication that even in the absence of meeting the 10,000 steps/day recommendation, the impact of moderate intensity physical activity is significantly greater than volume alone, is apparent, as similarly documented by Wilde et al⁴¹.

Mediation effect of waist circumference, percentage body fat and body mass index in the association between steps per day and clinical outcomes

Mediation analysis has emerged as a statistical technique for providing insights into the mechanisms of change, particularly in behavioural interventions. As such, in the area of physical activity and health, mediation analysis has been used to determine which behaviours contribute to weight loss. For example, Lubans et al showed, in an intervention promoting fathers and children increasing their physical activity, that fathers spending more time being physically active with their children resulted in their weight loss¹²⁶. This indicated that their child's physical activity mediated their (father's) weight loss¹²⁶. More recently van Stralen et al explored potential mediators of the long-term effect of a school-based multi-component intervention on sports participation, outdoor play and screen time in Dutch primary schoolchildren (35% overweight)¹²⁷. Potential mediators were self-reported psychological, social and physical environmental factors whilst outcome behaviours were self-reported sport participation, outdoor play, television viewing and computer use¹²⁷.

In general, studies of this nature have been intervention-based, studying the extent of social/environmental factors as mediators of physical activity or weight loss.

The notion that regular physical activity is associated with lower adiposity (body mass index, percentage body fat and waist circumference) and improved clinical measures is well documented. Resting Energy Expenditure, and the variation thereof is, however, largely due to differences in the extent of lean body mass and fat mass of an individual ²². Consequently, all associations between body size and other outcomes (such as cardiovascular risk factors) are partially confounded by the association with resting energy expenditure ²². Increased levels of physical activity are seen to increase energy expenditure and improve clinical measures, such as reducing blood pressure ²².

After accounting for physical activity, the positive correlation between increased resting energy expenditure and blood pressure, for example ¹²⁸ may direct us to the viewpoint that the association between physical activity and clinical outcomes might be mediated by factors relating to body fat.

From our mediation analysis, it is evident that the relationship between steps/day (both total steps/day and aerobic time) and clinical outcomes (blood pressure, blood cholesterol and blood glucose) are influenced (mediated) by body fat estimates. In our study, percentage body fat emerged as the strongest and significant mediator in this association, and may, therefore be a useful consideration when studying the associations between physical activity measures and clinical outcomes.

Strengths of the study

The research undertaken is among the first pedometer-based studies conducted in the Republic of South Africa, within an urban context, that establishes the association between ambulatory physical activity and health measures in an adult, employed population group.

The study was useful in establishing associations between volume, intensity (in terms of aerobic steps/day accumulated) and duration (total time spent in aerobic activity) of ambulatory physical activity and health measures.

Limitations

The cross-sectional nature of the study provided information on the association between ambulatory physical activity and clinical outcomes. No causal inference could, however be drawn due to the cross-sectional nature of the study.

The study was limited to those employees attending the health screening event and/or willing to participate in the study. This presents a selection bias, as the group agreeing to participate may be different from the non-participating employees.

Pedometers measure ambulatory physical activity. Our study was, therefore, limited to participants performing activities more specific to ambulation and did not include activities such as swimming, cycling and weight training.

The low steps/day volume noted in our study ($6,574 \pm 3,5416$) may be related to the paucity of the data obtained (i.e. 3-consecutive days of pedometer-wear, minimum wear-time of 10 hours) and to the sensitivity of the Omron pedometer is categorising

appropriate movement as steps. This is, however in keeping with the literature alluded to in Chapters 1 and 2 on studies that make reference to such cut-offs being appropriately used to reasonably estimate daily ambulatory physical activity⁵⁴⁻⁵⁶ and the reliability of the Omron pedometer at reliably categorising and calculating steps accumulated^{116,117}.

The 100 steps/minute criterion, used as a baseline criterion for moderate intensity physical activity, may not always be a true indication of moderate intensity physical activity at an individual level. For example, this estimate may likely be affected by factors such as aerobic fitness and the heart rate response to physical activity.

A number of studies that have directly measured moderate intensity as 3 METs have, however, concluded that 100 steps/minute is a reasonable heuristic value indicative of moderate intensity physical activity^{40,43,44,129}.

The sub-grouping of data according to intensity-based categories using 21 minutes/day of aerobic activity, as a proxy for current physical activity guidelines, may be viewed as a further limitation. However, due to the small number of participants accumulating any aerobic activity, the World Health Organisation's guideline of 150 minutes per week⁸ was averaged over 7 days and translated to a 21 minute approximation.

This criterion has allowed us to provide some level of differentiation of physical activity according to intensity and duration.

CONCLUSION AND RECOMMENDATIONS

The findings of this research highlights the association between an objective measure of ambulatory physical activity (using pedometers) and health measures (i.e. body weight, waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol). The mediation effect of typical measures of body fat (waist circumference, body mass index and percentage body fat) on the association between daily steps and health outcomes is also described.

Further studies using a similar but broader approach can be adopted so as to provide prevalence data rather than data through convenience sampling.

The study adds to current documented literature in providing some information on intensity-based steps/day with an attempt to relate such steps to current physical activity guidelines.

We demonstrate the use of pedometers, as an alternative to less direct measures of physical activity such as self-reported approaches, to determine ambulatory physical activity patterns of a population group. In doing this, particular reference has been made to volume, duration and intensity of physical activity, in the context of steps/day so as to relate to current guidelines that make reference to volume, duration and intensity of physical activity.

Further insights on the level of agreement between pedometer-measured ambulatory physical activity and self-reported physical activity may provide valuable knowledge in supporting this application.

CHAPTER 5

Pedometer-measured and self-reported physical activity, in relation to current guidelines and ambulatory physical activity

In submission: Journal of Physical Activity and Health

Julian D Pillay, Hidde van der Ploeg, Tracy L Kolbe-Alexander, Simone Tomaz, Willem van Mechelen, Estelle V Lambert

INTRODUCTION

Studies on physical activity behaviours and their association with morbidity and mortality rates²⁰, have been measured through indirect means²³. These measures are frequently used due to their practicality, including the low cost, low participant burden and general acceptance²³.

Self-reported data can provide useful insights into the physical activity levels of populations or sub-groups²³. Such data, is however often limited in their ability to accurately estimate physical activity energy expenditure and rates of inactivity or an absolute level of physical activity²⁰, as discussed in Chapter 1.

Objective or direct measures of physical activity are commonly used to increase precision and accuracy and, more recently, to compare with self-report measures¹³⁰. Despite the advantages of direct methods, the cost-intensive approach to most of these measures often limits their ability to be applied in large settings²⁴.

Most studies comparing self-reported measures to objective measures have, typically used accelerometers or doubly labelled water as the primary measurement tool. A review of such studies have been presented by Prince et al in 2008²⁰. The findings of this review have been described in more detail in Chapter 1. In general, the review showed no clear trends in the over-reporting, nor under-reporting, of physical activity by self-reported methods when compared to direct methods²⁰. Patterns of agreement that may exist, were more likely to differ depending on the type of direct method used and, often, the gender of the population studied²⁰.

Few studies ^{27,38} have attempted to measure the level of agreement between self-reported measures and steps/day data ^{63,131,132}. Furthermore, such studies have been accelerometer-based.

This is largely due to the fact that pedometers traditionally presented volume-based information, with little or no reference to intensity or duration of intensity-based physical activity. Furthermore, traditional pedometers can only provide information on ambulatory physical activity, whilst self-reported measures can incorporate information related to all types of physical activity.

Consequently, few pedometer-based studies ^{27,38} report the extent to which steps/day relate to self-reported physical activity data.

Miller and Brown provide information on physical activity, in terms of pedometer-determined steps/day, in relation to current guidelines ²⁷. Details of the study have been presented in Chapter 1. In summary, this study categorised pedometer data according to the widely used 10,000 steps/day message and compared total steps/day between those reporting to meet guidelines and those not ²⁷. The study demonstrated that the accumulation of 10,000 steps/day did not always correlate with meeting physical activity guidelines²⁷. The study reported that nearly 40% of participants who met guidelines, self-reported, did not reach the 10,000 steps/day target. The study did, however show that only approximately 10% of participants, who did achieve the 10,000 steps/day target, did not meet physical activity guidelines ²⁷.

Similarly, Strycker et al, in 2007, compared steps/day with self-reported physical activity data, in a population-based youth sample and post-menopausal women ³⁸

(described in Chapter 1). The study found low, but significant associations between steps/day counts and self-reported data in both sample groups³⁸.

Current steps/day guidelines make particular reference to intensity-defined steps^{30,39-41}. For example, recent studies have shown that 30 minutes of moderate-vigorous walking corresponds to a total of between 3,000 and 4,000 steps^{30,39-41}. The use of this message, i.e. 3,000 steps in 30 minutes, as a general physical activity promotion heuristic has, thus been recommended. Such messages have been directed towards complementing current physical activity guidelines by providing further options for meeting guidelines⁴⁴.

The need to incorporate elements of current guidelines, including volume, intensity, duration and frequency of physical activity, into pedometer-based messages have, therefore become an area of increased research. Such research continues to strengthen so as to ensure congruency between pedometer-based recommendations and physical activity guidelines.

The modern innovations in pedometry, complemented by intensity-based steps recommendations, provide the opportunity for the use of pedometers for further applications. The application of intensity-based steps/day recommendations and its association with current guidelines can, for example, be explored from this perspective. This may provide more accurate cross-sectional data on ambulatory physical activity levels than most self-reported approaches, within the context of current guidelines. The application of such features may also promote the use of pedometers as a less-costly alternative than other direct measurement instruments

used for such comparisons. This creates the opportunity to evaluate the relationship between pedometer-determined physical activity patterns and self-reported ambulatory physical activity.

The aim of our study was, therefore to compare pedometer-measured physical activity to self-reported data in those meeting or not meeting current physical activity guidelines. A further aim was to establish the level of agreement between pedometer-measured and self-reported physical activity, in relation to current guidelines and ambulatory physical activity.

METHODS

Study design

This chapter presents information from the data obtained during the cross-sectional study presented in Chapter 4. Details on study design, testing protocol, ethical considerations and pedometer-wear have therefore been presented in the methods section of Chapter 4.

Data recording

Data recording was performed, as indicated in Chapter 4.

Further to this, we re-classified bouts of ambulatory physical activity (pedometer-determined and self-reported) so as to relate to current guidelines.

Activity sustained for at least 10 consecutive minutes and at a minimum intensity of 100 steps/minute was considered as moderate intensity physical activity. The criteria used for this classification has been described in Chapter 4.

By this categorisation, elements of intensity and duration of steps/day that relate to current step recommendations for moderate intensity physical activity were incorporated.

We further summarised our pedometer data into 2 intensity-based categories i.e. “<21 minutes/day of aerobic activity” and “≥21 minutes/day of aerobic activity” as per the duration and intensity-based cut-offs described in Chapter 4. The “no aerobic activity” and “1-21 minutes/day of aerobic activity” categories were, however combined as a “<21 minutes/day of aerobic activity” category, as both these categories translate to “not meeting guidelines”. The self-reported physical activity data (Appendix E) was similarly grouped so as to provide a proxy to current guidelines.

In so doing, our steps/day data could be related to current physical activity guidelines.

Statistical analyses

General characteristics of the study group have been analysed, as described in Chapter 4.

A correlation analysis was performed to determine the extent of agreement between self-reported and pedometer-measured physical activity. In this analysis, we compared those meeting and not meeting current guidelines in both pedometer-determined and self-reported data, respectively.

RESULTS

Participant characteristics have been presented in the results section of Chapter 4.

Analysis of self-reported and pedometer data

Figure 5.1 presents the data according to those meeting current guidelines and those not meeting guidelines- self-reported (A) and pedometer-determined (B).

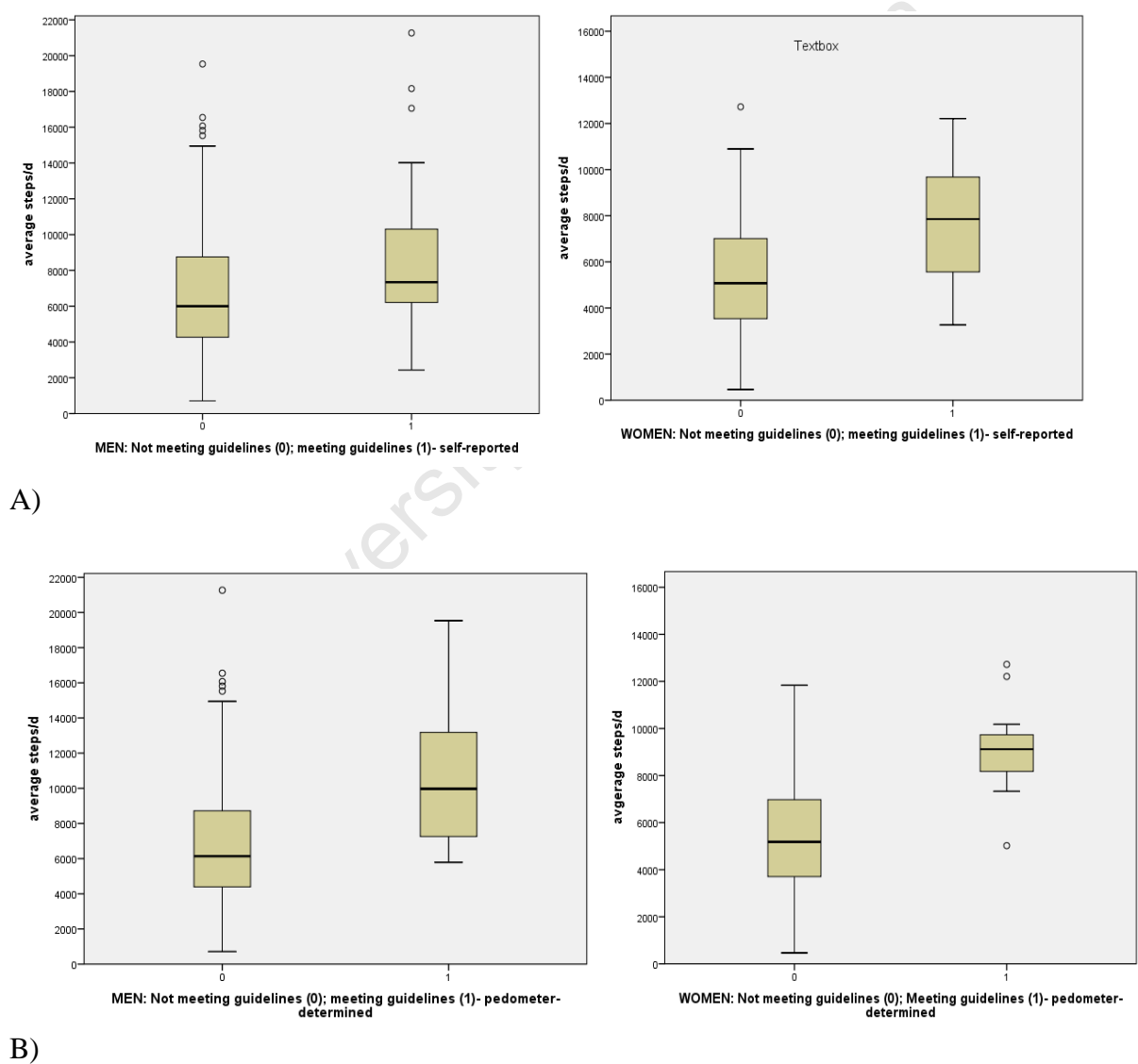


Figure 5.1: Steps per day in relation to physical activity guidelines- self-reported (A) and pedometer-determined (B)

Those participants reporting to meet guidelines (n=63) accumulated significantly more steps/day than those not meeting guidelines (8,753±4,251 steps/day versus 6,022±3,114 steps/day, respectively; P<0.0001).

A similar finding was observed for aerobic steps (1,772±2,020 steps/day versus 421±1,140 steps/day, respectively; P<0.0001). Even after adjusting for age, gender and total steps/day, significance was still noted in the volume of aerobic steps/day between the two groups (P<0.0001).

Analysis of pedometer data

Only 35 participants (11.2%) of the total study group accumulated aerobic steps for an average of at least 21 minutes/day according to the pedometer output, and could therefore be classified as meeting current guidelines. These participants accumulated significantly more total steps/day than those not meeting guidelines (10,092±3,445 steps/day versus 6,129±3,302 steps/day, respectively; P<0.0001). Similarly, these participants' accumulated significantly more aerobic steps/day than those not meeting guidelines (3,951±2,092 steps/day versus 282±603 steps/day, respectively; P<0.0001). Even after adjusting for age, gender and total steps/day, significance was still noted in the difference between average aerobic steps/day accumulated in the two groups (P<0.001).

Association between pedometer-determined and self-reported ambulatory physical activity

A correlation between self-reported and pedometer-measured ambulatory physical activity, using the categories: “meeting guidelines” and “not meeting guidelines”, is presented in Table 5.1.

TABLE 5.2: The association between pedometer and self-reported data in relation to physical activity guidelines

Current guidelines (self-reported)		Meeting guidelines (pedometer-determined)		
		0	1	Total
0	Count	231	18	249
	% within Meeting guidelines (self-reported)	92.8%	7.2%	100.0%
	% within meeting guidelines (pedometer-determined)	83.4%	51.4%	79.8%
	% of Total	74.0%	5.8%	79.8%
1	Count	46	17	63
	% within Meeting guidelines (self-reported)	73.0%	27.0	100.0%
	% within meeting guidelines (pedometer-determined)	16.6%	48.6	20.2%
	% of Total	14.7%	5.4	20.2%
Total	Count	277	35	312
	% within Meeting guidelines (self-reported)	88.8%	11.2%	100.0%
	% within meeting guidelines (pedometer-determined)	100.0%	100.0%	100.0%
	% of Total	88.8%	11.2%	100.0%

NB: 0: Not meeting guidelines; 1: meeting guidelines

Approximately 80% (n=249) of the total group did not meet guidelines, according to self-reported data.

The pedometer analysis showed that nearly 90% (n=277) did not meet guidelines.

Of the 63 participants' (20.2%; N=312) meeting guidelines, self-reported, only 27% (n=17) met guidelines according to pedometer data.

Thirty-five participants were classified as meeting guidelines, pedometer-determined, but more than half of these participants (51.4%) did not meet guidelines according to the self-reported data.

Participants reporting to meet guidelines were, however, more likely to meet guidelines, pedometer-measured (40%), than those who reported as not meeting guidelines (8%).

DISCUSSION

Our findings show that, in general, those participants who met guidelines (self-reported) accumulated 2,731 more steps/day than those who did not meet guidelines ($P<0.001$). This difference was more marked in women (2,781 steps/day; $P<0.001$) than men (2,247 steps/day; $P<0.005$).

In a study ²⁷ by Miller and Brown in 2004, a comparable outcome was noted. Participants (N=185) who met guidelines took 1,357 steps/day more than those who did not meet guidelines. Similarly, the difference was more marked among women (1,684 steps/day) than men (1,019 steps/day) ²⁷.

Categories of volume-based steps/day have identified 10,000 steps/day or more as a good indication of acceptable physical activity levels. A steps/day value $<5,000$ steps/day has, generally been classified as inactive ⁴⁰.

A popular public health message relating to pedometry is the 10,000 steps/day message. Several studies that have taken this message into consideration have shown positive health outcomes in those achieving this target compared to those not achieving the 10,000 steps/day target ^{17,41,65,69,88}.

Within the context of the 10,000 steps/day guideline, Miller and Brown demonstrated that the accumulation of 10,000 steps/day did not always correlate with meeting guidelines ²⁷, as discussed earlier (Introduction section of this chapter) and in Chapter 1. The study reported that nearly 40% of participants who met guidelines did not reach the 10,000 steps/day target. The study also reported that only approximately 10% of participants who did achieve the 10,000 steps/day target did not meet guidelines ²⁷.

Tudor-Locke and Meyers supported the viewpoint that 10,000 steps/day may be unrealistic and difficult to achieve ⁷⁹. More recent studies have presented intensity-based steps/day guidelines ^{40-42,120}. It is also emphasised in recent literature that intensity based steps/day may contribute towards achieving the 10,000 steps/day recommendation ^{3,113}. Documented literature further exemplifies that even in the absence of meeting the 10,000 steps/day recommendation, the impact of intensity-based steps (moderate intensity physical activity) is significantly greater than volume alone ⁴¹.

Our findings show that 56.1% of participants who reached the 10,000 steps/day target (n=41) still did not meet physical activity guidelines, self-reported. An additional finding was that 71.4% of participants who met guidelines (n=63), self-reported, did not achieve the 10,000 steps/day target.

In further providing comparisons by using pedometer data, and categorisations thereof, related to estimates of current guidelines, we show a similar pattern. Only 37.1% of participants who met guidelines (n=35) according to pedometer data, achieved the 10,000 steps/day target. Consequently, 68.3% of participants who did achieve the 10,000 steps/day target (n=41) did not meet guidelines, self-reported.

It was also shown that a large proportion of those individuals achieving 10,000 steps/day were still not accumulating sufficient steps at a moderate intensity. Furthermore, many of those meeting physical activity guidelines still did not accumulate 10,000 steps/day. The implication of this finding, therefore emphasises the importance of intensity-based steps

Strengths of the study

The research undertaken is among the first pedometer-based studies conducted in the Republic of South Africa, within an urban context, that establishes the association between pedometer-measured ambulatory physical activity and self-reported information.

Our study has, therefore specifically related self-reported physical activity and pedometer-determined steps/day, with consideration of both volume and intensity of daily steps accumulated, and current guidelines. The intensity-based output (from pedometer data) additionally included steps accumulated over a minimum duration and intensity. This allowed us to determine steps/minute rates, so as to closely relate to moderate intensity physical activity and current guidelines^{10,40,42,133,134}.

In so doing, we provide some estimate of the level of agreement between self-reported and pedometer-determined physical activity.

Limitations

Limitations around the sampling approach, inability of pedometers to capture non-ambulatory modes of physical activity and the steps/day estimates used for moderate intensity activity, have been discussed in limitations section of Chapter 4.

The sub-grouping of data according to intensity-based categories, using 21 minutes/day of aerobic activity, as a proxy for current physical activity recommendations, may be viewed as a further limitation. However, this categorisation has provided some level of differentiation of ambulatory physical activity according to intensity and duration of steps/day. This has allowed us to relate volume and intensity-based pedometer data to self-reported data, with particular reference to current guidelines, as a unique application to pedometry.

Pedometers are typically used to measure volume of steps/day. The reliability of information on intensity-based steps and/or the refinement of intensity-based steps through pedometry, and the application thereof to current guidelines may raise concern. This does, however, provide some level of determining a more direct measure of intensity-based ambulatory physical activity than self-reported means, and particularly valuable as a less costly alternative to other direct measures.

CONCLUSION AND RECOMMENDATIONS

Our study highlights the association between self-reported physical activity patterns and objectively measured ambulatory physical activity, with particular reference to both volume and intensity of steps/day, and current guidelines.

In view of our results showing a very small percentage of participants meeting current guidelines (from both pedometer data and self-reported data), further studies using a similar but broader approach can be adopted to enhance the reliability of our findings.

The importance of intensity-defined step/day recommendations is highlighted. The application of such (intensity-based steps/day) recommendations in pedometer-based interventions may provide useful insights on its effects in improving fitness and health.

CHAPTER 6

***Steps that count!* A pilot feasibility study of a pedometer-based health promotion intervention in an employed, South African population**

In submission: South African Journal of Sports Medicine

Authors: Julian D Pillay, Tracy L Kolbe-Alexander, Karin I Proper, Willem van Mechelen, Estelle V Lambert

INTRODUCTION

Despite the awareness of physical inactivity, solutions to the problem are complex as behavioural change is often difficult to achieve and, more importantly to sustain ¹³⁵. Small behavioural changes may, however, be more feasible to achieve and to maintain, the impact of which may be significantly beneficial towards improved clinical outcomes, as well as overall well-being ¹³⁶.

The use of pedometers as a motivational aid for increasing ambulatory physical activity ⁷⁴ has complemented strategies to increase physical activity. Pedometers have been shown to offer a good solution for a low cost, objective monitoring and behavioural modification tool and a practical aid for physical activity interventions ^{24,31,40,80,137}. Pedometers have therefore gained popularity for use in physical activity interventions in various settings ⁷⁸ to facilitate behavioural change.

Providing individualised feedback has been promoted as a useful adjunct to many health and well-being interventions and has often been used as an additional support measure to pedometer-based interventions ¹³⁸. A systematic review, conducted by Ogilvie et al in 2007 ¹³⁹, examined the effectiveness of interventions aimed at increasing walking. According to the review, the strongest evidence that exists support interventions targeted at individuals motivated to change ¹³⁹. A further finding was that the interventions which involved strategies such as brief advice and the use of pedometers, showed promising results ¹³⁹.

There is, however, a large gap between the development of effective interventions and their feasibility for use in public health practice ^{140,141}. A primary limitation is the

high cost and large time demands on both staff and participants ¹⁴¹. Using more cost-effective intervention strategies, such as pedometer-based approaches supplemented by email-based feedback, may possibly overcome the cost limitation.

The work-site is an appropriate setting to initiate health promotion intervention programmes where social and cultural disparities can often be overcome through the shared interest of well-being ¹⁴². Therefore, the aim of this pilot study was to evaluate the feasibility of a pedometer-based intervention complemented by individualised, email-based feedback promoting physical activity in an employed population. A second aim of this pilot study was to get an impression of the effects of the intervention on a number of clinical outcomes. Using the outcomes of this study, a work-site, pedometer-based intervention protocol will be developed to be administered as a future full-scale randomised controlled trial, in an adult, employed population.

METHODS

This pilot intervention was developed from the findings of Chapters 2-5 that have identified and highlighted the importance of the intensity of steps accumulated. This (intensity-based steps) outcome has complemented other recent pedometer-based studies that have promoted the use of steps per minute messages as a guideline for moderate intensity physical activity ^{40,42,43,120}. The term “*Steps that count!*”, and the pilot intervention presented has therefore been adopted as a term and a strategy for engaging people into accumulating intensity-based steps, and forms a key element of the intervention.

Study setting and study population

The pilot study was conducted at a tertiary academic institution based in the province of KwaZulu-Natal, Republic of South Africa. An advertisement was emailed to all staff members within a selected faculty of the institution inviting participants into the study subject to meeting the inclusion criteria.

Inclusion and exclusion criteria:

All employees willing to participate and between the age of 21 years and 49 years were eligible to participate.

Employees were excluded for the following reasons: pregnancy, diagnosis or treatment of cancer, any other condition that made physical activity difficult/impossible; contract workers whose employ with the company would end before the 12 week follow-up measurement; non-compliance to a minimum of 5 days of blinded pedometer wear, at the start and end of the intervention.

Ethical considerations and pre-participation screening

This pilot study was conducted in accordance with the Declaration of Helsinki, Good Clinical Practice as well as the ethical laws of South Africa. Ethical approval for the study was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (reference number: 044/2009) (Appendix A).

Following agreement to participate in the study, the Physical Activity Readiness Questionnaire ⁹⁸ (Appendix D) was administered, and an informed consent form (Appendix C) completed, as described in the methods section of Chapter 2.

Measurements

Clinical measures such as body height, body weight, waist circumference, percentage body fat, and blood pressure were measured, as described in Chapter 2 (Methods section).

Following the 10 week intervention, both the intervention and control groups were required to complete follow-up measures, as in week 1. Participants' of the intervention group were invited to complete a questionnaire relating to their perceptions and viewpoints of the intervention (Appendix I). A section on general comments and/suggestions for improvement of the intervention was included.

Baseline pedometer wear

All participants were requested to wear an Omron HJ 750 ITC pedometer, attached to the hip area, for 5 consecutive days.

The protocol for pedometer wear has been described in the methods section of Chapter 2.

Pedometer feedback

Pedometer feedback was provided to participants after the 5-day blinded pedometer wear, as described in the methods section of Chapter 2. Simple messages to improve physical activity levels were discussed by the researcher, as part of the

pedometer feedback session. Information discussed was in keeping with the current guidelines of 30 minutes of moderate intensity physical activity at least five times a week¹⁰. Participants were also encouraged to improve their physical activity levels steadily (for example, by 10% per week until 30 minutes of moderate intensity physical activity was achieved) during the subsequent 10 weeks.

Allocation of participants to intervention and control groups

Following the feedback on participants' physical activity levels from the pedometer data, participants' were randomly allocated to an intervention group or a wait-listed control group. The allocation of participants into intervention and control groups was achieved by a random selection of all participants from a composite participant list on a Microsoft excel spread-sheet.

Participants in the intervention group were provided with an un-blinded pedometer for the subsequent 10 weeks. They were informed by demonstration on how to upload their pedometer data and its interpretation and advised to upload data whenever convenient (Appendix F).

Figure 6.1 provides a flow of the study design.

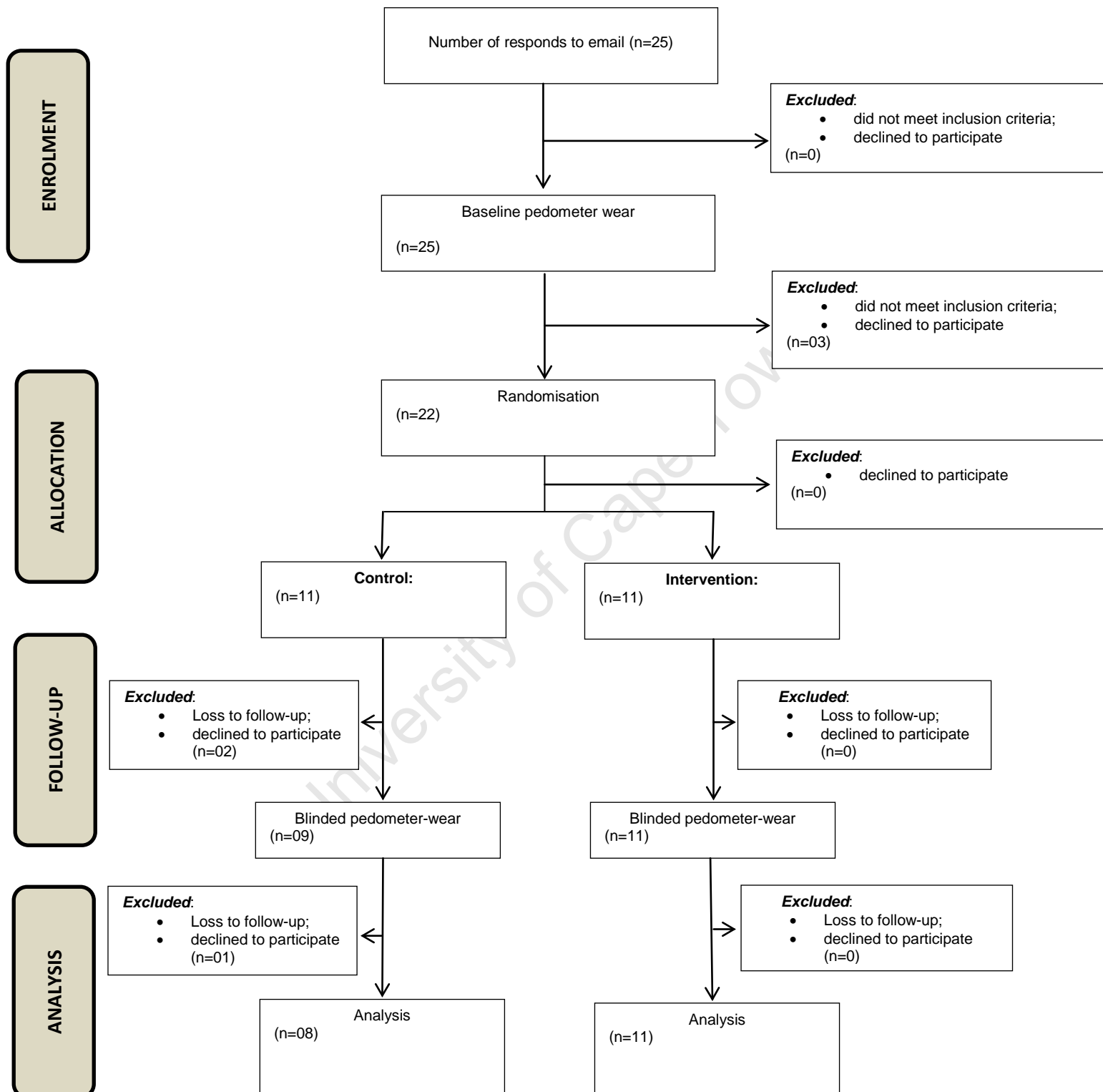


Figure 6.1: Flow of the study design (pilot intervention)

Intervention

The intervention group continued with un-blinded pedometer wear for the subsequent 10 weeks.

Pedometer data was requested (via e-mail) from participants in the intervention group at bi-weekly intervals. Following the bi-weekly receipt of pedometer data from the intervention group participants, they were provided with individualised, emailed feedback (Appendix G) and a generalised information sheet (Appendix H) on some strategies to increase ambulatory physical activity.

The individualised feedback included information in the form of a personalised email on the average daily steps/day accumulated; the highest number of steps/day accumulated over the past two weeks; the number of days (if any) that aerobic steps/day, i.e. *Steps that count*, were accumulated and; and the volume thereof.

The general supportive/motivational messages included a key message (such as “be active everyday” or “walk tall”) and a few strategies to achieve this. For example, “Use the stairs instead of the lift/escalator”; “Walk fast enough so as to increase your breathing rate yet not feel out of breath”.

The purpose of the bi-weekly email was to provide a summation of pedometer-based physical activity patterns and to provide some strategies and/or options for “adding steps” to your day.

The intervention attempted to motivate an increase in ambulatory physical activity by requesting commitment to small achievable goals, such as “adding 10 minutes of

'steps that count' to your day" or "increasing daily steps by 10% per week until 30 minutes of 'steps that count' are achieved". Through providing basic information on current physical activity, ambulatory patterns were summarised, current guidelines were reinforced and options on how to increase ambulatory physical activity were provided.

The control group were similarly provided with a generalised information sheet, as in the intervention group at bi-weekly intervals, but were not provided with a pedometer over the 10 weeks.

Outcome measures

Participants' perceptions and viewpoints on the value of the intervention, in terms of the appeal, support and benefits of the intervention were identified (Appendix I). Adherence to the goals, that were identified and agreed upon at the beginning of the study, was also established. This information served as a primary outcome measure in determining the feasibility of the intervention.

A section on general comments and/suggestions for improvement of the intervention was included. This information provided insights into strengths and areas for improvement so that a more effective intervention may be developed and applied, subsequently.

The secondary outcome measures (daily physical activity levels in terms of steps/day and biometric) were assessed at baseline (week 1) and follow-up (week 12) for both the intervention group and control group. This allowed for us to detect changes in daily ambulatory physical activity and biometric measures over time as a

function of the intervention. Data was derived from the pedometer and expressed as steps/day. More importantly, information on the volume of sustained and moderate-vigorous intensity steps (“*Steps that count*”) were assessed at baseline (week 1) and follow-up (week 12) for both the intervention group and the control group. The change in steps/day at the end of the intervention directed us towards establishing an adequate sample size for a future intervention of this nature.

Statistical analyses

From the questionnaire feedback, themes that emerged were identified and facilitating factors as well as barriers/limitations towards improving physical activity were established. Participants’ perceptions and viewpoints on the value of the intervention were also identified so as to determine the feasibility of the intervention.

General characteristics of the study group were summarised using descriptive statistics. An independent t-test was used to determine if any differences were present between the intervention group and control group at baseline (week 1) for each of the variables measured. The difference between baseline and follow-up measures for each variable was subsequently determined and similarly compared between the intervention group and control group using an independent t-test.

All analyses were performed with STATISTICA version 8 (StataSoft Inc., Tulsa, OK, USA) and the significance level was set at a $P < 0.05$.

A descriptive analysis was performed on the information gathered from the questionnaire.

RESULTS

Of the 25 participants that indicated interest in participating in the study, 22 participants completed the baseline measures and pedometer wear and were randomly allocated to control or intervention groups.

Two control group participants, upon being allocated to the control group, declined further participation in the study and 1 control group participant did not complete the pedometer wear and follow-up measures at week 12.

A total of 11 intervention group (2 Men; 9 Women) and 8 control group (1 Man; 7 Women) participants, respectively ($P=0.74$) completed follow-up measures and were included in the final analysis.

Table 6.1 presents a description of the study group.

Table 6.1: Descriptive baseline characteristics of participants (N=19)

Variable	Control (N=8)	Intervention (N=11)	P-value
Age (years)	38.3±7.7	37.6±8.6	0.75
Body height (cm)	168.9±5.0	165.1±8.3	0.47
Body waist (cm)	84.6±9.9	91.9±13.7	0.21
Body fat (%)	36.0±9.5	42.8±8.9	0.88
Body mass index (kg/m ²)	26.0±4.5	31.1±6.6	0.20
Body weight (kg)	74.4±14.0	84.4±17.4	0.57
Systolic blood pressure (mmHg)	118.1±15.6	117.8±13.2	0.75
Diastolic blood pressure (mmHg)	80.4±10.9	84.8±14.1	0.61
Daily steps (steps/day)	4,600±2,041	5,370±1,739	0.98
Aerobic steps (steps/day)	0	331±646	0.004*
Aerobic time (minutes/day)	0	19.3±39.3	0.008*

Note: Values are means ± standard deviation

*indicates statistical significance ($P<0.05$) between control and intervention group

No statistical significance was noted at baseline between the intervention group and control group for all of the variables other than those associated with “aerobic steps”.

The data indicated that of the 11 intervention group participants, 3 participants accumulated some “aerobic steps”. None of the participants in the control group accumulated “aerobic steps”.

Questionnaire evaluation on perceptions of the intervention

Themes that emerged from the questionnaire feedback were categorised as facilitating factors and barriers, particularly in terms of adherence to the intervention.

In general, most participants expressed that the pedometer intervention was “catchy” and that the pedometer, provided during the intervention, served as a useful motivational aid and a reminder of the need to increase steps/day. Participants also found the individualised feedback to be valuable in summarising their physical activity over the two-week period and therefore became more aware of the need to increase their steps/day.

The barriers identified by participants related to adherence to the intervention and the inability to increase daily ambulatory physical activity, in some participants. This was expressed to be largely due to being inactive at work and experiencing time limitations in incorporating physical activity into daily routine. Some participants also found it very difficult to achieve and/or increase “aerobic steps”, despite an overall increase in the total volume of steps/day. A few participants indicated that their interest in the intervention decreased as the intervention continued, whilst some participants felt that a longer intervention might assist them in further increasing their steps/day.

In order to establish the effect of the intervention on clinical measures, the difference between baseline and follow-up measures was determined and comparisons were made between the intervention group and control group.

Results of this analysis are presented in table 6.2.

Table 6.2: Net change of participants characteristics at follow-up (N=19)

Variable	Control (N=8)	Intervention (N=11)	P
Waist circumference (cm)	-0.38±2.0	+0.73±2.7	0.47
Body fat (%)	+0.26±1.3	+1.34±1.9	0.31
Body mass index (kg/m)	+0.13±0.5	+0.26±0.58	0.72
Body weight (kg)	+0.3±1.3	+0.67±1.6	0.88
Systolic blood pressure (mmHg)	-0.8±8.0	+0.3±8.9	0.81
Diastolic blood pressure (mmHg)	-3.1±3.7	-2.5±7.6	0.16
Daily steps (steps/day)	+97±750	+996±1,748	0.06
Daily aerobic steps (steps/day)	0	-54±2,746	0.01*
Daily aerobic time (minutes/day)	0	+0.9±23.	0.02*

Note: Values represent means ± standard deviation;

+ indicates an increase in the desired direction;

- indicates a decrease in the desired direction;

* indicates statistical significance ($p < 0.05$) between control and intervention group

No statistical significance was noted at follow-up between the intervention group and control group in mean change for any of the variables other than those associated with “aerobic steps”. An interesting observation was that the average “aerobic steps/day” decreased at follow-up in the intervention group, notwithstanding the small number of steps and the very large standard deviation. The aerobic time in the intervention group, however, increased slightly. No “aerobic steps” were accumulated at baseline and follow-up in the control group.

Power calculation and sample size estimation for a full-scale randomised controlled Trial

Based on a minimum improvement of 1,000 steps/day (as established from this pilot study) a future trial would require a sample size of approximately 85 participants each in the intervention and control group. This will ensure 80% statistical power, with a P-value set at $P < 0.05$. Considering this possibility, and the likelihood of performing sub-group analyses, as well as loss to follow-up, we estimate an appropriate target sample of 150 participants in the intervention group and control group, respectively.

DISCUSSION

The purpose of this paper was to evaluate the feasibility of a pilot intervention aimed at improving the daily ambulatory physical activity in a South African employed adult population. A further objective was to use the outcomes of the study to inform the development, and recommended sample size, of a pedometer-based intervention protocol, to be administered as a future randomised controlled trial.

Questionnaire evaluation on perceptions of the intervention

Adherence to physical activity emerged as a limitation to improving steps/day during the intervention. This was expressed to be largely due to being inactive at work and experiencing time limitations in incorporating physical activity into daily routine.

Several studies, as reported by Fox et al,¹⁴³ show similar findings and a growing body of research supports the need to build physical activity into daily routine⁷⁸.

Interventions may also need to focus on institutional-level efforts to support building activity into daily routines. Such support measures can include creating walk-paths around the work environment or incorporating a physical activity programme into the work-day ¹⁴³. Additional measures can include using motivational prompts encouraging/reminding people to be more active during work-time or foot-markers directing people to the stairwell instead of the lifts ¹⁴³.

In view of the aforementioned constraints experienced by participants (particularly work sedentarism and time limitations), engaging participants in worksite physical activity sessions might be a useful initiative to overcome these barriers. This may additionally ensure the accumulation of “aerobic steps” or *Steps that count*, as a way of aligning steps/day recommendations to current physical activity guidelines, as discussed in Chapters 2 and 3.

A few participants indicated that their interest in the intervention decreased as the intervention continued, whilst some participants felt that a longer intervention might have assisted them in further increasing their steps/day. To this effect, an on-going, low-key work-site physical activity programme, such as a 30 minute brisk walk, may provide a simple solution to this barrier. Additionally, this may improve adherence to physical activity by providing a practical option for engaging in moderate intensity physical activity. The feasibility of providing such options in a worksite setting may be a useful area of research as a second phase project to a pedometer intervention or alternatively independent of pedometry.

We further support the reporting of Heesch et al ⁸⁷ which suggested the need for future minimal-contact pedometer interventions. These include guidance for goal settings, regular submission of steps/day information, regular e-mail contact containing steps/day progress, and strategies to overcome barriers to physical activity ⁸⁷.

Pedometer outcomes

Due to the small sample size, it is inappropriate to draw conclusions based on statistical significance from the pedometer results observed. A useful finding, nevertheless, is the overall increase in total steps/day in the intervention group by approximately 1,000 steps/day.

Recently published papers and systematic reviews of pedometer-based interventions conducted from 1966-2007 ^{139,143,144} showed an average improvement of between 1,500 and 3,000 steps/day. These studies, however, generally showed a higher baseline steps/day volume than our study group (7,500 steps/day compared to 5,000 steps/day in our study). No reference has been made on intensity-based steps in any of these previous interventions. Our study, therefore, provides some uniqueness in suggesting the effect of intensity-based steps towards improved health outcomes.

With regards to clinical measures, there appeared to be change in the expected direction in both the intervention group and control group. An exception appeared to be waist circumference, which increased slightly in the control group at follow-up. Systolic blood pressure also increased slightly in the control group whilst diastolic blood pressure increased slightly in both groups. None of the differences observed,

however, emerged as being statistically significant, most likely due to the low number of participants associated with the pilot nature of this study.

Bravata et al, in 2007, analysing a total of 18 studies (mean intervention duration of 18 weeks), reported that participants decreased their body mass index by 0.38 from baseline ($P=0.03$)⁷⁸. In this review, intervention participants from 12 studies significantly decreased their systolic blood pressure by an average of 3.8mmHg ($P<0.001$)⁷⁸. Using a total of 7 studies, the review found no significant improvements in serum lipid levels or fasting serum glucose concentrations⁷⁸. However, the serum lipid and glucose levels were reported to be fairly normal at baseline, which was implied to be the reason for a lack of significance established⁷⁸.

Further details of this review have been highlighted in Chapter 1.

Emphasis must be placed on the value of such an intervention extending beyond simply assessing the extent of clinical/physical activity improvements to increasing awareness of physical activity and thereby creating a platform for improvements thereof. Heesch et al⁸⁷ reported a similar finding from participant feedback on a pedometer-based intervention. The concepts of awareness and motivation were often discussed by participants, during feedback. Tudor-Locke¹³⁵ reported a similar finding via focus group (n=38) and exit questionnaires (n=68) in a pedometer-based physical activity programme.

Modifications of the pilot intervention for application in future randomised controlled trial

The allocation of participants to a future trial should be based on a theoretical model for behavioral change. For example, the intervention should be targeted towards

participants at a specific stage of behavioral change. This may ensure that participants are mentored similarly to ensure improved uptake, compliance and overall impact of the intervention in terms of increased physical activity. As such, the intervention can be targeted specifically at individuals not meeting current guidelines and in the contemplation stage of behavioral change, as per the transtheoretical model of behavioural change ¹⁴⁵.

The emailed messages providing feedback to participants should provide more information than just a summation of pedometer results. Typically, the information provided to participants should also indicate how their results relate to current guidelines or intensity-based steps/day targets. This will contribute towards the reinforcement of public health recommendations which may prompt individuals to self-reflect on their current physical activity levels, in keeping with pre-determined goals.

The importance of intensity-based steps, i.e. *Steps that count*, should be further reinforced during the bi-weekly feedback emails, with particular emphasis on current guidelines. This will include a combination of duration and intensity-based steps data rather than on volume-based information alone. This may require some revision of the current “aerobic” classification used by the pedometer to a more appropriate one, as determined by recent studies ^{40,42,42,43,133,134}.

The general information provided to both the intervention group and control group was the same irrespective of individual progress toward improved ambulatory physical activity. Depending on the extent of resources available, more tailored feedback can be provided at an individual level based on the level of progress. In a

similar manner, barriers towards progress can be identified with improvement strategies provided on a more individual basis.

Strengths of the study

The study is among the first pedometer-based interventions that consider the importance of intensity of steps/day within the total volume of steps/day accumulated.

This is among the first pedometer-based interventions conducted in South Africa.

More importantly, this pilot intervention informs the further development and refinement of such a pedometer-based intervention that can be applied on a larger scale and in a wider context.

Limitations

The small sample size and the element of selection bias (as the study involved selection from a convenience sample of persons) was a primary limitation.

The control group received the same general motivational messages as the intervention group, bi-weekly, which may have led to increased physical activity in the control group and a resulting weakened effect of the intervention.

No theoretical model for behavioral change was applied. This implied that, using a convenience sample approach, participants were at various stages of change towards improving ambulatory physical activity. The study may have, therefore, also included participants who were already meeting current guidelines and were interested in further improving this through the intervention.

The emailed messages that were provided to participants only provided a summation of pedometer results but did not indicate how this related to current guidelines or intensity-based steps/day targets as a method of reinforcement.

CONCLUSION AND RECOMMENDATIONS

This study provides useful information on the potential for physical activity improvements through pedometry in an employed, adult group. In so doing, the study provides a basis to further pedometer-based intervention initiatives that can be applied in other contexts and settings and on a larger scale.

Consequently, this pilot intervention informs the development of a large scale intervention to be applied as a future randomised controlled trial.

CHAPTER 7

Study protocol

***Steps that count!* : The development of a
pedometer-based health promotion
intervention in an employed, health insured
South African population**

Published: BMC: Public Health 2012, 12:880

Authors: Julian D Pillay, Tracy L Kolbe-Alexander, Karin I Proper, Willem van Mechelen, Estelle V Lambert

(Elements of the original paper have been condensed in certain areas to avoid duplication from previous chapters, and referred to/referenced accordingly. Some aspects included in this chapter may, however, be repeated from previous chapters so as to maintain the integrity of the original paper)

INTRODUCTION

The work-site is an appropriate setting to initiate health promotion intervention programmes where social and cultural disparities can often be overcome through the shared interest of well-being¹⁴². For example, a critical review¹⁴⁶ identifying the effectiveness of work-site physical activity programmes on physical activity, physical fitness, and health showed support towards the implementation of worksite physical activity programmes. The review (4 randomised controlled studies and 4 controlled studies) made particular reference to an increase in the habitual levels of physical activity among employees through the interventions¹⁴⁶.

In South Africa, a large proportion of the working population can be reached through health risk appraisals, conducted by health insurers¹⁴⁷. This voluntary screening typically consists of anthropometric measures (such as body mass index and waist circumference) and clinical measures (such as blood glucose and blood cholesterol concentrations, blood pressure). Information related to health risk behaviour, including physical activity and readiness for change are also obtained.

Similar health risk appraisals are administered in other countries such as the Netherlands¹⁴⁸ and Denmark³⁶. More recent studies have adopted this approach as part of an intervention to evaluate the effectiveness of health risk appraisals and follow-up support^{149,150}.

The emergence of pedometers have been identified as a useful self-monitoring and feedback tool and therefore a useful motivational aid for increasing ambulatory physical activity^{24,74}. Consequently pedometers have complemented behavioural

change strategies with the objective of increasing ambulatory physical activity. Researchers have acknowledged that in terms of practicality, pedometers offer a good solution for a low cost, objective monitoring and behavioural modification tool and a practical aid for physical activity interventions ^{31,40,80,137}. Pedometers have therefore gained popularity for use in physical activity interventions in various settings ⁷⁸ to facilitate behavioural change.

Providing individualised feedback has been promoted as a useful adjunct to many health and well-being interventions and has often been used as an additional support measure to pedometer-based interventions ¹³⁸. A number of on-site and face-to-face programmes have been found to be effective ^{146,151}. There is, however, a large gap between the development of effective interventions and their feasibility for use in public health practice ^{140,141}. A primary limitation is the high cost and large time demands on both staff and participants ¹⁴¹. Using lower cost intervention strategies, such as pedometer-based approaches supplemented by email-based feedback, may have the potential to overcome this limitation. An attempt at evaluating the benefits of short-term interventions may, additionally, be useful in identifying whether significant changes in physical activity behaviour can be achieved within this time-frame.

This study provides an opportunity to evaluate the effect of a pedometer-based intervention complemented by individualised, email-based feedback in improving ambulatory physical activity in an employed adult population.

The aim of this study was, therefore, to develop a 10-week, pedometer intervention-*“Steps that count!”*- which examines the effectiveness of pedometer use complemented by individualised, email-based feedback on daily ambulatory physical activity levels, in an employed South African population.

METHODS

The proposed study is a randomised controlled trial on the effectiveness of *“Steps that count!”* in a worksite setting, primarily using pedometers and feedback messages through regular, bi-weekly emails.

The concept of *“Steps that count!”* is developed from the findings of previous chapters that identify and highlight the importance of intensity of steps accumulated^{133,134}. This (intensity-based steps/day) outcome complements other recent pedometer-based studies that have identified and recommended steps/minute rates for moderate physical activity^{40,42,43,120}.

A feasibility study conducted, and presented in Chapter 5, using a similar methodology, has further informed the development of this intervention and sample size calculation. The term *“Steps that count!”*, and the intervention presented, has therefore been adopted as a term and a strategy for engaging people into accumulating intensity-based steps. This message forms a key element of the intervention.

The behavioural strategies underlying *“Steps that count!”* include certain principles from several behavioural theories. These include the theory of planned behaviour

and reasoned action ^{152,153}, which proposes that a person's intention to perform a behaviour is the central determinant of performing that behaviour. In addition, the transtheoretical model ¹⁵⁴, provides an explanatory framework for intentional behavioural change. The theory is based on the observation that people tend to move through a series of stages (pre-contemplation, contemplation, preparation, action and maintenance) in their attempt to change a certain behaviour ¹⁵⁵. This intervention is specifically targeted at individuals in the contemplation phase of the transtheoretical model, i.e. individuals considering change even though they may be ambivalent about changing.

The intervention is not designed to test any particular theoretical model, but rather to incorporate elements from these models to initiate and sustain behavioural change. These behavioural strategies will be applied in a basic structure to improve ambulatory physical activity by providing cues and repetition that help make the new behaviours habitual.

Following the baseline pedometer wear, "*Steps that count!*" promotes and reinforces the intention to change physical activity behaviour. This is emphasised through feedback on physical activity from the pedometer data, a brief discussion around current guidelines, and identifying possible strategies to improve steps/day.

The intervention attempts to motivate an increase in physical activity by requesting commitment to small achievable goals, such as "adding 10 minutes of '*steps that count*' to your day" or "increasing daily steps by 10% per week until 30 minutes of "*steps that count*" are achieved.

Individual ambulatory physical activity patterns are summarised and presented, current guidelines reinforced and some options as to how to increase physical activity levels are provided in the emailed feedback.

Study setting and study population

The study will be conducted at selected worksite settings that are based in the province of KwaZulu-Natal, Republic of South Africa. The organisation will offer and conduct a health risk appraisal to employees attending a work-site health screening event. The health risk appraisal will identify cardiovascular risk factors (including: family history, dietary intake behaviour, smoking and stress). Biometric measures recorded will include body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol concentrations. In addition, self-reported physical activity as well as intention for change towards improved physical activity will be assessed.

Upon completion of the health risk appraisal, employees will be invited by the researcher and/or assistant to participate in the study (subject to meeting the relevant inclusion criteria).

All employees eligible to participate in the study will be requested to wear a blinded pedometer for 5 consecutive days as a baseline measure of ambulatory physical activity.

Sample size, recruitment and randomisation

We estimated a sample size on the basis of aiming to show an improvement of 2,500 steps/day (and a baseline value of 7,500 steps/day) with an approximate standard deviation of $\pm 3,000$ steps/day. This estimate was established through recently published papers and systematic reviews of pedometer-based interventions conducted from 1966-2007^{139,144,156}. We also considered the findings of Chapter 6 in our estimation.

A sample size of 30 participants each in the intervention and control groups of the study is required to ensure 80% statistical power and with a P-value set at $P < 0.05$. However, if a modest improvement of 1,500 steps/day (as established in Chapter 6) is considered, a sample size of approximately 85 participants in each group is required. Considering this possibility and the likelihood of performing sub-group analyses of the data based on factors such as age and gender, a sample size of 150 participants in the intervention and control groups respectively would be an appropriate estimate to account for these factors.

In order to achieve this, 1400 employees attending wellness events will be targeted. Of these, a minimum of 560 employees (40%) will be identified to be in the contemplation stage of transtheoretical model¹⁴⁵ and agree to participate. Of the 560 individuals, we assume that at least 90% ($n=450$) will complete a minimum 3 day blinded pedometer wear⁵³. Two hundred participants will, therefore, be randomly assigned to the intervention group and wait-listed control group, respectively. An expected 15-20% loss to follow-up^{148,157} and non-compliance to the follow-up blinded pedometer wear will result in a final minimum number of approximately 150 in the intervention and control groups, respectively for analyses.

Inclusion and exclusion criteria:

Employees attending the wellness event and willing to be included in the study will be eligible to participate. Other inclusion criteria include: being between the age of 21 years (inclusive) and 50 years (exclusive); being identified as in the contemplation stage of transtheoretical model towards improved physical activity and, having a contract with employer until end of the 12-week measurement period.

Employees will be excluded for the following reasons: pregnancy; diagnosis or treatment of cancer; any other condition that makes physical activity difficult/impossible; contract workers whose employ with the company will end before the follow up measurement at week 12 and; non-compliance of a minimum of 3 days blinded pedometer wear.

Ethical considerations and pre-participation screening

This study will be conducted in accordance with the Declaration of Helsinki, Good Clinical Practice as well as the ethical laws of South Africa.

Ethical approval for the study was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town, South Africa (reference number: 044/2009) (Appendix A) and the study has been registered by the South Africa, Department of Health (DOH-27-0112-3951).

Following agreement to participate in the study, completion of the Physical Activity Readiness Questionnaire ⁹⁸ (Appendix D) as described in Chapter 2, is required. Employees who agree to participate in the study will be asked to sign an informed consent form (Appendix C) prior to participating in the study.

Participants will be assured that their participation in the study is voluntary and that they may withdraw at any time. They will also be reassured that their withdrawal will not have any negative impact on their employment, and that they will continue to receive all usual care health insurance benefits and/or programmes. The participants' will also be assured that their employer will not have access to any of the information collected for the research study, and that all information will be treated as strictly confidential.

Testing protocol

All eligible employees who sign the informed consent will be requested to wear a blinded pedometer (Omron HJ 720 ITC) for 5 consecutive days during week 1 and week 12 of the study.

Upon return of the pedometer (after week 1), steps/day data will be electronically uploaded by the researcher according to the Omron Health Management Manager software protocol²⁸. Feedback, in terms of average total steps/day and information relating to moderate intensity steps ("*steps that count*"), will be provided to each participant.

Simple strategies to improve ambulatory physical activity levels will be discussed in keeping with the recommendation of 30 minutes of moderate intensity physical activity at least five times a week¹⁰. Participants will be encouraged to improve their physical activity levels steadily (for example by 10% per week until 30 minutes of ("*steps that count*") during the subsequent 10 weeks. They will then be randomly allocated to an intervention or wait-listed control group.

Participants in the intervention group will be provided with an un-blinded pedometer for the subsequent 10 weeks. Those included in the intervention group will be guided as to how to upload their pedometer data and its interpretation. A one-pager step by step guideline will be provided and participants will be advised to contact the researcher for assistance, if need be (Appendix F). Participants will be advised to upload data whenever suitable. This would provide the researcher with information as to how often the uploading feature was accessed.

Following the blinded pedometer wear at week 12 (intervention and control groups), a health risk appraisal, similar to the initial screening, will be conducted. The results obtained (health risk appraisal and pedometer data) will then be compared with the information obtained in week 1 to establish the intervention effect. Participants in the control group will be offered the pedometer intervention after the health screening event, conducted at week 12.

Figure 7.1 provides a flow diagram of the randomised controlled trial intervention plan.

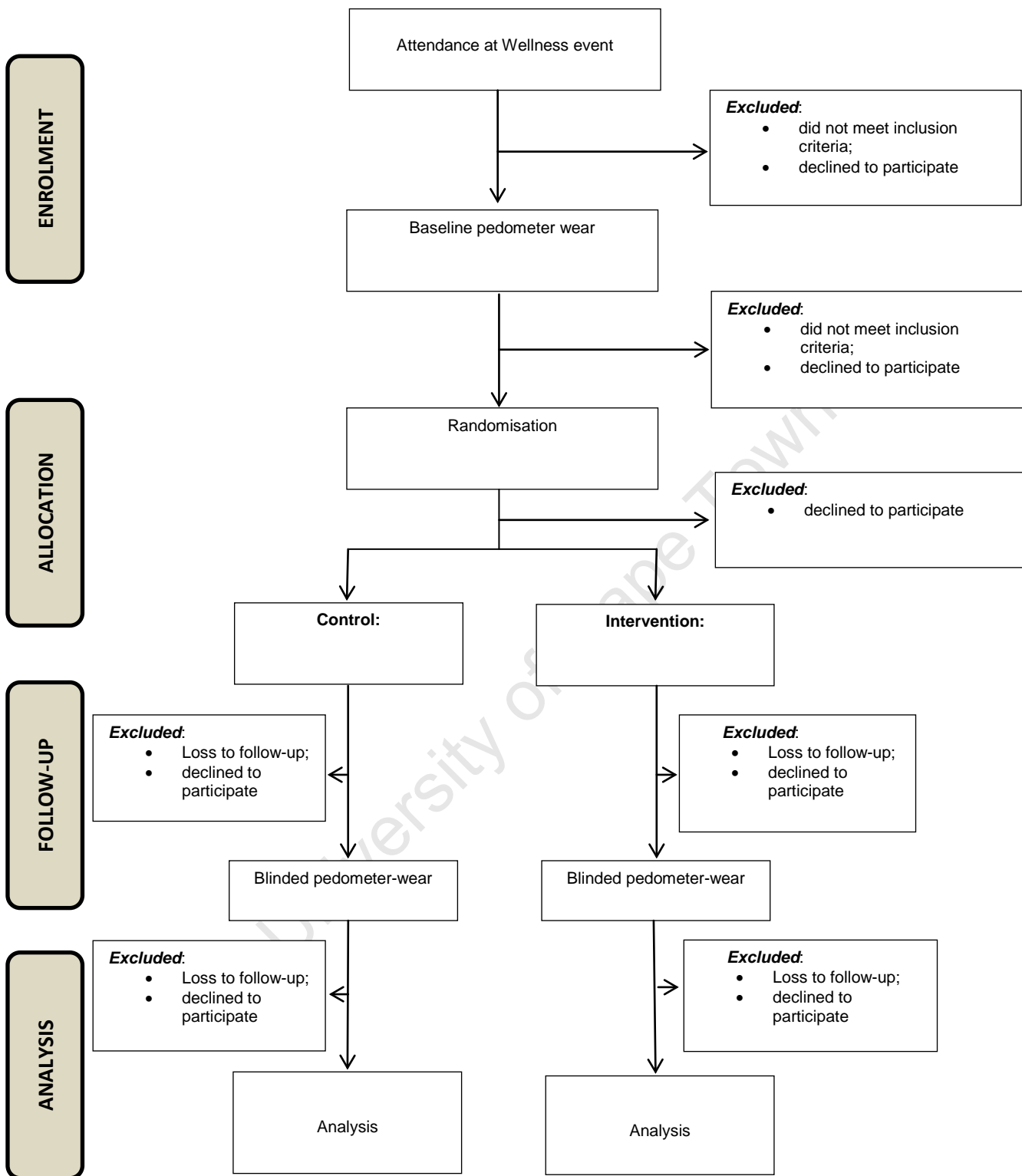


Figure 7.1: Flow of the study design (randomised controlled trial)

Health Risk Appraisal

Aspects of the health risk appraisal, relevant to our study, include demographic factors (i.e. age and gender), self-reported volume and intensity of physical activity. Information relating to intention and readiness for change toward improving physical activity is also determined, as part of the assessment. Additionally, blood pressure, body height and body weight, percentage body fat, body mass index and waist circumference will be measured, as described in Chapter 2.

The health risk appraisal will be conducted by qualified, trained staff and will form part of the health screening event conducted.

Pedometer wear and data recording

Details regarding pedometer-wear and data recording have been described in Chapter 6.

Details on the features as well as the validity and reliability of the pedometer have been described in Chapter 1.

After baseline measurement (week 1), only the intervention group will continue with subsequent un-blinded pedometer wear.

Intervention content

Pedometer data will be requested, and feedback provided, as described in Chapter 6.

Based on the outcomes of the feasibility study conducted (Chapter 6), some of the information provided has been modified according to participant feedback.

The individualised feedback (provided only to the intervention group) will include information on the average daily steps/day accumulated, the number of days (if any) that aerobic steps were accumulated, and the volume thereof, in the form of a personalised email (Appendix J). The feedback will also include information such as the highest number of steps/day accumulated over the past two weeks and the category within which the average steps/day fall, as per current steps/day categorisations⁴²⁻⁴⁴.

Participants will be encouraged to steadily increase their steps until the target of at least 30 minutes of *steps that count* is achieved and/or maintained by the end of the intervention.

The general supportive/motivational messages have been described in Chapter 6. (Appendix H).

Outcome measures

The primary outcome measure (daily physical activity levels, in terms of steps/day) will be assessed at baseline (week 1) and end (week 12) for both the intervention and control groups, in order to detect changes in daily ambulatory physical activity over time, as a function of the intervention.

Data will be derived from the pedometer and expressed as steps/day. More importantly, information on the volume of sustained and moderate-vigorous intensity steps ("*Steps that count*") will be assessed at baseline (week 1) and at the end of the intervention (week 12) for both the intervention group and the control group.

Secondary outcomes such as systolic blood pressure and diastolic blood pressure, body mass index and percentage body fat (as per clinical measures of the health risk appraisal) will be assessed at week 1 and week 12 in both groups.

Statistical analyses

Statistical analyses, to determine effectiveness of the intervention, will be based on group allocation, regardless of the actual intervention received or of adherence to the intervention, i.e. intention to treat analysis.

Linear regression analyses will be performed with the follow-up value of the outcome measure as the dependent variable and adjusted for the baseline value. Assumptions of linear regression analyses will be verified with residual analysis.

To assess whether the differences in the primary outcome between the groups are affected by random differences between them, an analysis of covariance (ANCOVA) will also be undertaken.

For the process evaluation, descriptive analyses will be conducted among the intervention only.

All analyses will be performed with STATISTICA version 8 (StataSoft Inc., Tulsa, OK, USA) and the significance level will be set at $P < 0.05$.

DISCUSSION

This chapter outlines the rationale behind, and the development of, an intervention aimed at improving the daily ambulatory physical activity in a South African employed adult population. This chapter describes the study protocol evaluating its effect.

Limitations

There is an element of selection bias, as the study will involve selection from a convenience sample of persons who are recruited as a result of attending a corporate health risk appraisal.

The general information provided to both the intervention group and control group is the same irrespective of individual progress toward improved physical activity. Also, the control group receives the same general motivational messages as the intervention group, bi-weekly. This may lead to increased ambulatory physical activity in the control group and a resultant weakened effect of the intervention.

A further limitation is that the pedometer will be used as a measurement tool (albeit blinded for measurement at weeks 1 and 12, respectively) as well as during the 10 week intervention.

Strengths

To our knowledge, this will be among the first pedometer-based intervention conducted in South Africa (other than the feasibility study, described in Chapter 6).

The study will provide useful information regarding potential for physical activity improvements through pedometry, in an adult working group.

This is the first pedometer-based intervention, to our knowledge, that takes into account intensity and duration of ambulatory physical activity during free-living wear. The intervention will further provide information on patterns of ambulatory physical activity in an employed, adult population. The study will, therefore be useful for further pedometer-based intervention initiatives that can be applied in other contexts and settings on a larger scale.

With a focus on daily ambulatory physical activity using individualised, brief feedback and self-monitored, pedometer-measured physical activity, the success of such an intervention will have widespread public health implications. This will be particularly valuable, if shown to produce successful outcomes, in the limited extent of external support.

CHAPTER 8

General Discussion

This chapter presents the main findings of the studies, followed by a reflection on the methodological considerations concerning the results of each study. We also discuss the implications for public health and directions for future research and practice.

University of Cape Town

MAIN FINDINGS

It is widely accepted that physical activity contributes to improved aerobic fitness and longevity^{111,112}. Evidence points to the viewpoint that aerobic fitness is an important predictor of longevity to which volume and intensity of physical activity are typically contributors of. There is, however, limited evidence on the association between steps/day, as an indicator of physical activity, and aerobic fitness.

The results of our first study (Chapter 2) show a positive relationship between estimated maximal oxygen uptake and steps accumulated. Further to this, the outcomes of our first study (Chapter 2) and the cross-sectional study (Chapter 4) support the existing evidence linking steps/day to health outcomes (including waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol). As such these outcomes are consistent with the observation that individuals accumulating <5,000 steps/day are more likely to be classified as obese and at high risk for cardiovascular disease⁶⁵.

Evidence that body composition may be influenced by both volume and intensity of physical activity is well documented. However, in the field of pedometry, attention has been primarily directed towards volume of steps/day, and its association with body composition variables, independent of intensity. Although more recent research has been directed towards intensity-based steps^{42,43}, the uniqueness of our research findings (Chapters 2, 4 and 5) is the application of volume, intensity and duration of sustained ambulatory physical activity, i.e. *Steps that count!*, within the field of pedometry.

A further contribution has been the application of pedometer-measured steps (including aspects around volume and intensity of steps) to current guidelines (Chapters 4 and 5). We were unable to demonstrate, in Chapter 5, an independent effect of intensity as a contributor to improved fitness or improved health measures (i.e. waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol). We noted, however, a direct increase in total steps/day in those accumulating intensity-based steps.

Chapter 2 reported that even after adjusting for total steps/day, differences in fitness and health measures (including aerobic fitness, waist circumference and systolic blood pressure) between volume and intensity-based group categories were noted. We therefore emphasise the strong interplay between volume and intensity of steps accumulated.

Exercise prescription and/or steps/day recommendations may therefore, benefit from being framed within the context of volume, intensity and duration of intensity-based steps, as suggested by recent accelerometer/pedometer-based studies^{42,103}. Such recommendations can be used to complement current guidelines and provide further options for improving physical activity.

In keeping with the main theme of this thesis- *Steps that count!*-, the term “brisk” walking, often used in directing public health messages as a proxy for moderate intensity physical activity, was translated into a steps/minute rate. The confirmation that self-paced brisk walking translates well to moderate intensity physical activity (Chapter 3) is important for exercise prescription. Over-estimation or under-

estimation of moderate intensity physical activity may affect the compliance to physical activity regimens and potentially impact negatively on the effect gained from participation in physical activity¹²³.

Further to this, a predicted steps/minute rate for moderate intensity physical activity, using a novel methodology, was established (Chapter 3) and related closely to the steps/minute rate of self-paced brisk walking.

Our findings suggest a step/minute rate of 122 steps/min (127 steps/minute and 116 steps/minute for men and women, respectively) as an estimate of moderate intensity physical activity.

Based on previous studies related to steps/day guidelines^{40,42,43}, we present our findings with caution, largely due to recruitment and measurement limitations. We nevertheless emphasise the novel methodological approach that can be applied, subject to overcoming the limitations described (Chapter 3).

Additional findings (Chapters 4 and 5) showed that only 11.2% of the total study group accumulated aerobic steps for an average of at least 21 minutes/day, as a proxy for current recommendations for moderate intensity physical activity. This value was lower than previous studies using comparable methodological approaches^{27,37}. This further directs us to the need for a more representative study of the South African population and future pedometer-based physical activity interventions that can motivate for increased physical activity^{27,37}.

The pilot intervention (Chapter 6) provides useful information on the potential for physical activity improvements through pedometry in an employed, adult group.

Modest, but non-significant improvements were noted in all health measures (i.e. body weight, waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol).

Small improvements are typically noted in short-term pedometer-based interventions^{139,143,144}. The value of the pedometer serving as a useful motivational aid and a reminder to increase steps/day is, however, commonly identified from participant feedback in pedometer-based interventions¹⁵⁸.

In our pilot study (Chapter 6), the feedback received on perceptions of the intervention similarly identified the motivational effect of the pedometer as a facilitating factor towards increasing ambulatory physical activity. The study provides a basis for further pedometer-based intervention initiatives that can be applied in other contexts and settings and on a larger scale.

Consequently, the pilot intervention informs the protocol of a large scale randomised controlled trial (Chapter 7).

METHODOLOGICAL CONSIDERATIONS

The findings described above should be viewed in the light of several methodological limitations. These limitations pertain to issues regarding study design, assessment and analyses of data. These issues are outlined in greater detail, below.

Internal validity

Participants'

The Physical Activity Readiness Questionnaire ⁹⁸ (Appendix D) was completed by all participants, to ensure that participants were not at any health risk in performing moderate-to-vigorous exercise, particularly for the 12-minute step test performed at the initial visit (Chapters 2 and 3).

Our studies were therefore limited to healthy adults, between the ages of 21-49. Whilst this is assumed to consider most of the adult population, this selection criterion excludes individuals with clinical conditions that might affect or be affected by physical activity.

Sample size

Due to limitations in access to corporate organisations, the results presented in all of our studies identify the sample size as a potential limitation.

Despite this limitation, current literature on studies of a similar design (relevant to the respective study), demonstrate significant variance in sample size. For example, methodological studies published, comparable in design to the studies presented in Chapters 2 and 3, have acquired sample sizes ranging from 19 ⁴³ to 96 ⁴². Sample sizes in recent pedometer-based cross-sectional studies of comparable design and outcomes measures to Chapters 4 and 5, however, typically include over 2500 participants and provide prevalence data ¹⁵⁹⁻¹⁶¹.

Cross-sectional designs

As is common in the social sciences ¹⁶², most of the studies reported in this thesis used cross-sectional data. No matter how advanced the statistical methods used to analyse cross-sectional data may be, arguments for causality cannot be drawn. Caution is, therefore, warranted when interpreting some of the findings reported in previous chapters.

We demonstrate the association between clinical outcomes (i.e. body weight, waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol) and physical activity (in terms of steps/day and aerobic steps/day). Whether there is a causal relationship between the associated factors, cannot however, be determined from our studies, due to the cross-sectional nature of our studies.

Selection bias

The potential selection bias inherent in any convenience sample, particularly if related to physical activity, is noted. Such a selection methodology may attract those who are more physically active and therefore have expectedly better aerobic fitness than the general population.

We attempted addressing this issue in our results by separating our analysis into aerobically fit and un-fit groups alike (Chapters 2 and 3). However, we could not stratify our groups further, according to gender or any other sub-categories, due to the limited size of the study group. This limitation does necessitate further studies in

other groups, and more importantly in a sample group more representative of the South African adult population, to confirm present findings.

The cross-sectional studies (Chapters 4 and 5) were limited to the adult, employed population group, as decided on prior to commencement of the study. Recruitment was, however, limited to employees attending a corporate health and wellness event and willing to participate in the study. These employees might be different from non-participating employees, particularly in relation to physical activity levels.

The study group was also more representative of white-collared workers, including administrative staff, managers, office staff and laboratory staff and scientists. The results we report, therefore, cannot be generalised to the entire employed adult population of South Africa.

Information bias

The categorisation of 'aerobic' steps as ≥ 60 steps/min by the Omron HJ750 ITC pedometer is substantively lower than those recommended by recent studies^{40,42}. Furthermore, the pedometer does not reflect any moderate-high intensity steps as aerobic steps if sustained for anything less than 1-minute in duration. This (≥ 60 steps/min; 1-minute or more) classification does provide some level of differentiation in the type and duration of steps accumulated throughout the day and has provided an intensity and duration component to typical pedometer data, as discussed in Chapter 2.

We recognise this added information provided through the enhanced features of the pedometer that was used and attempted applying this data to extrapolate further

information related to intensity of steps/day. We nevertheless, present information on “aerobic” steps/day (Chapter 2) with caution. This information bias has, however informed the consideration of the following two pertinent questions attempted to be answered in Chapter 3:

1. What is an approximate steps/minute rate for moderate intensity physical activity?
2. How does the steps/minute rate for moderate intensity physical activity relate to that of self-paced brisk walking?

Consequently the information obtained, with reference to similar published studies, informed the modifications of intensity-based steps in subsequent chapters.

Reporting bias

The categorisation of moderate intensity physical activity, as a minimum intensity of 100 steps/minute and over a minimum duration of 10 consecutive minutes, attempted to relate to the context of current guidelines (Chapters 4 and 5). There are, however, limitations, which we identify as a possible reporting bias. These, particularly include the manual tallying of the data, according to the modified classification and the manner in which the data were re-classified according to the criteria established.

The pedometer analyses in Chapter 5, presents some information on intensity-based steps as a proxy for current guidelines. The results presented, as an indication of current guidelines, must be considered with caution, due to limitations mentioned earlier. We nonetheless, report this as a non-differential bias between the two groups

(i.e. those meeting guidelines and those not meeting guidelines), as the possibility of misclassifying individuals is the same in all participants.

Compliance

The request to wear the pedometer for a minimum of 5 consecutive days (Chapters 2, 4 and 5) was often not complied with. We therefore relied on a minimum of 3 days of pedometer wear as a reasonable estimate of daily ambulatory physical activity^{53,54}. This also limited the ability for comparisons between weekend and week-day wear to be determined, as envisaged prior to the commencement of the studies, although several studies report similar steps/day data on all days of the week other than a Sunday^{53,54,56}.

Adherence

The use of pedometers as a self-motivational tool to improve ambulatory physical activity is well documented^{24,70-74,78}. Consequently, the extent of adherence to daily pedometer-wear in any pedometer-based intervention would, therefore, implicitly have an impact on the extent of improvements in ambulatory physical activity.

Whilst the pilot intervention primarily reported baseline and follow-up physical activity levels, adherence to pedometer wear during the 10-weeks intervention might have been inconsistent and hence impacted on follow-up results. The level of adherence to pedometer-wear during an intervention is therefore an area that needs to be considered, in conjunction with follow-up measures.

Measurement instruments/methods

The validity and reliability of the Omron HJ720-ITC brand and model of pedometers has been studied at various mounting positions under prescribed and self-paced walking conditions ^{54,152}. Comparisons have been additionally been made between both healthy and overweight adults and is suggested as an accurate measure of step counts ^{60,163}.

Participants were requested to wear the pedometer, attached to the left or right hip as worn in most studies ²⁴, despite the ability of the pedometer to tally step counts at various mounting positions ²⁸.

Pedometers cannot be worn during swimming and under-report physical activity during cycling ^{29,164}. Our studies were therefore limited to analysing participants who did not participate in these activities. Walking is nevertheless regarded as the most important activity to accurately assess, particularly in the majority of people who do not regularly participate in any exercise ^{12,165}.

The use of the pedometer as a measurement tool for baseline information prior to an intervention may present an information bias, as alluded to by Spence and colleagues in 2009 ¹⁶⁶. Efforts can be made to attempt overcoming/reducing this limitation, for example, the blinding of pedometers and further emphasis to participants to maintain “usual” physical activity levels during the baseline measure. An information bias on baseline data may still, however be apparent, and must be identified as a limitation. Such a limitation can, nevertheless be justified by ensuring the same measurement technique for obtaining baseline data in the control group, so that both the intervention and control groups are exposed to the same potential bias.

One has to, however, be cognizant of the fact that the baseline measure might not be an accurate level of regular ambulatory physical activity, as is a general phenomenon when using pedometers as a measurement instrument for baseline data, and discussed in Chapter 1.

Pedometers are typically used to measure volume of steps/day and the reliability of information on intensity-based steps may be questionable, particularly when relating intensity-based steps to current guidelines. This does, however, provide some level of determining a more reliable estimate of intensity-based physical activity than self-reported means, although limited to ambulatory physical activity. Such an estimate has allowed us to relate pedometer data to self-reported data, with particular reference to current guidelines.

A subgroup of accelerometers can be used to determine the level of agreement between pedometer and accelerometer data. Studies have demonstrated agreement between steps/day using accelerometers and pedometers ⁵¹. This was, however, with reference to volume-based steps. More recent advancements in pedometry provide an opportunity for further research on the level of agreement between accelerometers and pedometers, with reference to intensity-based steps. Such an application may have widespread implications in providing a reliable and affordable instrument for the measurement of steps, in relation to volume, intensity, duration and frequency of ambulatory physical activity. This would be of particular value in settings of limited resources that currently rely on indirect measures of physical activity and inferences thereof, with respect to current guidelines.

The use of pedometers may also provide a less costly alternative, to other direct instruments of physical activity measurement. Individuals may additionally benefit

from self-monitoring and directing their own physical activity, in relation to volume, intensity and duration of intensity-based steps/day.

The use of near infrared measuring (Chapter 2) to determine percentage body fat may be viewed as a limitation, as described in Chapter 2. Percentage body fat was, however used as an additional measure to body mass index and the results of both measures were analysed and reported separately. Subsequent studies (Chapters 3-6) measured percentage body fat using an instrument that estimates percentage body fat on the basis on bioelectrical impedance ¹²¹, as a more reliable estimate.

We were limited to using the percentage of age-predicted maximal heart rate to estimate the relative intensity of individual physical activity in the various trials (Chapter 3) as opposed to an absolute measure of oxygen uptake, to determine energy expenditure corresponding to moderate intensity physical activity.

Freedson and Miller provide some limitations to the use of heart rate measures as an estimate of physical activity intensity, particularly related to age, gender and aerobic fitness ³¹. Studies have also shown that calibration may be required to create a curve between the subject's heart rate and estimated energy expenditure ^{31,167,168}, typically involving a submaximal test at moderate intensity physical activity levels ^{31,169,170}.

Heart rate monitors may also confound factors such as emotional stress, caffeine intake, ambient temperature, or certain illness' ^{169,171} which may have a particular impact on low-intensity activities. Whilst our findings report age, gender and aerobic fitness in the study group, the estimation of energy expenditure corresponding to moderate intensity physical activity, using a relative measure of heart rate intensity, is identified as a primary limitation in this study (Chapter 3).

Furthermore, aerobic fitness was derived from the heart rate response based on a 12-minute intermittent step test (Chapters 2 and 3), as described in the relevant chapters. Whilst the information provided on aerobic fitness is a relative value, this test has been shown to explain 76% of the variance in actual measured maximal oxygen consumption^{101,172}.

External validity

As mentioned previously, the results presented in this thesis have been as a result of a selected group of volunteer participants/individuals. We therefore believe that the associations observed in our study should not be generalised to the entire population. We have adjusted most of our results to consider factors such as age, gender and aerobic fitness as potential covariates, but extrapolation of results to the adult population or even the current South African population, is not recommended.

PUBLIC HEALTH IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The research undertaken is the first pedometer-based study to our knowledge that differentiates walking according to a baseline level of intensity and duration. In a sample of people accumulating an average of approximately 6,500 steps/day, this categorisation has helped identify “*steps that count*” (i.e. ≥ 10 minutes of walking at a minimum intensity of 100 steps/min). This may be a useful way of establishing associations between “*steps that count*” and clinical and fitness measures, using pedometers. Such findings can be applied in other contexts and using larger population groups.

The possibility of expanding and modifying the current study (Chapter 4) into a large-scale prevalence study is recommended. Such a recommendation can be explored further, using a comparable approach, to provide more generalisable data, within the context administered.

The application of our cross-sectional data to current guidelines (Chapter 5) provides the potential to explore the use of pedometers as an alternative or complementary tool to self-reported measures. This may contribute towards determining patterns of physical activity, with particular reference to ambulatory physical activity and current guidelines. Such an alternative can be applied in a variety of settings (including both occupational and non-occupational) as a less costly alternative and a more free-living measure than other direct measures. Such studies can be conducted on a larger scale so as to provide information that can be generalised to the entire population.

Chapter 3 presented a novel method to determine approximate steps/minute rates for moderate intensity physical activity and self-paced brisk walking. The results obtained may not be generalisable, due to significant limitations. The novelty of aspects in the methodology can, however, be applied and modified for future research to enhance documented literature in support of intensity-based step recommendations.

The application of the theme “steps that count” may be validated by a large-scale methodological study that confirms a minimum steps/minute rate for moderate intensity physical activity. Such an outcome can subsequently be applied as a public

health message towards motivating and engaging people to increase moderate intensity physical activity, through pedometer-based steps.

The commercial application of the theme “*steps that count*” to pedometry may also provide a strategy towards improving the uptake of pedometry as a public health initiative.

More importantly, the outcomes of the pilot intervention (Chapter 6), aimed at improving the daily ambulatory physical activity in a South African employed adult group, has informed a protocol for a future pedometer-based randomised controlled trial. An appropriate sample size for this trial has also been recommended.

Emphasis must be placed on the value of such an intervention extending beyond simply assessing the extent of clinical/ physical activity improvements. Interventions of this nature can further serve towards increasing awareness of physical activity and thereby creating a platform for improvements, thereof.

CONCLUSIONS

This thesis concerns the association between pedometer-measured steps/day and health measures (i.e. body weight, waist circumference, body mass index, percentage body fat, blood pressure, blood glucose and blood cholesterol). The results of this thesis, presented as a series of studies, support the existing evidence linking volume and intensity of steps/day to fitness and health outcomes, as indicated below.

- Technological advancements in pedometry provide the opportunity to use pedometers as a less costly approach, to more expensive direct measures of physical activity, although limited to ambulation. Such advancements can provide information on ambulatory physical activity, with particular reference to volume and intensity of steps.
- Exercise prescription and/or steps/day recommendations may be enhanced if framed within the context of volume, intensity and duration of intensity-based steps, as supported by recent findings.
- The study adds to current documented literature in providing data on intensity-based steps/day with an attempt to relate these findings to current physical activity guidelines.
- Our study also provides some information on current ambulatory physical activity patterns in a South African adult, employed group.
- The pilot intervention has informed the protocol for a large scale intervention to be applied as a randomised controlled trial.

In summary, pedometers are being used more frequently in epidemiological research to provide objective estimates of ambulatory physical activity. Guidelines for consistent collection and interpretation have facilitated the widespread use of pedometers in physical activity health promotion initiatives.

The advancements in pedometry and the growing interest in intensity-based steps/day guidelines, however, warrants the need for further methodological and interpretation guidelines to be considered.

The study provides a basis for further pedometer-based intervention initiatives that can be applied in other contexts and settings and on a larger scale.

University of Cape Town

Reference list

1. Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med Sci Sports Exerc.* 2001;33(suppl):S364-S369.
2. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* 1995;273(5):402-407.
3. Le Masurier GC, Sidman CL, Corbin CB. Accumulating 10,000 steps: does this meet current physical activity guidelines? . *Res Q.* 2003;74:389-394.
4. Hu G, Tuomilehto J, Silventoinen K, Barengo N, Jousilahti P. Joint effects of physical activity, body mass index, waist circumference and waist-to-hip ratio with the risk of cardiovascular disease among middle-aged Finnish men and women. *Eur.Heart J* 2004;25(24):2212-2219.
5. Richardson CR, Kriska AM, Lantz PM, Hayward RA. Physical activity and mortality across cardiovascular disease risk groups. *Med.Sci.Sports Exerc.* 2004;36(11):1923-1929.
6. Paluska SA, Schwenk TL. Physical activity and mental health: current concepts. *Sports Med.* 2000;29(3):167-180.
7. Paffenbarger RS HR, Wing AL, Hsieh C-C. Physical activity, all-cause mortality and longevity of college alumni. *N Engl J Med.* 1986;314(10):605-613.
8. Organisation WH. *Global recommendations on physical activity for health World Health Organization.* Switzerland2010.
9. Haskell WL. What to look for in assessing responsiveness to exercise in a health context. *Med.Sci.Sports Exerc.* 2001;33(6(suppl)):S454-458.
10. Haskell WL, I-Min L, Pate RR, et al. Physical Activity and Public Health: Updated recommendation for Adults from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116(9):1081-1093.
11. Health CMODO. *At least five a week: Evidence on the impact of physical activity and its relationship to health- a report from the Chief Medical Officer.* London: Department of Health;2004.
12. Tudor-Locke CE, Myers AM. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Res Q Exerc Sport.* 2001;72(1):1-12.
13. Hallal PC, Azevedo MR, Reichert FF, Siqueira FV, Araujo CL, Victora CG. Who, when, and how much? Epidemiology of walking in a middle-income country. *Am.J.Prev.Med.* 2005;28(2):156-161.
14. Blair SN, ed *How to assess exercise habits and physical fitness.Behavioral health: A handbook of health enhancement and disease prevention.* New York: Wiley; 1984. In JD Matarazzo SW, JA Herd, & NE Miller (Eds), ed.
15. Masse LC, Ainsworth BE, Tortolero S, et al. Measuring physical activity in midlife, older and minority women. *Womens Health.* 1998;7(1)::57-67.
16. Alexander S, Cowburn G, Foster C. Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res.* 2006;21(6):826-835.
17. Chan CB, Spangler E, Valcour J, Tudor-Locke C. Cross-sectional relationship of pedometer-determined ambulatory activity to indicators of health *Obes Res.* 2003;11(12):1563-1570.
18. Ainsworth BE, LaMonte MJ, Tudor-Locke C. Physical activity: Obesity: etiology, assessment, treatment, and prevention. *Human Kinetics [In press].*

19. Montoye HJ, Taylor HL. Measurement of physical activity in population studies: a review. *Hum Biol.* 1984;56(2):195-216.
20. Prince SA, Adamo KB, Hamel ME, Hardt J, Gorber SC, Tremblay MS. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act.* 2008;5(1):56.
21. Ainslie PN, Reilly T, Westerterp KR. Estimating human energy expenditure: a review of techniques with particular references to doubly labelled water 38. *Sports Med.* 2003;33:683-698.
22. Nelson KM, Weinsier RL, Long CL, Schutz Y. Prediction of resting energy expenditure from fat-free mass and fat mass. *Am J Clin Nutr.* 1992;56:848-856.
23. Dishman RK, Washburn RA, Schoeller DA. Measurement of physical activity. *Quest.* 2001;53:295-309.
24. Tudor-Locke C. Taking Steps Toward Increased Physical Activity: Using Pedometers To Measure And Motivate. Washington D.C: President's Council on Physical Fitness and Sports 2002.
25. Tudor-Locke C, Washington TL, Ainsworth BE, Troiano RP. Linking the American Time Use Survey (ATUS) and the Compendium of Physical activity: Methods and Rationale. *Journal of Physical Activity and Health.* 2009;6(3):347-353.
26. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *Br J Sports Med.* 2003;37:197-206.
27. Miller R, Brown W. Meeting physical activity guidelines and average daily steps in a working population. *J Phys Act Health.* 2004;1:218-226.
28. Incorporated OH. Instruction manual: Pocket pedometer-model HJ-720ITC2007.
29. Bassett DR, Ainsworth BE, Leggett SR, et al. Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc.* 1996;28(8):1071-1077.
30. Welk GJ, Differding JA, Thompson RW, Blair SN, Dziura J, Hart P. The utility of the Digi-walker step counter to assess daily physical activity patterns. *Med Sci Sports Exerc.* 2000;32(suppl):S481-S488.
31. Freedson PS, Miller K. Objective monitoring of physical activity using motion sensors and heart rate. *Res Q Exerc Sport.* 2000;71(2 Suppl):S21-S29.
32. Tudor-Locke CE, Williams JE, Reis JP, Pluto D. Utility of Pedometers for Assessing Physical Activity: Construct Validity. *Sports Med.* 2004;34(5):281-291.
33. Schneider PL, Crouter SE, Bassett DR. Pedometer measures of free-living physical activity: comparison of 13 models. *Med Sci Sports Exerc.* 2004;36(2):331-335.
34. Murphy M, Nevill A, Nevill C, Biddle S, Hardman A. Accumulating brisk walking for fitness, cardiovascular risk, and psychological health. *Med Sci Sports Exerc.* 2002;9:1468-1474.
35. Coleman KJ, Raynor HR, Mueller DM, Cerny FJ, Dorn JM, Epstein LH. Providing sedentary adults with choices for meeting their walking goals. *Prev Med.* 1999;28(5):510-519.
36. Hansen AR, Sogaard J. Uncertain effects of health risk appraisals at worksites. *Ugeskr Laeg.* 2011;173(33):1945-1948.
37. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls and prospects. *Lancet.* 2012;380(9838):247-257.
38. Strycker LA, Duncan SC, Chaumeton NR, Duncan TE, Toobert DJ. Reliability of pedometer data in samples of youth and older women. *Int J Behav Nutr Phys Act.* 2007;4:4-11.
39. Tudor-Locke C, Bassett DRJ. How many steps/d are enough? Preliminary pedometer indices for public health. *Sports Med.* 2004;34(1):1-8.
40. Tudor-Locke C, Sisson SB, Collova T, Lee SM, Swan PD. Pedometer-determined step count guidelines for classifying walking intensity in a young ostensibly healthy population. *Can J Appl Physiol.* 2005;30(6):666-676.
41. Wilde BE, Sidman CL, Corbin CB. A 10,000 step count as a physical activity target for sedentary women. *Res Q Exerc Sport.* 2001;72(4):411-414.

42. Marshall SJ, Levy SS, Tudor-Locke CE, et al. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes *Am J Prev Med.* 2009;36(5):410-415.
43. Abel M, Hannon J, Mullineaux D, Beighle A. Determination of step rate thresholds corresponding to physical activity intensity classifications in adults. *J Phys Act Health.* 2011;8(1):45-51.
44. Tudor-Locke C, Craig CL, Brown WJ, et al. How many steps/day are enough? For adults. *Int J Behav Nutr Phys Act.* 2011;8:79-97.
45. Hatano Y, Tudor-Locke C. Pedometer-assessed physical activity: measurement and motivations. Paper presented at: American College of Sports Medicine Annual Meeting 2001; Baltimore.
46. Hatano Y. Use of the pedometer for promoting daily walking exercise. In: International Council for Health PEaR, ed. 291993:4-8.
47. General USS. Surgeon General's report on physical activity and health. From the Centers for Disease Control and Prevention. *JAMA.* 1996;276(7):522-531.
48. Services USDoHaH. *2008 Physical Activity Guidelines for Americans: Be Active, Healthy, and Happy!* Washington, D.C.2008.
49. Tudor-Locke C, Lutes L. Why do pedometers work? A reflection upon the factors related to successfully increasing physical activity. *Sports Med.* 2009;39(12):981-993.
50. Bauman A, Phongsaven P, Schoeppe S, Owen N. Physical activity measurement- a primer for health promotion. *Promotion & Education.* 2006;13(2):92-103.
51. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity: Convergent validity. *Sports Medicine.* 2002;32(12):795-808.
52. Brown W, Trost SG, Bauman A, Mummery K, Owen N. Test retest reliability of four physical activity measures used in populations. *Journal of Sports Science and Medicine.* 2004;7(2):205-215.
53. Tudor-Locke C, Burkett L, Reis JP, Ainsworth BE, Macera CA, Wilson DK. How many days of pedometer monitoring predict weekly physical activity in adults? *Prev med.* 2005;40:293-298.
54. Rowe DA, Kemble CD, Robinson TS, Mahar MT. Daily walking in older adults: day-to-day variability and criterion-referenced validity of total daily step counts. *J Phys Act Health* 2007;4:434-446.
55. Kang M, Marshall SJ, Barreira TV, Lee J. Effect of pedometer-based physical activity interventions: a meta-analysis. *Res Q.* 2009;80(3):648-655.
56. Hart TL, Swartz AM, Cashin SE, Strath SJ. How many days of monitoring predict physical activity and sedentary behaviour in older adults? *Int J Behav Nutr Phys Act* 2011;8:62.
57. Hasson RE, Haller HJ, Pober DM, Staudenmayer J, Freedson PS. Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports & Exerc.* 2009;41(4):805-809.
58. Crouter S, Schneider P, Bassett DJJ. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports & Exerc.* 2005;35(8):1673-1769.
59. Melanson EL, Knoll JR, Bell ML, Donahoo WT, Hill JO, Nysse LJ. Commercially available pedometers: considerations for accurate step counting. *Prev Med.* 2004;39(2):361-369.
60. Holbrook EA, Barreira TV, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci sports Exerc.* 2009;41(3):670-674.
61. Corder K, Brage S, Ekelund U. Accelerometers and pedometers: methodology and clinical application. *Curr Opin Nutr Metab Care.* 2007;10:597-603.
62. Crouter SE, Churilla JR, Basset DRJ. Estimating energy expenditure using accelerometers. *Eur J Appl Physiol.* 2006;98:601-612.
63. Tudor-Locke C, Ainsworth BE, Thompson RW, Matthews CE. Comparison of pedometer and accelerometer measures of free-living physical activity. *Med Sci Sports Exerc.* 2002;34:2045-2051.

64. Behrens TK, dinger MK. Comparisons of accelerometer and pedometer-determined steps in free living samples. *J Phys Act Health*. 2011;8:390-397.
65. Tudor-Locke C, Ainsworth BE, Whitt MC, Thompson RW, Addy CL, Jones DA. Relationship between pedometer-determined ambulatory and body composition variables. *Int J Obes*. 2001;25:1571-1578.
66. McClung CD, Zahiri CA, Higa JK, Amstutz HC, Schmalzried TP. Relationship between body mass index and activity in hip or arthroplastypatients. *J Orthop Res*. 2000;18:35-39.
67. Tyon WW, Goldberg JL, Morrison DF. Activity decreases as percentage of overweight increases. *Int J Obes*. 1992;16:591-595.
68. Wyatt HR, Peters JC, Reed GW, Barry M, Hill JO. A Colorado statewide survey of walking and its relation to excessive weight. *Med Sci Sports Exerc*. 2005;37(5):724-730.
69. Tudor-Locke C, Ham SA, Macera CA, Ainsworth BE, Kirtland KA, Reis P. Descriptive epidemiology of pedometer-determined physical activity. *International Journal of Obesity*. 2004;36:1567-1573.
70. Hornbuckle LM, Bassett DRj, Thompson DL. Pedometer-determined walking and body composition variables in African-American women. *Medicine and Science in sport and exercise*. 2005;37(6):1069-1074.
71. Krumm EM, Dessieux OL, Andrews P, Thompson DL. The relationship between daily steps and body composition in postmenopausal women. *Journal of womens health*. 2006;15(2):202-210.
72. Thompson DL, Rakow J, Perdue SM. Relationship between accumulated walking and body composition in middle-aged women. *Medicine and Science in sport and exercise*. 2004;36(5):911-914.
73. Yamanouchi K, Shinozaki T, Chikada K. Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. *Diabetes Care*. 1995;18(6):775-778.
74. Lubans DR, Morgan PJ, Tudor-Locke C. A systematic review of studies using pedometers to promote physical activity among youth. *Prev Med*. 2009;48:307-315.
75. Craig CL, Tudor-Locke, C., Bauman, A. Twelve-month effects of Canada on the Move: a population-wide campaign to promote pedometer use and walking. *Health Education Research*. 2007;22(3):406-413.
76. Brown WJ, Mummery K, Eaken E, Schofield G. 10,000 Steps Rockhampton: Evaluation of a whole community approach to improving population levels of physical activity. *Journal of Physical Activity and Health*. 2006;3:1-14.
77. De Cocker K, Bourdeaudhuij ID, Brown W, Cardon G. Effects of "10,000 steps Ghent": A whole-community intervention. *American Journal of Preventive Medicine*. 2007;33(6):455-463.
78. Bravata DM, Smith-Spangler CS, Sundaram V, et al. Using pedometers to increase physical activity and improve health- a systematic review *JAMA*. 2007;298(19):2296-2304.
79. Tudor-Locke CE, Meyers AM. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Med*. 2001;31:91-100.
80. Richardson CR, Newton TL, Abraham JJ, Sen A, Jimbo M, Swartz AM. A meta-analysis of pedometer-based walking interventions and weight loss. *Ann Fam Med* 2008;6(1):69-77.
81. Sidman CL, Corbin CB, Le Masurier G. Promoting physical activity among sedentary women using pedometers. *Res Q*. 2004;75(2):122-129.
82. Lauzon N, Chan CB, Myers AM, Tudor-Locke C. Participant experiences in a workplace pedometer-based physical activity program. *Journal of Physical Activity and Health*. 2008;5:675-687.
83. Izawa KP, Watanabe S, Onvya K. Effect of the self-monitoring approach on exercise maintenance during cardiac rehabilitation- a randomized controlled trial. *Am J Phys Med Rehabil*. 2005;86(11):2150-2156.

84. Ransdell LB, Robertson L, Trunnel E, Moyer-Mileur L. Generations exercising together to improve fitness (GET FIT): a pilot study designed to increase physical activity and improve health-related fitness in three generations of women. *Womens Health*. 2004;40(3):77-94.
85. Ornes LL RL, Robertson L, Trunnel E, Moyer-Mileur L. A 6-month pilot study of the effects of a physical activity intervention on life satisfaction with a sample of three generations of women. *Percept Mot Skills*. 2005;100(3 pt 1):579-591.
86. VanWormer JJ, Boucher JL, Pronk NP, Thoennes JJ. Lifestyle behavior change and coronary artery disease: effectiveness of a telephone-based counseling program. *J Nutri Educ Behav*. 2004;36(6):333-334.
87. Heesch KC, Dinger MK, McClary KR, Rice KR. Experiences of women in a minimal contact pedometer-based intervention: a qualitative study. *Womens Health*. 2005;41:97-116.
88. Jordan AN, Jurca GM, Locke CT, Church TS, Blair SN. Pedometer indices for weekly physical activity recommendations in postmenopausal women. *Med Sci Sports Exerc*. 2005;37(9):1627-1632.
89. McKay J, Wright A, Lowry R, Steele K, Ryde G, Mutrie N. Walking on prescription: the utility of a pedometer pack for increasing physical activity in primary care. *Patient Educ Couns*. 2009;76(1):71-76.
90. Mutrie N, Hannah M-K. Some work hard while others play hard. The achievement of current recommendations for physical activity levels at work, at home, and in leisure time in the west of Scotland. *Int J Health Promot Educ*. 2004;42:109-117.
91. Morris J, Hardman A. Walking to health. *Sports Med*. 1997;23:306-332
92. Simpson ME, Serdula M, Galuska DA, et al. Walking trends among U.S. adults. The behavioral risk factor surveillance system 1987-2000. *Am J Prev Med*. 2003;25:95-100.
93. Rowe DA, Welk GJ, Heil DP, Mahar MT, Kemble CD, Calabro MA. Stride rate recommendations for moderate intensity walking *Med Sci Sports Exerc*. 2011;42(1):2134-2140.
94. Beets MW, Agiovlasitis S, Fahs CA, Ranadive SM, Fernhall B. Adjusting step count recommendations for anthropometric variations in leg length. *J Sc Med Sport*. 2010;13(5):509-512.
95. Merom D, Phongsaven P, Chey T, Bauman A. Long-term changes in leisure time walking, moderate and vigorous exercise: were they influenced by national physical activity guideline? *J Sci Med Sport*. 2006;9:199-208.
96. Bergman P, Grijbovsci AM, Hagstromer M, Bauman A, Sjostrom M. Adherence to physical activity recommendations and the influence of socio-demographic correlates- a population-based cross-sectional study. *BMC Public Health*. 2008;8:367-376.
97. Schmidt MD, Cleland VJ, Shaw K, Dwyer T, Venn AJ. Cardiometabolic risk in younger and older adults across an index of ambulatory activity. *Am J Prev Med*. 2009;37(4):278-284.
98. Chisholm DM, Collis ML, Kulak LL, Davenport W, Gruber N, Stewart GW. *PAR-Q validation report: the evaluation of a self-administered pre-exercise screening questionnaire for adults*. Victoria:Canada: BC Ministry of Health and Health and Welfare;1978.
99. Balady GJ, Chaitman B, Driscoll D, Foster C, Froelicher E, Gordon N. Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. *Circulation*. 1998;97:2283-2293.
100. Analyzer UMFABC. *User Manual: Futrex Advanced Body Composition Analyzer*. Hagerstown: MD: Futrex Inc; 2003.
101. Keytel LR, Goedecke JH, Noakes TD, et al. Prediction of energy expenditure from heart rate monitoring during submaximal exercise. *J Sports Sci*. 2005;23(3):289-297.
102. Tudor-Locke C, Craig CL, Thyfault JP, Spence JC. A step-defined sedentary lifestyle index:<5000 steps/day. *Appl. Physiol. Nutri. Metab*. 2013;38:100-114.

103. Tudor-Locke C, Brashear MM, Johnson WD, Katzmarzyk PT. Accelerometer profiles of physical activity and inactivity in normal weight, overweight, and obese U.S. men and women. *Int J Behav Nutr Phys Act.* 2010;7:60.
104. Choi BCK, Pak AWP, Choi JCL, Choi ECL. Daily step goal of 10,000 steps: A literature review. *Clin Inves Med.* 2007;3:146-151.
105. Baranowski T, De Moor C. How many days was that? Intra-individual variability and physical activity assessment. *Res Q Exerc Sport.* 2000;71:74-78.
106. Stokes M. Reliability and repeatability of methods for measuring muscle in physiotherapy. *Physiother Pract.* 1985;1:71-76.
107. Schonhofer B, Ardes P, Geibel M, Kohler D, Jones PW. Evaluation of a movement detector to measure daily activity in patients with chronic lung disease. *Eur Respir J.* 1997;10(12):2814-2819.
108. Rowlands AV, Eston RG, Ingledew DK. Relationship between activity levels, aerobic fitness, and body fat in 8-10 year old children. *J Appl Physiol.* 1994;140:148-160.
109. National Institutes of Health NH, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res.* 1998;6(suppl):S51-210.
110. Totsikas C, Röhm J, Kantartzis K, et al. Cardiorespiratory fitness determines the reduction in blood pressure and insulin resistance during lifestyle intervention. *J Hypertension.* 2011;29(6):1220-1227.
111. Blair SN, Kohl III HW, Barlow CE, Paffenbarger RS, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *JAMA.* 1995;273:1093-1098.
112. Lee IM, Hsieh CC, Paffenbarger RSJ. Exercise intensity and longevity in men. The Harvard Alumni Health Study. *JAMA.* 1995;273:1179-1184.
113. Harber V, Bell G, Rodgers W, Courneya KS. Cardiovascular and Type 2 diabetes risk factor response to traditional fitness and 10,000 step exercise program: the health 1st study. *Med Sci Sports Exerc.* 2006;38(suppl):S369.
114. Cook I, Alberts M, Lambert EV. Relationship between adiposity and pedometer-assessed ambulatory activity in adult, rural African women. *Int J Obes.* 2008;32:1327-1330.
115. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: approach for developing guidelines on body mass index *Am J Clin Nutr.* 2000;72(3):694-701.
116. Hasson RE, Haller, J., Pober, D.M., Staudenmayer, J. Validity of the Omron HJ-112 pedometer during treadmill walking. *Medicine and Science in Sports and Exercise.* 2009;41(805-809).
117. Holbrook EA, Barreira, T.V., Kang, M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Medicine and Science in Sports and Exercise.* 2009;41(3):669-673.
118. Hopkins WG. Estimating sample-size for magnitude-based inferences: AUT University, NZ.
119. Eakin EG, Mummery K, Reeves MM, et al. Correlates of pedometer use: results from a community-based physical activity intervention trial (10,000 Steps Rockhampton). *Int J Behav Nutr Phys Act* 2007;4:31.
120. Tudor-Locke C, Camhi SM, Leonardi C, et al. Patterns of adult stepping in the 2005/2006 NHANES. *Prev Med.* 2011;53(3):178-181.
121. Bosy-Westphal A, Later W, Hitze B, et al. Accuracy of bioelectrical impedance consumer devices for measurement of body composition in comparison to whole body magnetic resonance imaging and dual x-ray absorptiometry. *Obes Facts.* 2008;1:319-324.
122. Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! . *Ann Behav Med.* 2008;35(2):136-149.

123. Adam C KV, Ravassolo M, Renson R, Tuxworth W, Kemper H, Van Mechelen W, Hlobil H, Beunen G, Levarlet-Joye H, Van Lierde A. *Handbook for the Eurofit Test of Physical Fitness*. Rome, Italy: Council of Europe. Committee for the Development of Sport; 1998.
124. MacKinnon DP, ed *Introduction to statistical mediation analysis*. Mahway, NJ2008.
125. Preacher KJ, Rucker DD, Hayes AF. Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research*. 2007;42(1):185-227.
126. Lubans DR, Morgan PJ, Collins CE, Boreham CA, Callister R. Mediators of weight loss in the 'Healthy Dads, Healthy Kids' pilot study for overweight fathers. *International Journal of Behavioral Nutrition and Physical Activity*. 2012;9:45.
127. Ainsworth BE, Sternfeld B, Slattery ML, Dasquise V, Zahm SH. Physical activity and breast cancer: evaluation of physical activity assessment methods. *Cancer*. 1998;83(3):611-620.
128. Luke A, Adeyemo A, Kramer H, Forrester T, Cooper RS. Association between blood pressure and resting energy expenditure independent of body size. *Hypertension*. 2004;43(3):555-560.
129. Morgenthaler T, Alessi C, Friedman L, et al. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders. *Sleep*. 2007;30(4):519-529.
130. Harris TJ, Owen CG, Victor CR, Adams R, Ekelund U, Cook DG. A comparison of questionnaire, accelerometer, and pedometer: measures in older people. *Med Sci Sports & Exerc*. 2009;41(7):1392 - 1402
131. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. *American Journal of Epidemiology*. 2008;167:875-881.
132. Matton L, Wijndaele K, Duvigneaud N, Duquet W, Philippaerts R, Thomis M. Reliability and validity of the Flemish Physical Activity Computerized Questionnaire in adults. *Research quarterly for exercise and sport*. 2007;78:293-306.
133. Pillay JD, Kolbe-Alexander TL, van Mechelen W, Lambert EV. Steps that count- the association between the number and intensity of steps accumulated and fitness and health measures. *J Phys Act Health [in press]*.
134. Pillay JD, Kolbe-Alexander TL, Proper KI, van Mechelen W, Lambert EV. Steps that count- Physical activity recommendations, brisk walking and steps per minute- how do they relate? *J Phys Act Health [in press]*.
135. Tudor-Locke C. Promoting lifestyle physical activity: Experiences with the First Step Program. *American Journal of Lifestyle Medicine*. 2009:50S-54S.
136. Pillay JD, Kolbe-Alexander TL, Achmat M, Carstens M, Lambert EV. Are point-of-decision prompts in sports science and medicine centre effective in changing the prevalence of stair usage? A preliminary study. *S Afr J SM*. 2009;21(2):58-64.
137. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. *Res Q for Exerc Sport*. 2000;71(2(suppl)):59-73.
138. Harrington NG, Noar SM. Reporting standards for studies of tailored interventions (R2). *Health Educ Res* 2012;27(2):331-342.
139. Ogilvie D, Foster CE, Rothnie H, et al. Interventions to promote walking: systematic review. *BMJ*. 2007;334:1204-1214.
140. Lenfant C. Shattuck lecture--clinical research to clinical practice-lost in translation? *N Engl J Med*. 2003;349(9):868-874.
141. Glasgow RE, Emmons KM. How can we increase translation of research into practice? Types of evidence needed. *Annu Rev Public Health*. 2007;28(1):413-433.
142. Pegus C, Bazzarre TL, Brown JS, Menzin J. Effect of the Heart at Work program on awareness of risk factors, self-efficacy, and health behaviors. *J. Occup. Environ. Med* 2002;44:228-236.
143. Fox AM, Mann DM, Ramos MA, Kleinman LC, Horowitz CR. Barriers to physical activity in East Harlem, New York. *J Obes*. 2012;2012:719140.
144. Chan CB, Ryan DAJ, Tudor-Locke C. Health benefits of a pedometer-based physical activity intervention in sedentary workers. *Prev Med*. 2004;39:1215-1222.

145. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *Am J Health Promot.* 1997;12(1):38-48.
146. Proper KI, Koning M, van der Beek AJ, Hildebrandt VH, Bosscher RJ, van Mechelen W. The effectiveness of worksite physical activity programs on physical activity, physical fitness, and health. *Clin J Sport Med.* 2003;13(2):106-117.
147. Kolbe-Alexander TL, Buckmaster C, Nossel C, et al. Chronic disease risk factors, healthy days and medical claims in South African employees presenting for health risk screening. *BMC Public Health.* 2008;8:228-239.
148. Groeneveld IF, Proper KI, van der Beek AJ, van Duivenbooden C, van Mechelen W. Design of a RCT evaluating the (cost-)effectiveness of a lifestyle intervention for male construction workers at risk for cardiovascular disease: The Health under Construction study. *BMC Public Health.* 2008;8:1-22.
149. Tarride JE, Harrington K, Balfour R, et al. Partnership in employee health. A workplace health program for British Columbia Public Service Agency (Canada). *Work.* 2011;40(4):459-471.
150. Hochart C, Lang M. Impact of a comprehensive worksite wellness program on health risk, utilization, and health care costs. *Popul Health Manag* 2011;14(3):111-116.
151. Beresford SA, Thompson B, Feng Z, Christianson A, McLerran D, Patrick DL. Seattle 5 a Day worksite program to increase fruit and vegetable consumption. *Prev Med.* 2001;32(3):230-238.
152. Ajzen I. The theory of planned behavior *Organ Behav Hum Decis Process.* 1991;50:179-211.
153. Courneya KS, McAuley E. Factors affecting the intention-physical activity relationship: intention versus expectation and scale correspondence. *Res Q Exerc Sport.* 1994;65(3):280-285.
154. Prochaska JO, DiClemente CC, Norcross JC. In search of how people change. Applications to addictive behaviors. *Am J Psychol.* 1992;47(9):1102-1114.
155. Conner M, Sheeran P, Norman P, Armitage CJ. Temporal stability as a moderator of relationships in the Theory of Planned Behaviour. *Br J Soc Psychol* 2000;39(4):469-493.
156. Brug J, Oenema A, Campbell M. Past, present, and future of pedometer-tailored nutrition education. *Am J Clin Nutr.* 2003;77(4(suppl)):1028S-1034S.
157. Strijk JE, Proper KI, van der Beek AJ, van Mechelen W. The Vital@Work Study. The systematic development of a lifestyle intervention to improve older workers' vitality and the design of a randomised controlled trial evaluating this intervention. *BMC Public Health* 2009;9:408.
158. De Cocker K, Bourdeaudhuij ID, Brown W, Cardon G. The effect of pedometer use in combination with cognitive and behavioral support materials to promote physical activity. *Patient Educ Couns.* 2008;70:209-214.
159. Strath SJ, Holleman RG, Ronis DL, Swartz AM, Richardson CR. Objective physical activity accumulation in bouts and nonbouts and relation to markers of obesity in US adults. *Prev Chronic Dis.* 2008;5(4):A131.
160. Hawkins MS, Storti KL, Richardson CR, et al. objectively measured physical activity of USA adults by sex, age, and racial/ethnic groups: a cross-sectional study. *Int J Behav Nutr Phys Act.* 2009;6:31.
161. Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined lifestyle activities in U.S. Adults. *Journal of Physical Activity and Health.* 2011;8:382-389.
162. Blossfeld HP, Rohwer G, eds. *Techniques of event history modeling*: Lawrence Erlbaum; 1995. Mahwah N, ed.
163. Giannakidou DM, Kambas A, Ageloussis N, et al. The validity of two Omron pedometers during treadmill walking is speed dependent. *Eur J Appl Physiol* 2012;112(1):49-57.

164. Hendelman D, Miller K, Baggett C, Debold E, Freedson PS. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine and Science in Sports and Exercise*. 2000;32(9(suppl)):S442-S450.
165. Tudor-Locke C, Bassett DRJ, Swartz AM, et al. A preliminary study of one year of pedometer self-monitoring. *Ann Behav Med*. 2004;28(3):158-162.
166. Spence JC, Burgess J, Rodgers W, Murray T. Effect of pretesting on intentions and behaviour: A pedometer and walking intervention. *Psychology & Health*. 2009;24(7).
167. Melanson EL, Freedson PS. Physical activity assessment: a review of methods. *Crit Rev Food Sci Nutr*. 1996;36(5):385-396.
168. Jones SL, Wood K, Thompson R, Welk GJ. Effect of monitor placement on output from three different accelerometers. *Med Sci Sports Exerc*. 1999;31(suppl):S142.
169. Crouter SE, Albright C, Bassett DR. Accuracy of Polar S410 heart rate monitor to estimate energy cost of exercise. *Med Sci Sports Exerc*. 2004;36(8):1433-1439.
170. Kurpad AV, Raj R, Maruthy KN, Vaz M. A simple method of measuring total daily energy expenditure and physical activity level from the heart rate in adult men. *Eur J Clin Nutr*. 2006;60(1):32-40.
171. Montoye H, Kemper H, Saris W, Washburn RA. *Measuring physical activity and energy expenditure*. Champaign (IL): Human Kinetics;1996.
172. Keytel LR, Lambert EV, Noakes TD. *Validation and Test-Retest Reliability of the BODY IQ Fitness Index, Based on Cardio-Respiratory Fitness and Heart Rate Response to Incremental Exercise*. Cape Town: University of Cape Town/Medical Research Council Research Unit for Exercise and Sports Medicine;2005.

Appendices

University of Cape Town

Appendix A: Ethics approval



UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: preaward@unic.uct.ac.za

12 November 2007

REC REF: 172/2005

Dr T Kolbe-Alexander
Human Biology
Sports Science Institute

Dear Dr Kolbe-Alexander

PROJECT TITLE: ARE 10 000 STEPS EQUIVALENT TO THE AMERICAN COLLEGE OF SPORTS MEDICINE AND THE CENTERS FOR DISEASE CONTROL'S GUIDELINES OF 30 MINUTES OF MODERATE PHYSICAL ACTIVITY FOR MOST DAYS OF THE WEEK?

Thank you for your letter to the Research Ethics Committee dated 01st October 2007.

It is a pleasure to inform you that the Ethics Committee has noted and approved the amendment to the above mentioned study.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROF M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

temjedi



Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: lamees.emjedi@uct.ac.za

04 August 2008

REC REF: 348/2008

Prof EV Lambert & Dr T Kolbe-Alexander
Human Biology
Sports Science Institute

Dear Prof Lambert & Dr Kolbe-Alexander

PROJECT TITLE: "STEPS PER DAY" CHRONIC DISEASE RISK FACTORS AND HEALTH CLAIMS IN SOUTH AFRICAN EMPLOYEES PRESENTING FOR HEALTH RISK APPRAISAL (HRA)

Thank you for submitting your study to the Research Ethics Committee for review.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 15 August 2009.

Please submit an annual progress report if the research continues beyond the expiry date. Please submit a brief summary of findings if you complete the study within the approval period so that we can close our file.

Please note two minor typos: informed consent: 3rd paragraph: ...identified only by (not be) a coded number.
Information sheet: page 2: to carry ON as per usual.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

lemjedi

Amendment Form

RESEARCH ETHICS COMMITTEE
 2012-07-03
 FACULTY OF HEALTH SCIENCES
 UNIVERSITY OF CAPE TOWN

Date	25 June 2012
HREC REF Number	044/2009
Protocol number (if applicable) & Protocol title	Working on Wellness (WOW): A worksite health intervention programme
Principal Investigator	Tracy Kolbe-Alexander
Department / Office Internal Mail Address	UCT/MRC Research Unit for Exercise Science and Sports Medicine (Department of Human Biology)

List of Proposed Amendments with Revised Version Numbers and Dates

The main aim of this study is to measure the effectiveness of a worksite health promotion programme, incorporating motivational interviewing techniques on improving physical activity behaviour and associated biological risk factors for CVD among South African employees at increased risk for cardiovascular diseases.

The intervention comprised of one-on-one counseling in which wellness specialists incorporated motivational interviewing. The required sample size was 840 in order to show a 10% difference in the prevalence of habitual physical activity between the control and intervention groups, with a power of 80%. However, we were unable to recruit sufficient participants in the intervention group.

One of the reasons postulated for the lower sample size was that the intervention is 'high touch' and requires the participant to attend the counseling sessions (face to face and telephonic). In the original submission, and in the informed consent form, we allocated a smaller, sub-sample who would also wear pedometers for a period of 4 days.

We would like to amend this subgroup, in that we would like to request that they wear the pedometers throughout the 10 week intervention period, and that they receive their feedback and motivational counseling via bi-weekly email, rather than face-to-face counseling. The email messages will be tailored according to the employees' readiness to change behavior, and will focus specifically on encouraging them to increase their habitual levels of physical activity. The amended consent form for the intervention group is attached.

This sub-group will be recruited similarly to the other groups, from wellness days and health risk appraisals at their worksite. These employees will be invited to participate in the email-based intervention. The rest of the methodology will remain the same as the original proposal, UCT REC 044/2009

HREC office use only (FWA00001637; IRB00001938)		
<input checked="" type="checkbox"/> Approved	<input checked="" type="checkbox"/> Type of review: Expedited	<input type="checkbox"/> Full committee
This serves as notification that all changes and documentation described above are approved.		
Signature Chairperson of the HREC	Date	4/7/2012

Appendix B: Participant Information Sheet

Title: The association between aerobic fitness and steps accumulated (Chapters 2 & 3)

Thank you for your interest in participating in the above research study to be performed in part at the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town and the Department of Basic Medical Sciences, Durban University of Technology.

Background to study

Evidence continues to accumulate that walking is the most easily accessible mode of accumulating daily physical activity. The accumulation of additional evidence regarding the frequency (how often), amount (how long) and intensity (how fast) of walking will enhance current recommendations for physical activity.

A study has been developed by the researchers in the above departments, in which a pedometer (small device clipped at waist/hip to measure the number of steps accumulated) and a heart rate monitor (strap positioned underneath clothes in chest area) are worn concurrently whilst walking on an indoor track. Participants will be required to walk at a self-regulated "brisk" pace and subsequent externally regulated walking paces. By this, a steps per minute rate for "brisk" walking will be determined based on the estimated energy expenditure and heart rate data.

Steps/day information will also be determined through the use of a pedometer worn by each participant for 5 days.

The aim of this study is therefore:

To determine, using pedometers, the association between aerobic fitness and ambulatory activity and to determine, using heart rate monitors and regulated timing, an appropriate steps per minute rate for physical activity.

Who will qualify to participate in this study?

- Healthy men and women of all fitness levels, 21-49 years of age.

- A person will NOT be included in the study if they currently have an injury, illness or chronic disease (particularly cardiovascular) that may prevent them from completing the study.
- A person will NOT be included in the study if they perform non-ambulatory aerobic physical activity, such as running, swimming and cycling that cannot be measured by a pedometer.
- A Physical Activity Readiness Questionnaire will be administered to all subjects prior to their enrollment to ensure that they are not at any health risk from performing the required exercises.

As a participant you will be asked to:

- Maintain your current exercise regimen for the duration of this study.
- On Day 1 you will be asked to sign an Informed Consent Form and to complete a Physical Activity Readiness Questionnaire.

Your height, body weight, resting heart rate and blood pressure will be determined and percentage body fat, body mass index and waist circumference measured. A 12-minute step test (outlined below) will be completed as an indication of fitness level. You will then be required to wear a pedometer for the following 5 consecutive days. Upon return, you will be required to wear a pedometer and a heart rate monitor whilst walking on an indoor track at a self-regulated “brisk” pace and five 6-minute walks at externally regulated walking paces (by means of an audible metronome). During this time measures of step per minute counts and energy expenditure will be measured.

Outline of tests:

A step test will be conducted using a 25cm high step. You will be required to step in accordance with different walking intensities (regulated by a metronome) for a total of 4 two-minute bouts with a one minute resting period after each bout. The frequency of stepping in each bout will increase steadily as dictated by an audible metronome. A heart rate monitor will be worn around the chest during the entire test so that heart rate fluctuations can be recorded. This monitoring will also be used to estimate maximal oxygen uptake and generate an overall aerobic fitness score. Furthermore, monitoring of the heart rate will ensure that your heart rate remains within an acceptable range (not exceeding 90% of age-predicted maximal heart rate).

You may decide to terminate the test, and the test must be stopped if there are any feelings of dizziness or other abnormal discomfort. This is a walking test and it is therefore unusual for major discomfort to result.

Benefits and risks to the participant

As a participant of this study you will receive comprehensive feedback on the anthropometrical and physiological measurements taken. The study's results may contribute practical advice to your individual training programs.

Participating in this study is entirely voluntary and as such you may refuse to participate or stop participating at any time without penalty. Your personal details will remain confidential and your anonymity ensured on publication of the results. Any questions concerning the equipment used and procedures of the study are encouraged.

Should you have any queries or wish to obtain further details regarding this study, please do not hesitate to contact the researcher:

Researcher:

Julian Pillay

mobile: 082 603 9111 plljul004@uct.ac.za

Supervisors:

Prof V.E Lambert; Dr T Kolbe-Alexander

Title: A cross sectional study of ambulatory activity in South African adult employees
(Chapters 4 & 5)

Thank you for your interest in participating in the above research study to be performed in part at the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town and the Department of Basic Medical Sciences, Durban University of Technology.

Background to study

Several studies have suggested that there is a linear relationship between physical activity and the health benefits derived from physical activity.

For example, epidemiological studies have shown protective effect of regular physical activity for several chronic diseases including coronary heart disease, hypertension, non-insulin-dependent diabetes mellitus, osteoporosis, and among others colonic cancer. However, more research is needed in determining the association between physical activity (in terms of the number of steps accumulated per day) and clinical outcomes (such as blood glucose, blood cholesterol, blood pressure and body fat measures).

A study has been developed by the researchers in the above institutions, in which participants are invited to wear a pedometer for a period of 5 consecutive days so that data regarding physical activity patterns can be determined and compared with health measures and self-reported information.

The aim of this study is therefore:

To determine the association between clinical measures (such as such as blood glucose, blood cholesterol, blood pressure and body fat measures) and steps per day, measured using commercially available pedometers in an employed South African, adult group.

Who will qualify to participate in this study?

- Healthy men and women of all fitness levels, 21-49 years of age.

- A person will NOT be included in the study if they currently have an injury, illness or chronic disease (particularly cardiovascular) that may prevent them from completing the study.
- A person will NOT be included in the study if they perform non-ambulatory aerobic physical activity, such as running, swimming and cycling that cannot be measured by a pedometer.
- A Physical Activity Readiness Questionnaire will be administered to all subjects prior to their enrollment to ensure that they are not at any health risk from performing the required exercises.

As a participant you will be asked to:

- Sign an Informed Consent Form and to complete a questionnaire regarding your current physical activity and health.
- After having undergone voluntary screening (demographics and body measures) you will be invited to subsequently wear a pedometer for 5 consecutive days.

Benefits and risks to the participant

The study's results may contribute practical advice to your individual physical activity programs.

Participating in this study is entirely voluntary and as such you may refuse to participate or stop participating at any time without penalty. Your personal details will remain confidential and your anonymity ensured on publication of the results. Any questions concerning the equipment used and procedures of the study are encouraged.

Should you have any queries or wish to obtain further details regarding this study, please do not hesitate to contact me:

Researcher:

Julian Pillay – 082 603 9111 or pilljul004@uct.ac.za

Supervisors:

Prof VE Lambert

Dr T Kolbe-Alexander

Title: A pedometer-based health promotion intervention in an employed adult group
(Chapters 6 & 7)

Thank you for your interest in participating in the above research study to be performed in part at the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town and the Department of Basic Medical Sciences, Durban University of Technology.

Background to study

Several studies have suggested that there is a linear relationship between physical activity and the health benefits derived from physical activity.

For example, epidemiological studies have shown protective effect of regular physical activity for several chronic diseases including coronary heart disease, hypertension, non-insulin-dependent diabetes mellitus, osteoporosis, and among others colonic cancer. However, research continues on the effects of physical activity programs using alternative strategies to improve physical activity.

A study has been developed by the researchers in the above institutions, in which participants are invited to participate in a 10-week pedometer-based program aimed at improving physical activity and health.

The aim of this study is therefore:

The aim of this study is to evaluate the effectiveness of a pedometer-based intervention complemented by individualised, email-based feedback promoting physical activity.

Who will qualify to participate in this study?

- Healthy men and women of all fitness levels, 21-49 years of age.
- A person will NOT be included in the study if they currently have an injury, illness or chronic disease (particularly cardiovascular) that may prevent them from completing the study.
- A person will NOT be included in the study if they perform non-ambulatory aerobic physical activity, such as running, swimming and cycling that cannot be measured by a pedometer.

- A Physical Activity Readiness Questionnaire will be administered to all subjects prior to their enrollment to ensure that they are not at any health risk from improving their current physical activity levels.

As a participant you will be asked to:

- Sign an Informed Consent Form and to complete a questionnaire regarding your current physical activity and health.
- After having undergone voluntary screening (demographics and body measures) you will be invited to subsequently wear a blinded pedometer for at least 5 consecutive days.
- Pedometer feedback will be provided upon returning the pedometer, and strategies to improve physical activity levels will be discussed.
- You will then be randomly allocated to an intervention group or a wait-listed control group.
- The intervention group will be required to wear an un-blinded pedometer for 10 consecutive weeks as a motivational tool to improve ambulatory physical activity. Intervention group participants will also be required to forward (via email) bi-weekly pedometer data to the researcher. Feedback on pedometer data will be provided to all intervention group participants.
- Control and intervention group participants will receive general motivational messages on strategies to improve physical activity levels.
- After the 10 week intervention (week 12) all participants will be required to wear a blinded pedometer for at least 5 consecutive days and screening measurements (as conducted on Day 1) will be performed upon return.
- Control group participants will be subsequently offered the intervention.

Benefits and risks to the participant

The study's results may contribute practical advice to your individual physical activity programs.

Participating in this study is entirely voluntary and as such you may refuse to participate or stop participating at any time without penalty. Your personal details will remain confidential and your anonymity ensured on publication of the results. Any questions concerning the equipment used and procedures of the study are encouraged.

Should you have any queries or wish to obtain further details regarding this study, please do not hesitate to contact me:

Researcher:

Julian Pillay – 082 603 9111 or pilljul004@uct.ac.za

Supervisors:

Prof VE Lambert

Dr T Kolbe-Alexander

University of Cape Town

Appendix C: Informed consent

Title: The association between aerobic fitness and steps accumulated (Chapters 2 & 3)

I, _____ hereby volunteer to participate in the research study on “Comparing exercise dose-response to steps per day, measured using commercially available pedometers”, to be performed at the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town and Department of Basic Medical Sciences, Durban University of Technology.

I understand the procedures of this study, which have been described in detail in the Participant’s Information Sheet provided. Briefly, I have been asked to maintain my current exercise regimen for the duration of this study;

I will complete a Physical Activity Readiness Questionnaire regarding my current ability to perform physical activity. I will have my body measurements such as height, body weight, blood pressure and body fat measures and I will perform an aerobic fitness test (12-minute step test).

During this test, I will be required to walk on a stepper at regulated walking intensities for four 2-minute bouts with a 1-minute rest period between each bout and at the end of the last bout.

I will then be required to wear a blinded pedometer for the subsequent 5 consecutive days. Upon return, I will be required to wear a pedometer and a heart rate monitor whilst walking on an indoor track at a self-regulated “brisk” pace for 10 minutes and five subsequent 6-minute walks at externally regulated walking paces (by means of an audible metronome).

I am aware that the fitness test may result in exhaustion. I am thus aware that the risks of this test may be similar to that of vigorous exercise. I acknowledge that, although remote, the possibility does exist that I may lose my balance. I have also been informed that my personal details will remain confidential and my anonymity ensured on publication of the results of this study.

I acknowledge that I am participating in this study of my own free will. I understand that I may refuse to participate or stop participating at any time without penalty. If I wish, I will be given a copy of this consent form. I have been informed that I may ask any questions about the procedures and results of the study, and that, upon completion of the study, I will be

provided with comprehensive feedback on my personal results and the results and interpretations of the study.

Participant's name: _____

Signature: _____ Date: _____

Investigator's name: _____

Signature: _____ Date: _____

Witness's name: _____

Signature: _____ Date: _____

University of Cape Town

Title: A cross sectional study of ambulatory activity and health claims costs in South African health insured employees
(Chapters 4&5)

I, _____ hereby volunteer to participate in the research study on “The association between health claims costs and physical activity, measured using commercially available pedometers in an employed South African health insured population”, to be performed by the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town.

I understand the procedures of this study, which have been described in detail in the Participant’s Information Sheet provided. Briefly, I have been asked to maintain my current exercise regimen for the duration of this study; on Day 1, after having undergone voluntary screening (demographics, height, body mass index, waist circumference, cholesterol, glucose, blood pressure) I will be required to complete a questionnaire regarding my current health and physical activity and to wear a blinded pedometer for the subsequent 5 days.

I have also been informed that my personal details will remain confidential and my anonymity ensured on publication of the results of this study.

I acknowledge that I am participating in this study of my own free will. I understand that I may refuse to participate or stop participating at any time without penalty. If I wish, I will be given a copy of this consent form. I have been informed that I may ask any questions about the procedures and results of the study, and that, upon completion of the study, I will be provided with comprehensive feedback on my personal results and the results and interpretations of the study.

Participant’s name: _____

Signature: _____ Date: _____

Investigator’s name: _____

Signature: _____ Date: _____

Witness's name: _____

Signature: _____ Date: _____

University of Cape Town

Title: A pedometer-based health promotion intervention in an employed adult group
(Chapters 6 & 7)

I, _____ hereby volunteer to participate in the research study on “The association between health claims costs and physical activity, measured using commercially available pedometers in an employed South African health insured population”, to be performed by the UCT/MRC Research Unit for Exercise Science and Sports Medicine within the Department of Human Biology, University of Cape Town.

I understand the procedures of this study, which have been described in detail in the Participant’s Information Sheet provided.

- On Day 1, after having undergone voluntary screening (demographics, height, body mass index, waist circumference, cholesterol, glucose, blood pressure) I will be required to complete a questionnaire regarding my current health and physical activity.
- I will be thereafter required to wear a blinded pedometer for the subsequent 5 days.
- Pedometer feedback will be provided to me, upon returning the pedometer, and strategies to improve physical activity levels will be discussed.
- I will then be randomly allocated to an intervention group or a wait-listed control group.
- If allocated to the intervention group, I will be required to wear an un-blinded pedometer for 10 consecutive weeks as a motivational tool to improve ambulatory physical activity. I will also be required to forward (via email) bi-weekly pedometer data to the researcher. Feedback on pedometer data will be provided to me and a general motivational messages on strategies to improve physical activity levels will accompany this feedback information.
- Should I be allocated to the control, I will receive general motivational messages on strategies to improve physical activity levels, bi-weekly. I will not, however, be provided with a pedometer during the 10 weeks.

- After the 10 week intervention (week 12) I will be required to wear a blinded pedometer for at least 5 consecutive days and screening measurements (as conducted on Day 1, will be performed upon return.
- As a control group participant, I will be offered the intervention.

I have also been informed that my personal details will remain confidential and my anonymity ensured on publication of the results of this study.

I acknowledge that I am participating in this study of my own free will. I understand that I may refuse to participate or stop participating at any time without penalty. If I wish, I will be given a copy of this consent form. I have been informed that I may ask any questions about the procedures and results of the study, and that, upon completion of the study, I will be provided with comprehensive feedback on my personal results and the results and interpretations of the study.

Participant's name: _____

Signature: _____ Date: _____

Investigator's name: _____

Signature: _____ Date: _____

Witness's name: _____

Signature: _____ Date: _____

Appendix D: Modified Physical Activity Readiness Questionnaire

Name			Date
DOB	Age	Home Phone	Work Phone

Regular exercise is associated with many health benefits, yet any change in activity may increase the risk of injury. Completion of this questionnaire is a first step when planning to increase the amount of physical activity in your life. Please read each question carefully and answer every question honestly:

Yes	No	1) Has a physician ever said you have a heart condition and you should only do physical activity recommended by a physician?
Yes	No	2) When you do physical activity, do you feel pain in your chest?
Yes	No	3) When you were not doing physical activity, have you had chest pain in the past month?
Yes	No	4) Do you ever lose consciousness or do you lose your balance because of dizziness?
Yes	No	5) Do you have a joint or bone problem that may be made worse by a change in your physical activity?
Yes	No	6) Is a physician currently prescribing medications for your blood pressure or heart condition?
Yes	No	7) Are you pregnant?
Yes	No	8) Do you have insulin dependent diabetes?
Yes	No	9) Are you 69 years of age or older?
Yes	No	10) Do you know of any other reason you should not exercise or increase your physical activity?

If you answered yes to any of the above questions, talk with your doctor BEFORE you become more physically active. Tell your doctor of your intent to exercise and to which questions you answered yes. If you answered no to all questions, you can be reasonably positive that you can safely increase your physical activity gradually. If your health changes so you then answer yes to any of the above questions, seek guidance from a physician.

Participant Signature	Date
------------------------------	-------------

For Smokers only: Please tick only one of the options that best describe your current smoking situation

- I have no intention of becoming tobacco free in the next 6 months.
- I intend to become tobacco free in the next 6 months.
- I am trying to become tobacco free, but I am not always successful.
- Although I am currently using tobacco again, in the past I have been tobacco free for more than 3 months.

Non Smoking Declaration

I confirm that I am a non-smoker and that:

1. I do not smoke and have not smoked any tobacco products, regularly or occasionally, within the last 3 months.
2. I agree to inform my insurers within 3 months of commencing smoking. I also agree to the reversal of any points that may have been awarded for being a non-smoker, if they are awarded within the same calendar year in which I commenced smoking.
3. I agree to undergo an u-cotine test to prove my non-smoker status should my insurer request one. I understand that such requests are made randomly.

Please sign here to accept this declaration.

3.2. Alcohol Use: Please make the appropriate selection relating to your weekly alcohol consumption.

- I don't have any alcoholic drinks
- Never more than 1 - 2 drinks per occasion or per day.
- 3 - 4 drinks in a day, only 2 - 3 per month.
- 3 - 4 drinks in a day, 4 times per month
- 3 or more drinks in a day, more than once a week and / or more than 4 drinks at a time.

3.3. Sleep: Please make the appropriate selection relating to your sleeping pattern.

- Undisturbed sleep
 - Disturbed sleeping pattern, 3-4 nights per week
 - Disturbed sleeping pattern, 1-2 nights per week
 - Disturbed sleeping pattern, 5-7 nights per week
- In general, I wake up:
- Refreshed
 - Unrefreshed

3.4 Stress Management:

Are you coping with your daily stress?

- No, and I have no intention to implement coping strategies in the next 6 months.
- No, but I intend to learn how to cope with my daily stress in the next 6 months.
- I am trying to cope but I do not always cope successfully.
- Yes, I have been coping with my daily stress, but for LESS than 6 months.
- Yes, I have been coping with my daily stress for MORE than 6 months.
- Although I am not coping well with my daily stress, in the past I have coped well for more than 3 months.

3.5 Dietary Assessment

Think about your eating habits over the past year or so. Approximately how often do you eat each of the following foods? Tick one box for each food.

Meat/Snack	Never/Once or less than once per month	2-3 times per month	1-2 times per week	3-4 times per week	5+times per week
Hamburgers or cheeseburgers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Red meat, e.g. beef and mutton	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fried chicken (with skin)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hot dogs, frankfurters, salami, Russians, sausages	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cold meats, e.g. polony, cheese / olive loaf, beef (+ fat), etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Salad dressing, mayonnaise	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Margarine or butter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eggs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bacon or pork sausage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cheese or cheese spread	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Full-cream milk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Potato crisps, corn chips, popcorn, etc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Potato chips ("slap chips")	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ice cream	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Doughnuts, cake, cookies, puddings, etc	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Fruit/Vegetables/Fibre					
	Never/Less than once per week	about once per week	2-3 times per week	4-5 times per week	Every day
Brown rice / wholewheat pasta	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit (not counting juice)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Green salad	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Potatoes with skin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dried beans,e.g baked beans, Kidney beans, legumes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
High-fibre/bran cereal or high-fibre porridge or oat porridge	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wholewheat, brown or high-fibre bread (e.g. rye)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Do you currently feel that you are following a healthy diet?

- No, and I have no intention of following a healthy diet in the next 6 months.
- No, but I intend to follow a healthy diet in the next 6 months.
- I am trying to follow a healthy diet, but I am not always successful.
- Yes, I have been following a healthy diet, but for LESS than 6 months.
- Yes, I have been following a healthy diet for MORE than 6 months.
- Although I am currently following a less healthy diet, in the past I have followed a healthy diet for more than 3 months.

SECTION 4. Physical Activity Assessment

4.1. Current Physical Activity Levels: Please tick the most appropriate description of your current level of physical fitness.

- Poor
- Fair
- Acceptable
- Good
- Excellent

4.2. Work and/or daily activities: Please tick the box that best describes your activities in the working day (e.g. office and home based) - not your leisure time physical activity.

- I sit down and do not walk about much.
- I mostly walk and also lift heavy loads or climb stairs.
- I walk about a lot, but do not carry heavy loads.
- I do heavy manual work and physically strain myself.

4.3. Physical Activity Status: A typical exercise session consists of 20-30 minutes of exercise.

Over the past three months I would describe myself as having been:

- Inactive (please go straight to 4.4)
- Occasionally active - "at least 1-4 sessions per month"
- Somewhat active - "at least 1-2 sessions per week"
- Reasonably active - "at least 2-3 sessions per week"
- Active - "at least 3-4 sessions per week"
- Very active - "more than 4 sessions per week"

Over the past three months, the duration of my exercise sessions and/or recreational activity has ranged between a **minimum** of, and a **maximum** of:

(Minimum) Column A	(Maximum) Column B	On average, my total exercise time for the week is:	On average, I would describe the intensity of these sessions as:
<input type="checkbox"/> 0-15 minutes	<input type="checkbox"/> 0-15 minutes	<input type="checkbox"/> <60 minutes per week	<input type="checkbox"/> Very light (seated activity)
<input type="checkbox"/> 15-30 minutes	<input type="checkbox"/> 15-30 minutes	<input type="checkbox"/> 60-90 minutes per week	<input type="checkbox"/> Light (eg: housework)
<input type="checkbox"/> 30-60 minutes	<input type="checkbox"/> 30-60 minutes	<input type="checkbox"/> 90-120 minutes per week	<input type="checkbox"/> Light sweat
<input type="checkbox"/> 1-2 hours	<input type="checkbox"/> 1-2 hours	<input type="checkbox"/> 2-3 hours per week	<input type="checkbox"/> Sweating
<input type="checkbox"/> >2 hours	<input type="checkbox"/> >2 hours	<input type="checkbox"/> 3-4 hours per week	<input type="checkbox"/> Vigorous
		<input type="checkbox"/> >4 hours per week	

4.4. Please tick only one of the six options that best describe your current situation or what you intend to do regarding physical activity in the future. **Are you moderately physically active?**

- No, and I have no intention of becoming moderately physically active in the next 6 months.
- No, but I intend to become moderately physically active in the next 6 months.
- I am trying to become moderately active, but my exercise routine is irregular.
- Yes, I have been moderately physically active, but for LESS than 6 months.
- Yes, I have been moderately physically active for MORE than 6 months.
- Although I am currently inactive, in the past I have been physically active for more than 3 months.

Appendix F: Uploading pedometer data

Step 1

Download CD and save on desktop. This is only carried out to download the Omron programme onto your PC and need not be done thereafter.

Step 2

Open Omron health manager programme

Step 3

Connect pedometer to computer via USB cable. The letters "PC" will appear on your pedometer. It is now ready to download pedometer data.

Step 4

Click on the "add user" option on top of page and click "ok"

Step 5

Under the "user name" option on left hand side of page, type in your name with a number 1 next to it. (for example JD1). Thereafter, each time you download pedometer data, use the subsequent numeric eg JD2, JD3 etc).

Step 6

Click the "graphs screen" option on top of page. Now click on the "walking style step counter" option.

Step 7

Click the "download data" option on top of page and click "yes" on the 2 subsequent pop-up boxes that appear in the middle of the page.

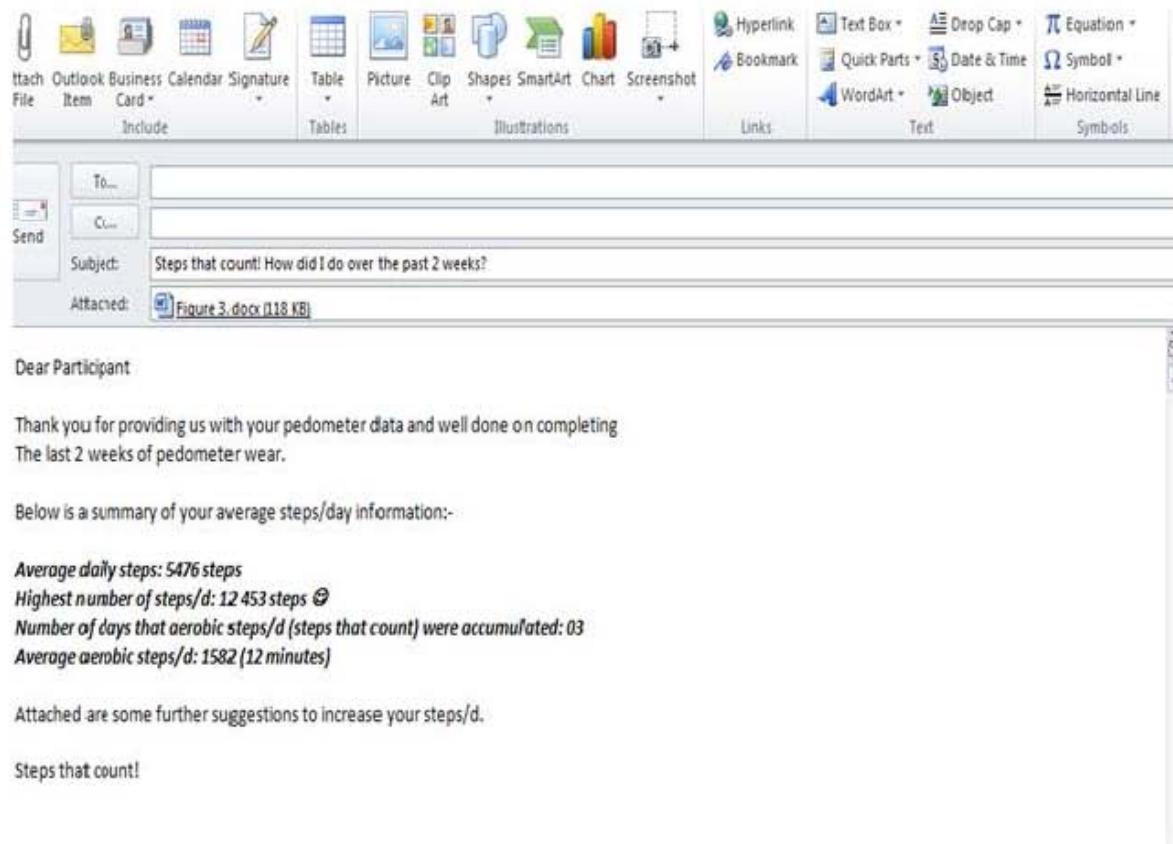
Step 8

Once the "completed" box appears, click "ok".

Your download is now complete and you can view your latest results. Should you wish to look at previous results downloaded, click on "file" and choose the "back to user management" option. This will provide you with the list of downloads recorded for you to choose the relevant download for viewing.

Enjoy using your pedometer

Appendix G: Feedback information provided to participants (Feasibility study)



The screenshot shows an Outlook email window. The ribbon at the top includes 'Include', 'Tables', 'Illustrations', 'Links', 'Text', and 'Symbols' tabs. The email header shows the subject 'Steps that count! How did I do over the past 2 weeks?' and an attachment 'Figure 3.docx (118 KB)'. The body of the email contains the following text:

Dear Participant

Thank you for providing us with your pedometer data and well done on completing The last 2 weeks of pedometer wear.

Below is a summary of your average steps/day information:-

Average daily steps: 5476 steps
Highest number of steps/d: 12 453 steps 🏆
Number of days that aerobic steps/d (steps that count) were accumulated: 03
Average aerobic steps/d: 1582 (12 minutes)

Attached are some further suggestions to increase your steps/d.

Steps that count!

Steps that count: Be physically active every day.

Physical activity need not be strenuous to be beneficial. A start of just 10 minutes of brisk walking a day can produce immediate benefits such as improved cardiovascular fitness, muscular strength, mood-enhancement and improved self-confidence.

There are many ways to increase your daily steps. Use your imagination and come up with your own list. As a start, here are four useful suggestions:-

- 1. Take a walk with your spouse, child, friend or pet***
- 2. Use the stairs instead of the lift/escalator***
- 3. Park farther from your destination***
- 4. Window shop 😊***





Steps that count: Walk tall

Maintain a good posture while walking to maximise the benefits of physical activity.

Here are a few do's and don'ts:-

Do's:-

1. Use good posture. Walk tall, look forward, keep your chest raised, and shoulders relaxed.
2. Tighten your abs and buttocks.
3. Breathe naturally. As you walk, take deep, rhythmic breaths, to get the maximum amount of oxygen through your system.
4. Walk fast enough that your breathing is increased yet you are not out of breath.

Don'ts

1. Do not over stride
2. Do not use too vigorous arm movements
3. Do not look at the ground
4. Do not hunch your shoulders

Steps that count: Walk faster

Walk at a moderate-vigorous walking pace. A good indication of having reached this pace is an evident increase in breathing rate.

A useful way of reaching and maintaining a brisk pace is to find a walking buddy to help “keep the pace” and make a date, each day for a walk towards wellness.

University of Cape Town

Steps that count: Walk longer

30 minutes of moderate intensity physical activity at least 5 days a week is the recommended physical activity guideline. This can also be accumulated in bouts of 10 minutes.

The best way to attain such a goal is to time-table this target into your day.

Log Physical Activities

Note: Your usual daily activities are already accounted by Fitness Assistant. Please, log only activities that contribute to ADDITIONAL calories burned compared to your ordinary activities

Date and Logged Activities

May, 2008

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Logged Activities 31 May 2008	Duration	Burned	Added
07:37 PM Bicycling, 10-11.9 mph, leisure, sl...	20 min	149 cal	119 cal

Activity Filter Activities:

Activity: Bakery, general, moderate effort
Bakery, light effort
Bicycling, 10-11.9 mph, leisure, slow, light effort
Bicycling, 12-13.9 mph, leisure, moderate effort
Bicycling, 14-15.9 mph, racing or leisure, fast, vigorous effort
Bicycling, 16-19 mph, very fast, racing general
Bicycling, <10 mph, leisure

MET Value: Duration: minutes
Time of Day:

Burned: Additional:

Steps that count: A recap

Here's a recap of all of the ideas presented over the past weeks:-

Be physically active every day.

Increase your daily steps. Use your imagination and come up with your own list.

Walk tall

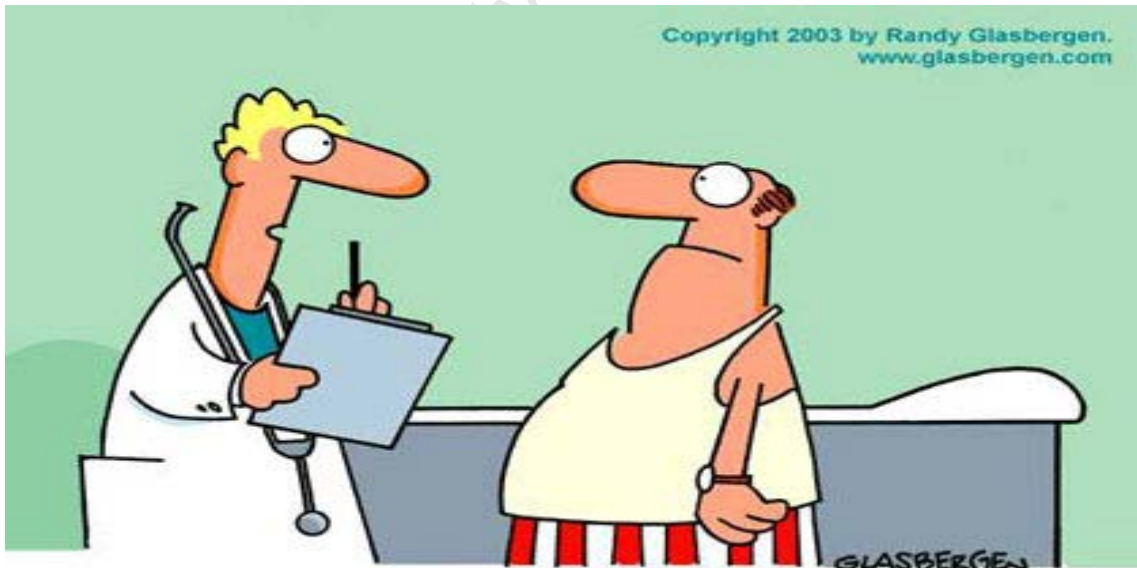
Maintain a good posture while walking to maximise the benefits of physical activity.

Walk faster

Walk at a moderate-vigorous walking pace. A good indication of having reached this pace is an evident increase in breathing rate

Walk longer

Time-table physical activity into your day.



What suits you better- walking for 30 minutes a day or being dead 24 hours a day?

Appendix I: Pedometer Intervention feedback Questionnaire

Name: _____

Thank you for taking the time to complete this questionnaire. This will take approximately 10 minutes and will really help us to improve the programme. Thank you very much.

C (Evaluation)

Please circle the number that best describes how you think about the following questions:

1. Did the intervention catch your attention?	1	2	3	4	5	6	7
	(not at all)					(Very)	
2. How informative was the health information from the clinical measures and tests?	1	2	3	4	5	6	7
	(not at all)					(Very)	
3. How beneficial was the health information provided to you?	1	2	3	4	5	6	7
	(not at all)					(Very)	
4. How encouraging/motivating was the information provided to you in the intervention?	1	2	3	4	5	6	7
	(not at all)					(Very)	
5. How useful was the intervention in helping you reach your goal?	1	2	3	4	5	6	7
	(not at all)					(Very)	
6. How trustworthy was the information, in your opinion?	1	2	3	4	5	6	7
	(not at all)					(Very)	
8. How likely is it that you will, in the future, use a pedometer?	1	2	3	4	5	6	7
	(not at all)					(Very)	
9. How likely is it that you will encourage others to wear a pedometer?	1	2	3	4	5	6	7
	(not at all)					(Very)	
10. How likely is it that you will make changes in your behavior or lifestyle based on the pedometer information?	1	2	3	4	5	6	7
	(not at all)					(Very)	

D (Adherence)

How were your physical activity patterns during the intervention?

1. I followed the recommendation of steadily increasing steps/day until at least 30 minutes of aerobic steps were attained at least 5 days a week.	1 (not at all)	2	3	4	5	6 (Very)	7
2. My physical activity patterns were consistent throughout the 10 weeks.	1 (not at all)	2	3	4	5	6 (Very)	7
3. I stuck to my goals for improving physical activity throughout the 10 week intervention.	1 (not at all)	2	3	4	5	6 (Very)	7
4. I was physically active during the intervention (e.g. taking stairs, walking instead of driving etc.)	1 (not at all)	2	3	4	5	6 (Very)	7
5. I exercised regularly	1 (not at all)	2	3	4	5	6 (Very)	7
6. Overall, I became more physically active during the intervention.	1 (not at all)	2	3	4	5	6 (Very)	7

E (self-efficacy exercise)

A number of situations are described below that can make it hard to stick to an exercise routine. We would like to know how confident you are that you can get yourself to perform your exercise routine regularly.

Circle the number that best describes your feeling of confidence to perform exercise in each situation according to the following scale:

0 1 2 3 4 5 6 7 8 9 10
Not confident **very confident**

1. I can perform my exercise routine when I am feeling tired

0 1 2 3 4 5 6 7 8 9 10

2. I can perform my exercise routine when I am feeling under pressure from work

0 1 2 3 4 5 6 7 8 9 10

3. I can perform my exercise routine during bad weather

0 1 2 3 4 5 6 7 8 9 10

4. I can perform my exercise routine after recovering from an injury that caused me to stop exercising

0 1 2 3 4 5 6 7 8 9 10

5. I can perform my exercise routine during or after experiencing personal problems

0 1 2 3 4 5 6 7 8 9 10

6. I can perform my exercise routine when I am feeling depressed

0 1 2 3 4 5 6 7 8 9 10

7. I can perform my exercise routine when I am feeling anxious

0 1 2 3 4 5 6 7 8 9 10

8. I can perform my exercise routine after recovering from an illness that caused me to stop exercising

0 1 2 3 4 5 6 7 8 9 10

9. I can perform my exercise routine when I feel physical discomfort when I exercise

0 1 2 3 4 5 6 7 8 9 10

10. I can perform my exercise routine I can perform my exercise routine after a vacation

0 1 2 3 4 5 6 7 8 9 10

11. I can perform my exercise routine when I have too much work to do at home

0 1 2 3 4 5 6 7 8 9 10

12. I can perform my exercise routine when visitors are present

0 1 2 3 4 5 6 7 8 9 10

13. I can perform my exercise routine when there are other interesting things to do

0 1 2 3 4 5 6 7 8 9 10

14. I can perform my exercise routine if I don't reach my exercise goals

0 1 2 3 4 5 6 7 8 9 10

15. I can perform my exercise routine without support from my family or friends

0 1 2 3 4 5 6 7 8 9 10

16. I can perform my exercise routine during a vacation

0 1 2 3 4 5 6 7 8 9 10

17. I can perform my exercise routine when I have other time commitments

0 1 2 3 4 5 6 7 8 9 10


18. I can perform my exercise routine after experiencing family problems

0 1 2 3 4 5 6 7 8 9 10

Aspects I likes about the intervention

Aspects that I did not like/could be improved in the intervention

**Appendix J: Feedback information provided to participants
(Randomised controlled trial)**

Send	To...	
	Cc...	
	Subject:	Steps that count! : How did I do over the past 2 weeks?
	Attached:	 Figure 3.docx (119 KB)

Dear Participant.

Thank you for providing us with your pedometer data and well done on completing the last 2 weeks of pedometer wear.

Below is a summary of your average steps/day information:-

Average daily steps/d accumulated: 5476 steps

Number of days that aerobic steps were accumulated: 03

Average aerobic steps/d (steps that count): 1582 (12 minutes)

Remember, the current public health recommendation for physical activity is a minimum of **30 minutes of moderate intensity physical activity (or steps that count!) at least 5 days a week** so keep going.

The suggestion to increase your steps by approximately 10% per week until the target of at least 30 minutes of **steps that count** is achieved and maintained is a steady way to ensure improvement towards reaching this target.

Attached are some further ideas to increase your steps per day.

Steps that count!

ABOUT THE AUTHOR

Julian David Pillay was born in Durban, South Africa on the 11th of June 1975. After matriculating in 1992, he was accepted at the University of Durban-Westville for tertiary studies and completed an honours degree in Medical science in 1996, majoring in Human Anatomy and Pharmacology. He then took up a lecturing position at the ML Sultan Technikon, Durban in 1997 teaching Anatomy and Physiology to allied health students. In 2001, he began pursuing a masters' degree in Public health at the University of KwaZulu Natal and completed this in 2005. After succeeding in attaining a scholarship from the National Research Foundation (South Africa), he enrolled for the PhD program in 2007 at the University of Cape Town, Department of Human Biology. During this year (2007), he completed coursework modules related to sports science and identified a specific research area, a research topic and supervisors that assisted in formulating a research proposal for his doctoral research. In 2008 he was invited to be co-supervised by academics in the Netherlands as part of a collaborative initiative between the University of Cape Town (RSA) and the Vrije University (Netherlands). In December 2012, Julian submitted his thesis at the University of Cape Town, RSA.

Julian will continue working as an academic and further his research endeavours in the field of physical activity and public health. As such, he hopes to provide mentorship and supervision to other post-graduate students embarking on master's and doctoral research.

Julian will also continue and strengthen the collaborative links with the University of Cape Town, Vrije University and other local and international institutions through continued research and capacity building. Additionally, he plans to use pedometer-based physical activity and health promotion initiatives as a vehicle for community engagement and public health awareness.