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Physical behaviours in adults with lower limb absence: Motivations and barriers; the role of healthcare professionals; measurement; and free-living patterns

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Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Abstract

Strong evidence exists to support participation in physical activity to maintain and improve health in general and clinical populations. However, little is known about the physical behaviours of adults with lower limb absence.

This thesis makes four original contributions to knowledge. The first contribution is a systematic review conducted to explore the motivations and barriers to participation in physical activity, exercise and sports in people with lower limb absence. Findings show that adults with lower limb absence are not participating in physical activity conducive to health benefits. Post-amputation levels of participation are lower than pre-amputation levels, and more barriers than motivations exist to participation.

The second contribution is the exploration of healthcare professionals' awareness and understanding of physical activity guidelines and how physical activity is promoted in clinical settings. Results from an online survey designed for United Kingdom healthcare professionals show that this group has awareness and knowledge of physical activity guidelines. With appropriate support and resources prosthetic healthcare professionals can be encouraged to incorporate physical activity promotion into routine clinical practice.

The third contribution is the examination of reliability and validity of an accelerometer when worn by adults with lower limb absence. The activPAL™ accelerometer is a reliable and valid measurement tool in adults with lower limb absence when used in a laboratory setting, and placement of the monitor on the sound side limb is recommended for testing.

The fourth contribution is the findings from a free-living study of physical behaviour in adults with lower limb absence who are shown to be physically active daily but could be encouraged to be more active and less sedentary. Data were also matched on gender, age and employment status to that of a non-clinical control group where it was shown those with limb absence are less active than healthy individuals.

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In conducting this research, I wanted to understand whether a positive difference could be made to improving the health, well-being and knowledge of adults with lower limb absence and their healthcare professionals. It is through their voluntary participation that this has been possible and I am indebted to everyone for their contribution.

I am grateful to colleagues and fellow students in the Physical Activity for Health research group for making me feel welcome and supported. Similarly, my friends and colleagues in the National Centre for Prosthetics and Orthotics, and later the Department of Biomedical Engineering, have been extremely helpful over the years. In particular, Mr Harry Kinsman, an excellent listener, was regularly sought for his shrewd advice. It has also been a pleasure to collaborate with Dr Philippa Dall and her colleagues from Glasgow Caledonian University and I thank them for their contributions.

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For everyone who has limb absence and those who care for them.

In dedication to my father the late R. Barry Gledhill
and to our daughter Madeleine Jane Deans.
I wish you were both here.

Career pathway leading to PhD study

My maternal grandfather had an undiagnosed congenital heart condition, subsequently developed diabetes mellitus, and latterly led a sedentary lifestyle. At the age of 63 he passed away a few days following below-the-knee amputation surgery due to compromised circulation in his foot. He did not undertake prosthetic rehabilitation which may have given him new-found and increased mobility using a prosthesis. This must have been engrained in my psyche; in 1988 I embarked on a BSc in Prosthetics and Orthotics at the University of Strathclyde, only one of a few International Society for Prosthetics and Orthotics approved worldwide programmes.

Following qualification as a Prosthetist/Orthotist, I spent four years in a hospital in South Wales providing care for people with limb absence. I then studied in New York City and gained American Council on Exercise (ACE) Personal Trainer certification. The opportunity arose in 1997 to return to Strathclyde to take up the position of Lecturer at the National Centre for Prosthetics and Orthotics. Being expertly advised by the late Professor Hughes to undertake research in areas that interested me, I broadened my horizons and enjoyed early career research experience and education on the MSc. in Medicine and Science in Sports and Exercise facilitated by the Universities of the City of Glasgow. Professor Nanette Mutrie supervised my dissertation in which I explored physical activity and quality of life in people with limb absence. One of the findings from my published research was that this population were motivated to increase their physical activity levels if suitable support mechanisms were in place. I was keen to explore this further.

Building on this work, the opportunity arose to undertake part-time PhD study beginning in early 2009. Again Professor Mutrie and Mrs Sandra Sexton were encouraging supervisory team members offering important guidance and support. Upon their 2010 departure from the University of Strathclyde, Drs Rowe, Kirk and McGarry seamlessly undertook the roles and responsibilities of expert PhD supervisors.

Aims, clinical relevance of research, research questions and thesis overview

There were four aims of this research. The first aim was to identify existing gaps in the evidence around motivations and barriers to physical activity, exercise and sport in people with limb absence. The second aim was to explore the awareness and knowledge of United Kingdom prosthetic rehabilitation healthcare professionals in relation to recommended physical activity guidelines. Their current and desirable practices in relation to physical activity promotion were also explored. The third aim was to investigate the reliability and validity of the activPAL™ accelerometer as a measurement tool for use in adults with lower limb absence. The final aim was to examine the free-living behaviour of adults with lower limb absence and to compare this with healthy matched controls.

This research has clinical relevance. The findings from this work can be used to form recommendations about how best to increase prosthetic rehabilitation healthcare professionals' knowledge of physical activity guidelines, and to encourage their involvement in promotion of physical activity. The research findings can also inform this clinical population or those involved in their care about: methods for measuring physical behaviour; patterns of physical behaviour of people with lower limb absence in the United Kingdom; and the importance of developing interventions to help maintain or increase participation in a physically active lifestyle.

There are four research questions:

1. What are the motivations and barriers to participation in physical activity, exercise and sports for those who have limb absence? (Study 1)
2. What is the awareness and knowledge of prosthetic rehabilitation healthcare professionals in relation to physical activity guidelines, and what are the current and desirable practices of prosthetic rehabilitation healthcare professionals in relation to physical activity promotion? (Study 2)
3. Is the activPAL™ monitor a reliable and valid device for measuring physical behaviour in adults with lower limb absence? (Study 3)

4. What is the free-living physical behaviour of adults with lower limb absence? (Study 4)

Chapters 1 and 2 introduce the key topics and present an appraisal of the literature. Under-researched areas were identified which led to the creation of the research questions and the design of the four thesis studies.

Chapter 3 introduces Study 1 which describes the development and implementation of a systematic literature review. This detailed review served to inform the reader about the state of the science with regards to the motivations and barriers in sports, exercise and physical activity. The findings from this first study also led to the refocussing and narrowing of the research to examine only physical activity for health in subsequent studies, and not sports and exercise.

Chapter 4 presents Study 2. A survey was designed for healthcare professionals caring for people with lower limb absence to determine their awareness and knowledge of physical activity guidelines, and their current and desirable physical activity promotion practice.

Studies 3 and 4 are detailed in Chapter 5 and Chapter 6 and transfer focus from healthcare professionals to adults with lower limb absence. These chapters aim to provide an understanding of physical behaviour patterns in this clinical population. Chapter 5 describes Study 3 which examined interrater reliability of directly observed participant stepping and reclining was ascertained. Further, this study explored the reliability and validity of a measurement instrument for measuring stepping and reclining of 15 adults with lower limb absence in a laboratory setting.

The fourth and final study is described in Chapter 6. In Study 4, a sample of United Kingdom dwelling participants were recruited to a free-living study and accelerometer data collected from eight days of continuous wear by 57 adults with lower limb absence. Data from a healthy control group were matched with the clinical group data to provide a description of the comparisons in physical behaviours.

Chapter 7 is the final chapter and provides a resume of the thesis aims and research questions, an evaluation and interpretation of the findings, and makes recommendations for research foci for the future.

Publications and conference presentations

Thesis publications and manuscripts

Deans, S., Burns, D., McGarry, A., Murray, K. and Mutrie, N. (2012). Motivations and barriers to prosthesis users participation in physical activity, exercise and sport: A review of the literature. *Prosthetics and Orthotics International.* 36, 260-269. doi: 10.1177/0309364612437905

Deans, S.A., Kirk, A.F., McGarry, A.C., Rowe D.A. Awareness and knowledge of physical activity guidelines, and current and desirable practice towards physical activity promotion: An online survey for prosthetic rehabilitation healthcare professionals (manuscript in preparation for submission to *Prosthetics and Orthotics International*)

Deans, S.A., Dall, P.M., Kirk, A.F., McGarry, A.C., Rowe D.A. Objectively measured free-living physical behaviour in adults with lower limb absence (manuscript in preparation for submission to *PLOS One*)

Deans, S.A., Kirk, A.F., McGarry, A.C., Rowe D.A. Objective measurement of simulated lifestyle activities in adults with lower limb absence: Reliability and validity of the activPAL™ accelerometer during simulated lifestyle activities (manuscript in preparation for submission to *Journal for the Measurement and Physical Behaviours*)

Thesis conference presentations

Rowe, D.A., Deans, S.A., Kirk, A.F., McGarry, A.C., Mitchell, H., Sloan, L. Walker, A. (2017). Interrater reliability of directly-observed stepping and reclining in lower limb amputees in a laboratory setting. *International Conference on Ambulatory Monitoring of Physical Activity and Movement, Maryland, USA.* (Poster)

Rowe, D.A., Deans, S.A., Kirk, A.F., McGarry, A.C., Mitchell, H., Sloan, L. Walker, A. (2017). Reliability and validity of the activPAL for measuring stepping and reclining in unilateral lower limb amputees. *International Conference on Ambulatory Monitoring of Physical Activity and Movement, Maryland, USA.* (Poster)

Deans, S.A., Kirk, A.F., McGarry, A.C., Rowe D.A. (2014). Physical activity for health in prosthetic rehabilitation: Are we doing enough? *British Association of Prosthetists and Orthotists 20th Annual Conference, Manchester, United Kingdom*. (Winner of best prosthetic oral presentation prize)

Publications and presentations in associated areas

Pires, G.K., da Silva, F.C., Filho, P.J.., de Alvarenga, J.G., Deans, S.A., da Silva, R. (2018). Semantic equivalence in Brazilian Portuguese translation of the Trinity Amputation and Prosthesis Experience Scales - Revised (TAPES-R). (Manuscript submitted February 2018 to *Prosthetics and Orthotics International.* Awaiting decision)

Sherman, K., Roberts, A., Deans, S., Murray, K., Jarvis, H. (2017). Step count levels during and away from in-patient rehabilitation: A study of British military bilateral amputees. (Manuscript submitted August 2017 to *Prosthetics and Orthotics International.* Awaiting decision).

Dyer, B. T. and Deans, S.A. (2017). Swimming with limb absence: A systematic review. *Journal of Rehabilitation and Assistive Technologies Engineering,* 35, 1-10. doi: 10.1177/2055668317725451

Watters, K., and Deans, S.A. (2015). Physical activity perceptions of prosthesis users: An interpretative phenomenological analysis. *International Society for Prosthetics and Orthotics World Congress, Lyon, France.* (Poster)

da Silva, R., Rizzo, J. G., Filho, P. J. B. G., Ramos, V., Deans, S. (2011). Physical activity and quality of life of amputees in southern Brazil. *Prosthetics and Orthotics International,* 35, 432-438. doi: 10.1177/0309364611425093

Deans, S., Gailey, R., Harsch, P., Hirons, C., Sexton, S. (2010). Physical activity, exercise and sports: The bar is being raised in prosthetic rehabilitation. *International Society for Prosthetics and Orthotics World Congress, Leipzig, Germany.* (Instructional Course)

Deans, S.A, and Sexton, S. The need for SPEEAD: Sporting prosthetics for everyday and elite athletes with a disability. *British Association of Prosthetists and Orthotists Annual Conference, Bolton, United Kingdom.* (Oral presentation)

Deans, S. A., McFadyen, A. K., Rowe, P. J. (2008) Physical activity and quality of life: a study of a lower-limb amputee population. *Prosthetics and Orthotics International. 32,* 186-200. doi: 10.1080/03093640802016514.

Deans, S. A., McFadyen, A. K., Rowe, P. J. (2007) Physical activity and quality of life: A study of a lower-limb amputee population. *International Society for Prosthetics and Orthotics World Congress, Vancouver, British Columbia.* (Oral presentation)

Definitions of terms

This section provides a definition of some of the terms used throughout this thesis.

Accelerometer. A device that measures acceleration (or rate of change of velocity) of a body from rest or another velocity.

Aerobic physical activity. Activity in which the body's large muscles move in a rhythmic manner for a sustained period of time. Aerobic activity improves cardiorespiratory fitness.

Amputation. The surgical removal of all or part of a limb/extremity such as an arm, leg, foot, hand, toe, or finger.

Cadence. The rate at which a person ambulates expressed in steps per minute.

Clinical population. A group of people which is studied for public health reasons, in this case, people who have limb absence.

Congenital absence. Absence of all or part of a limb/extremity due to disease or physical malformation in utero which is present from birth.

Diabetes mellitus (diabetes). A group of metabolic diseases in which there are high blood sugar levels over a prolonged period. Long-term complications include heart disease, stroke, chronic kidney failure, foot ulcers, and damage to the eyes.

Disability. An impairment which substantially affects a person's life activities. May be cognitive, developmental, intellectual, physical, sensory, or a combination of these

Energy expenditure. The amount of energy (or Calories) a person needs to carry out a physical function such as breathing or physical movement.

Exercise. A subcategory of physical activity that is planned, structured, repetitive, and purposive. The improvement or maintenance of one or more components of physical fitness is the objective of exercise.

Flexibility. The range of motion possible at a joint such as the knee joint.

Frequency. The number of times an exercise or activity is performed generally expressed in sessions, episodes, or bouts per week.

Health-enhancing physical activity. Activity, when added to baseline activity, produces health benefits. Brisk walking, playing tennis or playing football are examples.

Health-related fitness. A type of physical fitness that includes cardiorespiratory fitness, muscular strength, endurance, body composition, flexibility, and balance.

Intensity. The amount of work being performed or the magnitude of the effort required to perform an activity or exercise.

Lifestyle activities. Activities that a person carries out in the course of daily life and that can contribute to energy expenditure.

Limb absence. Used to describe a person who has undergone amputation surgery of an extremity, or who has had a part of an extremity missing from birth.

Measurement. The action of determining the size, length, or amount of something.

Metabolic equivalent (MET). The amount of oxygen consumed while sitting at rest and is equal to 3.5 ml $O2 \cdot kg^{-1} \cdot min^{-1}$

Moderate intensity physical activity. On an absolute scale, physical activity performed at 3.0 to 5.9 times the intensity of rest. Moderate-intensity physical activity is usually scored 5 or 6 on a scale of 0 to 10.

Multidisciplinary team. A group of expert healthcare professionals who are members of different disciplines and professions, for example prosthetists and physiotherapists. Each have specific knowledge and training related to the patient's condition.

Orthosis. An externally applied device used to support or correct the structural and functional characteristics of the neuromuscular and skeletal system.

Orthotist. An orthotist is a health professional who assesses and where appropriate designs and fits orthoses for any part of the body affected by a medical condition.

Peripheral artery (or arterial) disease. A common circulatory problem in which narrowed arteries reduce blood flow to extremities.

Physical activity. Any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level.

Physical behaviour. Actions performed by an individual throughout the day, for example, sleep, exercise, physical activity, and sedentary behaviour.

Physical fitness. The ability to carry out daily tasks with vigour and alertness, without undue fatigue. Includes a number of components consisting of cardiorespiratory endurance, skeletal muscle endurance, strength, and power, flexibility, balance, speed of movement, reaction time, and body composition.

Physiotherapist. A health professional working in physical medicine and rehabilitation who, by using mechanical force and movements, remediates impairments and promotes mobility, function, and quality of life through examination, diagnosis, prognosis, and physical intervention.

Prosthesis. An artificial replacement of a part of the body, such as a limb

Prosthetist. A health professional who assesses, measures, designs, fabricates, fits, and/or services a prosthesis, and who assists in the formulation of the prosthetic prescription for the replacement of limbs that are absent due to amputation or congenital reasons.

Rehabilitation. Specialised health care dedicated to improving, maintaining or restoring physical strength, cognition and mobility with maximized results. In health settings, it is undertaken by a professional qualified to give the care within their scope of practice.

Reliability. The quality of a test such that it produces consistent scores across different measures taken on different occasions.

Sedentary behaviour. Waking behaviour characterized by an energy expenditure $\leq$ 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture.

Step. The single complete movement of raising one foot and putting it down in another spot, as in walking.

Strength. A health and performance component of physical fitness that is the ability of a muscle or muscle group to exert maximal force in a single repetition.

Stride. The distance covered by two steps taken by left and right lower limbs.

Thrombosis. The formation of a blood clot inside a blood vessel, obstructing the flow of blood through the circulatory system.

Transfemoral absence. Amputation or absence occurring through the femur, also known as above-knee amputation or absence.

Transtibial absence. Amputation or absence of the lower leg and across the tibia. Also known as below-knee amputation.

Validity. The extent to which inferences made are appropriate, meaningful, and useful.

Vigorous intensity physical activity. On an absolute scale, physical activity that is performed at more than six times the intensity of rest.

Table of contents

List of Appendices

List of Figures

List of Tables

Chapter 1 Introduction

Chapter overview

This chapter will introduce the definition of physical behaviour. Included with this, the health and well-being benefits of physical activity, and the motivations and barriers to increasing physical activity for health benefits will be presented. Physical activity guidelines and how physical activity is promoted in health and community-based settings are also discussed. Measurement of physical behaviour including subjective and objective measures, accelerometers, and reliability and validity considerations are described. Finally, a description of the population with limb absence is presented, complimented by an overview of the role of prosthetic rehabilitation healthcare professionals, lower limb amputation management, and the physical behaviour of this population.

Definition of physical behaviour

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen, Powell, & Christenson, 1985). The term physical activity includes activities that involve bodily movement performed as part of playing, working, active transportation, home chores and recreational activities. In order to quantify the effort or intensity of the physical activity being performed, the descriptors light, moderate and vigorous can be applied and in turn a metabolic equivalent (MET) value placed on the descriptor. One MET is defined as the resting metabolic rate, that is, the amount of oxygen consumed at rest and is calculated as 3.5 ml of oxygen per kilogram of body weight per minute. Two METS requires twice the resting metabolism or 7.0 ml O_2/kg/min, and in this way the energy cost of being physically activity or sedentary can be expressed as a multiple of the resting metabolic rate (Jetté, Sidney, & Blümchen, 1990). Light-intensity physical activity is 1.5-2.9 METS, moderate-intensity is 3-5.9 METS, and vigorous-intensity is ≥6 METS (Dencker & Andersen, 2011). A system for quantifying the energy cost of adult human physical activity was developed in 1993 from measured MET values derived from published sources (Ainsworth et al., 1993). For example, major types of activities such as running or gardening have categories and MET values apportioned. The original compendium was later updated in 2000 and 2011 (Ainsworth et al., 2011; Ainsworth et al., 2000).

Conversely, sedentary behaviour is defined as any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting or reclining posture (Sedentary Behaviour Research Network, 2012). While evidence is well established on the benefits of incorporating physical activity into daily living, recognition of the importance of reducing sedentary behaviour independent of physical activity has only recently gathered momentum. Indeed, sedentary behaviour has been defined as a lack of physical activity or being inactive; it is now defined as a distinct behaviour. Prolonged periods of sedentary behaviour should be avoided and sitting periods interrupted by physical activity (Healy et al., 2008; Owen, Healy, Matthews, & Dunstan, 2010; Rutten, Savelberg, Biddle, & Kremers, 2013). The same follows for people with lifestyle-related conditions such as diabetes with the idea that sitting less and moving more should be promoted (Dempsey et al., 2016). Further, sedentary behaviour is characterised by low energy expenditure and both the type of movement and the energy cost are equally important features for understanding behaviour (Biddle, Marshall, Murdey, & Cameron, 2003).

Sedentary physiology and exercise physiology have been described as being on a movement continuum. As behaviours move along the continuum they may provoke different physiological responses (Tremblay, Colley, Saunders, Healy, & Owen, 2010). Sleep is at one extreme of the continuum and vigorous-intensity exercise is at the other end of the continuum. In this paper the researchers also use the following terms to describe the movement continuum: sedentary; sedentarism; physically active; and physical inactivity. Being sedentary is characterised by little physical movement and low energy expenditure of less than or equal to 1.5 METs. Being physically active means meeting the established physical activity guidelines. Physical activity is any bodily movement produced by the skeletal muscles that requires energy expenditure (Maxwell & Granat, 2014). Physical behaviours however encompass both sedentary behaviour and physical activity.

This thesis will not discuss sleeping behaviour. It will however focus on sedentary and physical activity concepts of the movement continuum and patterns of sedentary and physical activity behaviour during waking hours. Understanding patterns of behaviour is also of increasing value in moving towards lessening the negative physiological effects of prolonged bouts of sedentary time, and increasing daily movement (Chastin & Granat, 2010; Healy et al., 2011; Owen et al., 2011; Thorp, Owen, Neuhaus, & Dunstan, 2011).

Health and wellbeing benefits and motivations and barriers to increasing physical activity

Physical activity has many physiological, psychological and social health benefits irrespective of age, clinical status, gender and race. Regular physical activity improves cardiorespiratory, metabolic and bone health and decreases the risk of developing or worsening cardiovascular disease, cerebrovascular disease, diabetes mellitus, and some cancers such as those of the colon and breast (Warburton, Nicol, & Bredin, 2006). Psychological benefits include better mood (Penedo & Dahn, 2005), and reduction in symptoms of depression (Blumenthal et al., 2007).

Understanding motivations to participate in physical activity is important in encouraging a less sedentary lifestyle. Intrinsic and extrinsic motivators exist on a continuum (Deci & Ryan, 1985). Being intrinsically motivated means carrying out an activity for the inherent satisfaction and enjoyment it provides and valuing the actual experience. Being extrinsically motivated is to participate in physical activity to gain something outside of the activity, for example weight-loss or health benefits. There is some indication that a predominance of intrinsic motivation is especially important for longer-term physical activity participation (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). Conversely, evidence is consistent with the hypothesis that reporting well-internalized extrinsic regulations, such as personally valuing certain outcomes of physical activity participation, is a particularly important factor for initial adoption.

Although the benefits of physical activity are well known, barriers exist that prevent people from meeting the recommendations stated in physical activity guidelines. By understanding these barriers it is possible to design and implement interventions that promote physical activity for both the general and clinical populations. Lack of time and fear of being injured are reported as barriers (Sallis et al., 1990). The following reasons for not being more physically active are also reported; inconvenience; lack of motivation or life management skills; boredom; little mastery or confidence in one's ability; and lack of encouragement, support, or companionship from family and friends (Lee, Ory, Yoon, & Forjuoh, 2013). The same research shows environmental factors can also influence participation such as inclement weather and unattractive or unsafe communities. For people with disabilities or chronic conditions, the conditions in themselves are independent barriers to participation.

Physical activity guidelines

Two physical activity guidelines are of relevance to this work; the global physical activity guidelines (World Health Organization, 2017), and United Kingdom guidelines for general populations (Department of Health, 2011). Australia and the United States of America also have guidelines (Australian Government Department of Health, 2012; U.S. Department of Health and Human Services, 2008). Guidelines exist for clinical populations such as those who have cancer, cardiovascular disease, diabetes, and disabilities. One paper of note acknowledges that evidenced-based guidelines should be rigorously developed (Woolf, Grol, Hutchinson, Eccles, & Grimshaw, 1999). This way, any harm which may be brought about by following the recommendations contained in the guideline can be minimised. The researchers also showed that evidence-based guidelines are not the only option for the improvement of patient care. It is important for healthcare professionals who understand the content of guidelines to look beyond their knowledge and identify barriers to behaviour change.

Without exception, everyone should aim to be as active as possible within safe limits. The Australian Government's statement "any activity is better than none" is clear and accurate (Australian Government Department of Health, 2005). The World Health Organisation states that cardiorespiratory health, muscular fitness and bone health can be improved, and the risk of non-communicable diseases and depression can be reduced by participating in physical activity (World Health Organization, 2017). To achieve this, adults aged 18–64 years should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week. Alternatively, adults can also accumulate at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week. An equivalent combination of moderate- and vigorous-intensity activity can provide similar health benefits. Aerobic activity should be performed in bouts of at least 10 minutes duration. For additional health benefits, adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity. Muscle-strengthening activities should involve major muscle groups on two or more days a week (World Health Organization, 2017). In addition to these recommendations, the United Kingdom's Chief Medical Officer advises that adults of 19-64 years of age should minimise the time spent being sedentary. In terms of the above points, walking briskly would be an example of moderate-intensity physical activity. Vigorous-intensity physical activity might elicit a more laboured breathing during and following participation.

Also of relevance in this thesis is the population of adults who are older than 65 years; the same recommendations apply to this age group with the additional recommendation that those who are at risk of falls should incorporate physical activity to improve balance and co-ordination on at least two days per week. Engaging in activity even at a level and time period lower than the recommended, can provide some health benefits as opposed to being completely inactive. Therefore, it is recommended that older adults engage in some physical activity every day.

Guidelines exist to inform people to lead a more active lifestyle. Published guidelines can also help support healthcare professionals to deliver a positive, active living message to their patients. Yet, it is questionable whether the active living message is communicated effectively enough for adults to make sense of, heed and implement the recommendations. For example researchers have shown that American adults have knowledge about how to be physically active, yet this knowledge alone is not sufficient to prompt engagement in physical activity sufficient for health benefits (Morrow, Krzewinski-Malone, Jackson, Bungum, & Fitzgerald, 2004).

Finally, there are guidelines specific to clinical populations and the details of these for clinical groups of greatest most relevance to adults with lower limb absence are discussed in the literature review in Chapter 2.

Promoting physical activity in clinical and community-based settings

The recommendation of undertaking physical activity is akin to prescribing a course of medicine (Sallis et al., 2015). Clinical interventions are delivered in settings such as general practitioners' surgeries, out-patient units and in-patient hospital environments. An advantage of clinical settings is the specificity of the given advice for the population in question, and the structured nature of the guidance. An example might be physical activity promotion and engagement at a hospital-based cardiac rehabilitation programme centre for people who have had a cardiac event. However, these clinically-based interventions may be shorter episodes of care than those delivered in the community. Data from the 2011–2012 National Health and Nutrition Examination Survey, suggests that only 36% of adult Americans had received physical activity advice as part of a healthcare episode (Centers for Disease Control and Prevention and National Center for Health Statistics, 2011). In addition, the challenge exists to continue clinical interventions when care is transferred to the community or the home-based setting. That said, community based settings offer other advantages for the promotion of physical activity. According to the Centers for Disease Control and Prevention (U.S. Department of Health and Human Services, 2011), community-wide campaigns deliver messages through television, radio and newspaper. Physical activity promotion can be carried out through patient support and self-help groups. Physical activity counselling can also be delivered in community-based settings. Risk factor screening and education at workplace, schools, and community events may also be established. Policy and environmental changes can be implemented for example through public access to school facilities, and creating walking trails (U.S. Department of Health and Human Services, 2011).

Researchers examined adults with disabilities who visited a health professional in a 12-month period (Carroll et al., 2014). Data from the 2009–2012 National Health Interview Survey (NHIS) were used to estimate the prevalence of, and association between, aerobic physical activity (inactive, insufficiently active, or active) and chronic diseases (heart disease, stroke, diabetes, and cancer) among adults aged 18–64 years by disability status and type (hearing, vision, cognitive, and mobility). The prevalence of, and association between, receiving a health professional recommendation for physical activity and level of aerobic physical activity was assessed using 2010 data. Overall, 11.6% of U.S. adults aged 18–64 years reported a disability, with estimate for disability type ranging from 1.7% (vision) to 5.8% (mobility). Compared with adults without disabilities, inactivity was more prevalent among adults with any disability (47.1% versus 26.1%) and for adults with each type of disability. Approximately 44% of adults with disabilities received a recommendation from a health professional for physical activity in the past 12 months. Further, multifactorial problems exist in promoting participation in physical activity and encouraging health maintenance in people with physical disabilities due to primary and secondary conditions, a lack of validated guidelines, and environmental influences (Lui & Hui, 2009). Challenges exist in conveying and reinforcing the active living message in both general and clinical populations.

Even with this evidence, considerable uncertainty remains as to the effectiveness of physical activity promotion strategies that use guidelines as a basis, or whether they are an efficient use of resources in communicating a health benefits message for people who are inactive (Sanchez, Bully, Martinez, & Grandes, 2015). Prescriptive, controlled, bespoke methods of engagement, such as clinical or community based exercise-referral schemes, may appear to be a more successful way of assuring adherence and outcomes than health promotion strategies (Pavey et al., 2011). To support this, editorial commentary specified that bespoke interventions can be effective in increasing physical activity for up to six months following counselling (Hellénius & Sundberg, 2011). It has been reported that exercise referral schemes can have a small effect on sedentariness. Further interventions should focus on increasing uptake and improving adherence by addressing barriers to participation (Williams, Hendry, France, Lewis, & Wilkinson, 2007). It seems logical to have guidelines for specific populations to underpin the facilitation of exercise-referral schemes, yet the most effective method of maintaining physical activity adherence in both general and clinical populations remains unknown.

Measurement of physical behaviour

Physical activity, sedentary behaviour and sleeping time are main components of the circadian cycle of human movement and posture known to strongly impact human health and to relate with multiple cardio metabolic risk factors (Rosique-Esteban et al., 2017). Sleep, sedentariness, low physical activity, and moderate to vigorous physical activity have relatively recently been conceptualised as a connected set of physical behaviours. Measurement of such physical behaviour is important to report on true habitual patterns of behaviour and the effect of interventions.

Subjective and objective measures

Using subjective measures involves the qualitative or descriptive recall or reporting of a person's physical behaviour. Examples of subjective measures are physical activity diaries or logbooks. They can be less reliable than objective methods of measuring physical activity because human memory recall can be fallible in terms of accuracy of time and detail. Yet subjective measures can be more easily administered at a lower cost to large population groups and subgroups than objective measures. Data collected using subjective measures can show a strong relationship in the variables the measures are designed to capture, but can be prone to cognitive biases (Jahedi & Méndez, 2014). The same authors also describe subjective measures as being able to carry information that objective measures often lack such as being able to capture participant perceptions and feelings. Participant compliance in research studies using both types of measures can also be higher in subjective methods over objective methods. This can be attributed to the fact that people can be more comfortable in offering their views and attitudes on an issue without the sense of being examined or judged (Innerd et al., 2015).

Objective methods of assessing physical behaviour usually generate quantitative data, while subjective methods may involve both quantitative and qualitative data. Pedometers or accelerometers are examples of objective measurement tools. These methods are more reliable, can be highly accurate and tend to remove some of the bias disadvantages associated with subjective measures. However, they can be expensive and preparation of the measurement instrument can be time consuming due to the individualised approach. Because of these issues, study participant numbers also tend to be smaller. While objective measures can be more suitable for clinically-based studies rather than large population-based studies, objective measures are being used on whole samples and subgroups of large surveillance studies (Dollman et al., 2009).

Careful consideration must be given to the appropriate measurement instrument best suited to the research study design, the expected study outcomes, and the participants and any health-related conditions they may have. When selecting a physical activity instrument, additional considerations should include the literacy level requirements of the target population, the recall or time period to measure, the validity and reliability evidence, and the generalisability of the results to diverse populations (Ainsworth, Cahalin, Buman, & Ross, 2015). As the accuracy and precision of the measurement instrument increases, the ease of use tends to decrease (Broderick, Ryan, O'Donnell, & Hussey, 2014). In using a subjective measurement tool, people often overestimate levels of physical activity, and underestimate sedentary time when compared with an objective measurement instrument (Dyrstad, Hansen, Holme, & Anderssen, 2014). Technology advancements mean that objective measurement instruments can measure time aspects of physical behaviour over hours, days, weeks, months and years. Appropriate measures can be selected according to the characteristics of the population being examined. For example, a long-term activity monitor fitted to the shin tube of a prosthesis can be used to record lifestyle data of people with limb absence. As a result of these extended monitoring periods and based on the memory and storage of the measurement device being adequate, detailed data collection and analysis can occur (Ainsworth et al., 2015). A combination of measurement techniques can also be successfully implemented into study methodologies in order to quantify all aspects of physical activity under free-living conditions (Schutz, Weinsier, & Hunter, 2001).

Accelerometers

Measurement tools or devices provide researchers with a quantifiable variable. Accelerometers measure motion, vibration and shock. In physical activity measurement applications, a strain gauge within the device can determine impact, and depending on location of attachment, can differentiate between sitting and lying due to the tri-axial rotational element contained within. Accelerometers have the most accurate and reliable step counting mechanism available (Lee & Shiroma, 2014; Westerterp, 2009). In considering the measurement of human physical behaviour, it is desirable to select a monitor featuring proprietary algorithms that provide outputs on time spent sitting/lying, standing, stepping, step counts, and step cadence. In addition, energy expenditure of the subject and time spent in different intensities of activity can also be determined.

Reliability and validity

Reliability pertains to the consistency, or repeatability of a measure. There are four types of reliability evidence: test-retest (also referred to as stability); inter-rater (and intra-rater); internal consistency; and equivalence reliability (also known as parallel forms or inter-instrument reliability). The reliability of a measurement is an important consideration in the choice of the primary outcome measure for a clinical trial (Lachin, 2004). Reliability can depend on decreasing the measurement error, for example by training researchers in the use of equipment, and in using quality measurement instruments. Reliability is important in order to assure consistency in scores across trials, on different occasions, with one or more raters, and with one or more instruments (Yun & Ulrich, 2002).

Validity of measurement indicates the degree to which the scores from the test measure what they are supposed to measure.

The following historical terms have been used for validity evidence:

1. content-related validity evidence.
2. criterion-related validity evidence.
3. construct-related validity evidence.

Validity is an important factor in choosing an instrument to measure physical behaviour. It is also important for researchers to report sufficient information about validity evidence to enable the reader to judge the quality of their research (Rowe & Mahar, 2006).

Whilst the importance of testing validity and reliability is recognised, it is necessary for researchers in the field of physical activity measurement to adopt consistency in a number of areas. Standardised approaches should be taken when determining measurement parameters, in selecting validation instruments, and in the reporting of findings (Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012).

Persons with lower limb absence

Amputation is the surgical removal of all or part of a limb or extremity such as an arm, leg, foot, hand, toe, or finger. Major lower limb amputation refers to any amputation performed above the level of the ankle. Foot amputations are those at or below the ankle. Congenital absence describes all or part of a limb/extremity missing due to disease or physical malformation present from birth. Amputation performed without an attempt at limb salvage (for example revascularization, bony repair, soft tissue coverage) is termed primary amputation, whereas amputation following a failed attempt at revascularization is termed secondary amputation (Dillingham, Pezzin, & Shore, 2005). Traumatic amputation refers to limb loss that occurs at the time of injury, as opposed to planned or elective surgery performed with prior consultation with the medical team.

During 2011-2012, 5906 people were referred to United Kingdom regional prosthetic rehabilitation services, of whom the majority were male (n = 4121). Of this total number of referred people, 5389 had lower limb absence (91.2%). Almost 70% of those with lower limb absence were referred due to compromised vascular causes (impaired circulation) and were over 54 years of age (United National Institute for Prosthetics Orthotics Development, 2011-2012).

Prosthetic rehabilitation healthcare professionals

Prosthetic rehabilitation is generally delivered in the United Kingdom by a consultant-led service supported by Health and Care Professions Council (HCPC) registered prosthetists, physiotherapists, occupational therapists, and clinical nurse specialists (British Society of Rehabilitation Medicine, 2003). In the UK context, a prosthetist is a person who holds State Registration to practise in a clinical environment caring for those who have upper or lower limb absence. Regional National Health Service (NHS) Disablement Services Centres exist throughout England, Northern Ireland, Scotland and Wales with the number of prosthetists working at each centre varying from one to 10 depending on the regional patient case-load. A review of UK artificial limb and wheelchair services determined it was reasonable for an individual prosthetist to have a case-load not exceeding 300 patients (McColl, 1986). Each Disablement Service Centre will have access to physiotherapists who will be specialists in amputation physiotherapy rehabilitation. Although it is possible to retrieve data on the number and gender of prosthetists, orthotists, and physiotherapists registered with HCPC, it is not possible to derive the proportion of these professional groups who specialise in prosthetic rehabilitation (Health and Care Professions Council, 2016), In addition to socialised prosthetic care, there are a number of independent, privately owned rehabilitation facilities operating in the United Kingdom (Limbless Association, 2014).

Lower limb amputation management

The multi-disciplinary team is involved in five phases of the management and rehabilitation of a person who has planned elective or traumatic amputation surgery (British Society of Rehabilitation Medicine, 2003). The five phases are:

1. pre-amputation.
2. amputation.
3. post amputation.
4. primary prosthetic rehabilitation.
5. prosthetic review and maintenance.

The first phase is focussed on medical and physical assessment and surgical education. The surgeon might discuss planned pain management, the possibility of phantom pain and short- and long-term rehabilitation goals. Researchers have shown that meeting with an established patient by way of peer visitation can help improve patient outcomes and attitudes (Gallagher & MacLachlan, 1999). The surgeon and prosthetist can discuss limb length and optimum conditions for prosthetic success. A physiotherapist can also begin a pre-operative therapy programme as a basis for post-operative exercise.

The second phase is amputation surgery which will follow a recognised technique and with optimal prosthetic functional outcome in mind (Smith, Michael, & Bowker, 2004). The third phase deals with post-operative pain management, dressings, and determining which therapy services require to be accessed, for example physiotherapy, occupational therapy, clinical psychology. Readiness and timing of assessment by a prosthetist should be based on the patient's overall post-surgical status (Stewart & Jain, 1993).

Phases four and five cover primary prosthetic rehabilitation, review and maintenance. The decision to attempt prosthetic rehabilitation is made based on patient-centred factors such as their lifestyle, their expectations and any physical or other limitations. Again, physiotherapy input at this time will be important in helping the patient to gain strength and in learning to walk with their prosthesis. Following discharge from physiotherapy rehabilitation, the review and maintenance phase encompasses review of the socket fitting and prosthetic prescription, and any repairs to the prosthesis or replacement of component parts. Ongoing patient education and psychological support is also provided by the appropriate health care professional as required. It is important to appreciate that the relationship between a patient and prosthetist is a lifelong one, rather than one that is centred on a transient episode of care.

Physical behaviour in persons with lower limb absence

Guidelines do not exist to support patients or healthcare professionals in promoting physical activity to people with limb absence. There are however online resources for patients with the aim of promoting awareness of and participation in sports and exercise and physical activity (Amputee Coalition, 2017; Navy and Marine Corps Public Health Centre, 2017). These resources present general physical activity guidance without formally describing national physical activity guidelines. The caveat is made that individuals must seek the condition-relevant health professional advice before participation. There are similar resources aimed at UK-based people with limb absence and those who support them, albeit with a focus on fitness and sports rather than increasing physical activity (Limbless Association, 2017).

Systematic reviews have been carried out to examine people with limb absence and sports, and to examine motivations and barriers to participation in sports, exercise and physical activity (Bragaru, Dekker, Geertzen, & Dijkstra, 2011; Deans, Burns, McGarry, Murray, & Mutrie, 2012). Further, a qualitative study using an interpretative phenomenological analysis (IPA) approach sought to explore patients' motivations and barriers to physical activity participation (Deans & Watters, 2015).

Interpretative phenomenological analysis aims to provide an examination of the personal lived experience, producing an account of the lived experience in its own terms rather than one prescribed by pre-existing theoretical preconceptions (Smith & Osborn, 2004). Whilst these two evidence sources provide an understanding of possible facilitators or barriers to engagement in physical activity for adults with amputation, promotional resources in the form of guidelines and healthcare professional education are not available.

Summary of Chapter 1

This introduction has provided an overview of the topics that underpin the thesis, namely: the definition of physical behaviour; measurement of physical activity; and the clinical population with lower limb absence. Leading on, Chapter 2 will present a comprehensive account of published research relevant to these topics. Chapter 2 will also identify gaps in the research to justify the research questions and design and implementation of the studies included in this thesis.

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Chapter 2 Literature Review

Chapter overview

This chapter is a review of the literature with the aim of presenting the evidence on key research areas related to topics covered in this thesis. The chapter is structured in six sections. Motivations and barriers to physical activity participation in the general population, in relevant clinical populations, and in the population of those with limb absence are covered in the first section. The benefits of participating in physical activity and a rationale for physical activity being promoted to people with disabilities are also presented in the first section. The second section describes physical activity guidelines in the general population, in relevant clinical populations, and for those with limb absence. The third section discusses promotion of physical activity, including a description of who should hold responsibility for activity promotion, and if and how physical activity is promoted in those who have limb absence.

Section four presents literature on objective measurement of physical behaviour, and describes the evidence around accelerometer reliability and validity studies in the general population and in the limb absent population. Free-living studies which utilise accelerometers in the methodologies will be presented in section five. Section six summarises the limitations of the evidence and the research questions. A description of the research studies designed to answer the research questions is also contained therein. Finally, the breadth and scope of physical behaviour research is sizeable. Therefore, in order to present a relevant overview, the most current evidence and literature relevant to people with limb absence will be presented.

Motivations and barriers to participation in physical activity

The health benefits of regular physical activity have been expertly researched and promoted. Yet data show that more than half of adults do not meet the recommended levels of physical activity, and sedentary lifestyles are increasingly the norm (Department of Health, 2011). Understanding the motivations to being more physically active is therefore an important area of research in all populations. A study, using a self-report, 20-item questionnaire and completed by 1885 participants examined motivations for engaging in physical activity and how the motivations varied across the lifespan (Gavin, Keough, Abravanel, Moudrakovski, & McBrearty, 2014). The aim was to show how the findings might guide physical activity promotion and interventions and the focus was on age groups of participants rather than gender. Participants (N = 1885) were grouped into five decade-defined categories based on participants' reported actual ages. These were: teens (n = 180); 20-29 years (n = 846); 30-39 years (n = 431); 40-49 years (n = 256); and 50 years and older (n = 172). Four motivational factorial groupings were derived using an exploratory factor analysis. This analysis was conducted on the 20 questions which focussed on potential sources of motivation including improving endurance, making friends, and living life more adventurously. The four motivational factorial groupings were: Mental toughness; Toned and fit; Fun and friends; and Stress reduction. An analysis of variance was conducted for group differences in motivations. Following a decreasing linear trend, the two groupings of Mental toughness and Fun and friends were regarded as being less important with increasing age [($F_{1, 1880} = 38.11$, $p < .001$, $\eta^2 = .02$) and ($F_{1, 1880} = 24.31$, $p < .001$, $\eta^2 = .01$)]. Conversely the two groupings Toned and fit and Stress Reduction increased in relevance with increasing age showing an increasing linear trend [($F_{1, 1880} = 23.79$, $p < .001$, $\eta^2 = .01$) and ($F_{1, 1880} = 5.37$, $p < .001$, $\eta^2 = .01$)]. The authors concluded that it would be beneficial to create targeted promotion or interventions in the hope of increasing physical activity in ageing adults. The authors also proposed that this population be encouraged to appreciate the wider benefits such as the psychological and social aspects of being physically active in addition to physiological maintenance or improvement benefits.

Understanding barriers to being or becoming physically active can help in devising strategies to make physical activity part of daily life for health benefits (Cerin, Leslie, Sugiyama, & Owen, 2010). As with motivations, barriers can be different between genders and across different cultural and socioeconomic populations. For example, one study of 2236 participants (927 men, 1309 women) aged between 30 and 50 years, explored barriers to physical activity according to data collected through a questionnaire (Sequeira, Cruz, Pinto, Santos, & Marques, 2011). The differences in perceived barriers between genders were analysed. The most cited barriers were lack of time (55% of participants cited this reason) and the cost of participating (20% of the sample cited this reason). Other barriers included the desire to do other things in leisure time, the idea that athletic prowess was required to participate, and the lack of community infrastructures near where participants lived. Among the most cited barriers, women reported costs more than men (12% male vs. 25% female, $p < 0.001$). Other researchers have documented the same barriers of lacking in time and a lack of confidence in having the skills to participate in physical activity (Cerin et al., 2010). In this study, data from two validated questionnaires were analysed ($N = 2194$) where participants commented on their recreational walking and other leisure time activities. The questionnaires asked about psychosocial correlates and health status of participants. Providing fun environments in which leisure time activity can take place and creating social support during participation are important in reducing barriers to participation.

Qualitative research methodologies are often utilised in studies on motivations and barriers to physical activity participation. A reason for this could be the multifactorial and complex nature of behaviour associated with either participation or non-participation. For example, one study that investigated barriers, motivators, and preferences of community-dwelling female African American older adults used a focus group approach (Gothe & Kendall, 2016). Three focus groups were conducted with female older adults ($N = 20$, mean age 63.15 years). Discussion was encouraged utilising a topic guide to explore the following questions: What motivates you to participate in physical activity?; What prevents or constrains you from participating in physical activity?; and What are the barriers you face? The motivations included perceived health benefits of physical activity, social support, and enjoyment associated with engagement in physical activity. Prominent barriers included time and physical limitations, peer pressure, family responsibilities, and unsuitable weather and poor neighbourhood conditions. Group activities involving a dance component and novel exercises such as tai-chi or yoga were preferred choices. These findings highlight the need to take population-specific factors into account when designing or implementing community physical activity programs for different social, economic and cultural groups.

As previously noted, the limb absent population in western societies is generally older therefore studies that research the physical behaviour of older adults are of relevance and interest. It is known that physical activity progressively decreases with age (Haskell et al., 2007; U.S. Department of Health and Human Services, 1996). In older adults, as discussed earlier, there are age-specific barriers which become apparent. Research that was historically centred on healthy young and middle aged adults has now encompassed older populations. Predictors of physical activity adherence are described in a review article as being unreliable in older populations (Schutzer & Graves, 2004). For example, symptoms of sweating, laboured breathing and muscle soreness may present during physical activity participation and can have negative connotations. Conversely, these symptoms may not present in an older population therefore predictors of non-participation in a younger population may not be applicable in an older population. In another qualitative study of 33 previously sedentary, underactive adults who were ≥ 75 years of age, barriers were explored using an in-depth qualitative interview approach containing open-ended questions (Grossman & Stewart, 2003). Results showed that participants regarded sedentary behaviour as harmful, yet their perception was that they were active. Poor health, lack of time, effects of aging, and adverse environments were identified as factors influencing physical activity. People continue to be interested in physical activity as they age, but can be unsure of the recommended amount of physical activity in which to participate. Some misperceptions about physical activity also exist. For example, this age group experienced health problems associated with growing older and were reluctant to exacerbate the health condition or worsen symptoms. However, this group believed physical activity promotion by doctors to be valued and considered helpful. This supports the conclusions of Schutzer and Graves who agree that doctors can play an important role in the initiation and maintenance of exercise behaviour among the older population (Schutzer & Graves, 2004).

Theoretical models exist to understand and influence individuals' physical behaviour and behaviour change. A review of these theoretical models is beyond the scope of this chapter however it is important to acknowledge that these should be considered alongside motivations and barriers when developing interventions to promote physical activity.

Motivations and barriers to participation in clinical populations

The area of motivations and barriers to physical activity participation in those with limb absence may have been explored through research, yet the peer-reviewed evidence is limited. That said, research on other clinical populations with conditions such as neurological conditions may inform researchers to a degree. A systematic review study of five relevant databases yielded 28 articles (Mulligan, Hale, Whitehead, & Baxter, 2012). These articles were independently appraised by two researchers using two quality checklist tools to identify barriers to physical activity participation for males and females with neurological (progressive and non-progressive) conditions such as multiple sclerosis, cerebral palsy and stroke. The barriers were categorised into the framework domains of the International Classification of Functioning, Disability and Health (World Health Organization, 2001) which offers an international, scientific tool for understanding human functioning and disability for clinical, research, policy development (Üstün, Chatterji, Bickenbach, Kostanjsek, & Schneider, 2003). Mulligan et al. (2012) concluded that factors that presented as barriers to physical activity participation in the general population also presented as factors for individuals with non-progressive conditions. The barriers to participating in physical activity included physical and social environmental factors such as a lack of available, affordable and accessible transport, and a lack of expectation for this population to be physically active and a lack of support when doing so. Personal barriers included low self-efficacy and the belief that participating in physical activity is without physical benefit. There is clear evidence from high quality articles that there are universal barriers to physical activity participation for individuals with a range of disabling conditions. Further, other qualitative and narrative review studies have been conducted which focus on people with osteoporosis (Baert, Gorus, Mets, & Bautmans, 2015), and people with rheumatoid arthritis (Veldhuijzen van Zanten et al., 2015). These studies suggest that health care professionals should emphasise motivations to be more physically active in order for barriers to be eliminated. Strengthening a social network to support participation was also deemed to be important.

It was felt relevant in this literature review to present and discuss the evidence on a range of conditions to understand more fully additional barriers which may arise from impairments to body structure and function and how secondary conditions can impact on the barriers to participation. A qualitative methodology was again adopted in a study to identify motivations and barriers in those with disabilities (Rimmer, Riley, & Jurkowski, 2004). Together with architects, town planners and fitness professionals, participants with disabilities were asked to provide their personal perspectives on accessibility of physical activity and recreation facilities and programs for people with disabilities. Recruitment took place across 10 United States regions with four focus groups taking place in each region. Four to six individuals per focus group were recruited (approximately $N = 200$). Male and female participants ($n = 42$) were recruited for the disabilities grouping through ten regional offices of the Disability and Business Instructional Technology Assistance Centers (DBITACs). Health conditions of these participants included limited ability to use arms and hands, limited ability to use legs, spinal cord injury, and back problems. Ten categories related to facilitators and barriers to participation in physical activity were identified including environment, cost, education and training, emotional and attitudes. Content analysis of qualitative data revealed more barriers than motivations to participate (178 barriers vs. 130 motivations). These motivations and barriers were grouped for thematic analysis. From this there is the suggestion that resources should be focussed on reducing barriers to participation particularly in older adults when participation reduces and motivations and barriers change.

Motivations and barriers to participation in individuals with limb absence

Limited research has explored motivations and barriers to participation in physical activity for people with lower limb absence. A cross-sectional descriptive study was conducted to investigate the relationship between physical activity and perceived quality of life in people with lower limb amputation, including exploration of perceived restrictions towards physical activity (Deans, McFadyen, & Rowe, 2008). In this study, a section of the Trinity Amputation and Prosthetic Experience Scales (TAPES) questionnaire was used to measure activity restriction through athletic, functional, and social subscales (Gallagher & MacLachlan, 2000). Findings showed that a mixed gender sedentary clinical group with either transtibial or transfemoral amputation (*N* = 25, mean age 66 years) prioritised gaining comfort and confidence, and maintaining social standing through the maintenance or strengthening of relationships rather than trying to achieve a particular level of physical functioning. These findings relate to those presented in another research study which examined those with osteoporosis (Baert et al., 2015). The recommendation was made for physical activity education to involve not only the patient, but relatives, friends, and important peers also.

Crawford et al (2016) conducted a qualitative study to investigate the barriers and facilitators to physical activity participation in people with limb absence (Crawford, Hamilton, Dionne, & Day, 2016). Semi-structured interviews were conducted to collect data from nine men with transtibial, osteomyoplastic amputation (mean age 42 years). Participants reported that they were limited during running and resistance exercises during, before and after amputation surgery. Most participants valued physical activity benefits related to the prevention of chronic disease, but failed to recognise potential functional benefits and health improvement. This suggests an individual's motivation to participate can serve as both a facilitator and barrier to physical activity participation. Having the opportunity to socialise during physical activity was important to the study participants. This supports the findings of Deans, McFadyen and Rowe (2008) and Gallagher & MacLachlan (2000) in identifiying strengthening of relationship as an important motivation for physical activity participation (Deans et al., 2008; Gallagher & MacLachlan, 1999). In the latter study, the quality of the postoperative prosthetic care program was deemed to have a direct influence on the long-term physical activity participation for participants with limb absence. Further, the health care team was recognised as playing a significant role in the adoption of a physically active lifestyle for people with transtibial amputation.

The benefits of physical activity participation for people with disabilities

Participation in physical activity is perhaps more important for people with disabilities relative to people without disabilities (Martin, 2013). Individuals who are physically active enjoy a range of benefits spanning physiological, emotional, cognitive and social categories. An article by Rimmer and Chen in in 2009 proposed there was a lack of evidence-based data on the potential impact of physical activity in achieving certain health outcomes in people with disabilities (Rimmer & Chen, 2009). This systematic review examined the evidence on the effects of physical activity in improving health among people with disabilities. 139 exercise trials were identified across 11 physical and cognitive disability subgroups under six categories of health: cardiorespiratory, musculoskeletal, functional, mental, healthy weight and metabolic health, and secondary conditions. Based on this classification scheme, there was strong evidence that physical activity improved cardiorespiratory, musculoskeletal, functional, and mental health. Moderate evidence presented for reducing secondary conditions and there was limited evidence for reducing body weight and improving metabolic health. The review concluded that promoting public health guidelines for people with disabilities requires a coordinated effort among health professionals and organisations in identifying evidence-based interventions that have documented success for improving key outcomes.

Physical activity guidelines for the general population, clinical populations, and for those with limb absence.

Guidelines are important tools for clinical decision makers to provide the best care for their patients. Public health guidelines make recommendations on local interventions that can help prevent disease and improve health. Physical activity guidelines produced at a national level generally include descriptions on mode, frequency, volume and intensity of physical activity. Guidelines may also focus on a particular activity component such as intensity of physical activity or flexibility for example. A particular population or a particular setting, for example a primary care facility, may also be a focus. Increasing physical activity is a global health concern and major health organisations from several countries have published guidelines on physical activity for health improvement (Australian Government Department of Health, 2012; Department of Health, 2011; U.S. Department of Health and Human Services, 2008). Since 2014, the National Institute for Health and Care Excellence in England has used a single, unified process in the development of several guidelines specific to the improvement of health through physical activity or the reduction of sedentary behaviour in specific populations (National Institute for Health and Care Excellence, 2017). The Scottish Intercollegiate Guidelines Network (SIGN) has not produced guidelines relevant to physical activity in specific populations. In summary, the United Kingdom guidelines on physical activity for health state that healthy adults aged 19-64 years should be active daily and participate in:

- at least 150 minutes of moderate aerobic activity per week and strength exercise on two or more days per week, or
- 75 minutes of vigorous aerobic activity and strength exercises on two or more days a week, or
- A mix of moderate and vigorous aerobic activity per week and strength exercises on two or more days per week that work all the major muscles (Department of Health, 2011)

The levels stated for all of the above components are minimum levels which should be attained, often described as threshold levels. Adults in this age category are also advised to minimise the amount of time spent being sedentary (sitting) for extended periods. An additional component of the guideline for adults aged 65 and over is the recommendation that older adults at risk of falls should incorporate physical activity to improve balance and co-ordination on at least two days a week.

Physical activity guidelines for clinical populations

International guidelines for clinical populations which are most applicable to the population group under investigation in this thesis are presented in Table 1. Cancer, cardiovascular disease, diabetes and disability are included for populations in the United Kingdom, United States and Australia. The list is not exhaustive and additional evidence is available for populations with mental health conditions and bone and joint diseases for example (Paluska & Schwenk, 2000; Warburton, Nicol, & Bredin, 2006). However, by including these four non-communicable disease categories in the geographical context of these three countries, the health status is representative of most people in the developed world who have limb absence. In the case of clinical guidelines, there are condition-specific refinements documented to optimise health benefits and condition management, and ensure safe and enjoyable participation. However, differences still remain in the content of different clinical guideline versions which may cause possible confusion and dilution of the impact of what should be consistent, clinically relevant advice. For example, the first entry in Table 1 shows that the Australian guideline for those with cancer refers readers to the National Physical Activity Guidelines for Adults website rather than offering advice relevant to the medical condition. There is also a focus on participation in physical activity in order to prevent cancer developing. This differs from United Kingdom and United States guidelines which specifically recommend 30 minutes and 30-60 minutes respectively of moderate to vigorous intensity physical activity on five or more days of the week for people with cancer.

Clinical guidelines recommend how healthcare professionals should care for people with specific medical conditions. Clinical guidelines can cover any aspect of a condition and may include recommendations about providing information and advice, prevention, diagnosis, treatment and longer-term management. A systematic review of 64 observational studies and international guidelines showed there is strong evidence that, according to international guidelines, physical activity should be adopted as a tool in the prevention and treatment of many chronic diseases (Adami, Negro, Lala, & Martelletti, 2010).

Guidelines and public health messages have tended to focus on the specific aspect of people achieving 150 minutes of moderate to vigorous aerobic activity, with less emphasis on other components of the guidelines such as flexibility and resistance training. Flexibility training is important in maintaining joint range of movement, and resistance training is important in maintaining muscle strength (Garber et al., 2011). However, these key components of physical activity may not be communicated in the form of active living messages as often or as clearly as they could be in order to increase uptake of and compliance with the physical activity guidelines. This can be supported by a statement in the Scottish Health Survey that the proportion of all adults meeting the guidelines for moderate to vigorous intensity physical activity, ranging from 62-64%, has not changed significantly since 2012 (Scottish Government, 2017).

Table 1 Physical activity guidelines for clinical populations

Organisation	Citation	Origin	Grouping	Age	Recommendations	Additional Notes
British Association of Sport & Exercise Sciences (BASES)	(Campbell, Stevinson, & Crank, 2011)	UK	Cancer	All	Supports American Cancer Society's recommendation of 30-60 mins of moderate-vigorous-intensity >5 days/wk for survivors who are otherwise healthy.	BASES Expert Statement states cancer survivors should follow the health-related guidelines for the general UK population and avoid inactivity. A general approach to guidelines but adhering to ACSM 2010.
American College of Sports Medicine	(Schmitz et al., 2010)	USA			30mins of moderate activity/d, 5d/wk Exercise to be tailored to individuals, and considering fitness, diagnosis, safety factors.	Cancer Research UK upholds ACSM 2010 review and recommendations. No formal guidelines for cancer survivors published in the UK.
Cancer Council Australia (ACC)	(Cancer Council Australia, 2015)	Australia			ACC website (2015) focusses on prevention rather than physical activity in those living with cancer	ACC website refers readers to National Physical Activity Guidelines for Adults website
National Institute for Health and Care Excellence (NICE)	(National Institute for Health and Care Excellence, 2012, 2015a, 2015b)	UK	Diabetes Types 1 & 2	All	**Type 1 Diabetes** Give info on: - appropriate intensity and frequency role of self-monitoring of changed insulin and/or nutritional needs - effect of activity on blood glucose levels - effect of exercise on blood glucose levels when hyperglycaemic appropriate adjustments of insulin dosage and/or nutritional intake for exercise and post-exercise in the 24h period following - interactions of exercise alcohol -further contacts sources of information	Promote the benefits of and engagement in regular PA at diagnosis when motivation for change is highest.

					Type 2 Diabetes All recommendations based on (Department of Health, 2011). In cases where recommendation would be unrealistic, then tailored advice can be offered.	Advice introduced on explaining the need to reduce sedentary time.
Association of British Clinical Diabetologists (ABCD)	(Association of British Clinical Diabetologists, 2016; Nagi & Gallen, 2010)	UK	Diabetes Types 1 & 2	All	**Type 1 Diabetes** PA recommendations same as for those without diabetes. Consider restrictions imposed by the presence of micro- or macrovascular complications. Specific, specialist, individualised advice incl.: • insulin adjustment and dietary modification both before and after exercise to reduce risk of hypoglycaemia • blood glucose targets pre post exercise • regular blood glucose monitoring • management of hypoglycaemia and exercise-induced hyperglycaemia Type 2 Diabetes 3-5 times/wk with no more than 48-hour between intervals Mild- to moderate-intensity (aerobic and/or resistance training) 15–60 min/session with warm up and cool down periods approx 5mins Examples are brisk walking, jogging or running, swimming, bicycling, tennis, etc	

American College of Sports Medicine and American Diabetes Association	(Colberg et al., 2016)	USA	Diabetes Type 2	All	>150 min/wk moderate-vigorous aerobic exercise over at least 3d/wk with ≤2 consecutive days between aerobic bouts. 75 min/wk) of vigorous-intensity or interval training may be sufficient for younger and fitter individuals Resistance exercises 2-3 d/wk non-consecutive days Flexibility training 2-3 d/wk	Precautions should be taken specific to the individual. Pre-exercise medical clearance is generally unnecessary for asymptomatic individuals prior to beginning low- or moderate-intensity physical activity not exceeding the demands of brisk walking or everyday living.
Diabetes Australia	(Diabetes Australia, 2015)	Australia	Diabetes Types 1 and 2		General advice. Not evidenced-based. 30 mins/day or time can be divided in 3 x 10 mins sessions. For weight loss, 45-60 min every day. Should be moderate intensity. Advice given on foot care - middle-aged and elderly people esp. to inspect feet before and after exercise. Avoid stress on feet (e.g. running). choose bicycle, swimming. Exercise tips given on fluid and carbohydrate intake during and after exercise to avoid dehydration. Monitor blood glucose levels before, if possible during, and after exercise. Discuss appropriate adjustments to exercise schedule with doctor or Credentialed Diabetes Educator.	Position statements available on website. Position statement on physical activity and/or exercise in diabetes not available

National Institute for Health and Care Excellence (NICE)	(National Institute for Health and Care Excellence, 2014)	UK	Cardiovascular disease	All	Advise people at high risk of or with CVD to do the following every week: - at least 150 minutes of moderate- intensity aerobic activity **or** - 75 minutes of vigorous-intensity aerobic activity or a mix of moderate and vigorous aerobic activity in line with national guidance for the general population - muscle-strengthening activities on ≥2 d/wk working all major muscle groups Those unable to perform moderate-intensity physical activity because of comorbidity, medical conditions or personal circumstances to exercise at their maximum safe capacity.	
American College of Sports Medicine and American Heart Association	(Haskell et al., 2007; Thompson, Arena, Riebe, & Pescatello, 2013)	USA			Should be encouraged to consult with their physician prior to initiating a vigorous-intensity physical activity program. While medical evaluation is taking place, the majority of these people can begin without consulting a physician light- to moderate-intensity physical activity programs such as walking.	Recommendations for this population challenging to research. Majority focus on disease prevention rather than recommendations for exercise in this clinical population. Family practitioner and cardiologist advice necessary before commencing anything more than a walking program.

The National Heart Foundation of Australia	(Briffa et al., 2006; National Heart Foundation of Australia, 2006)	Australia	Cardiovascular disease	All	Survivors of recent CV events should be offered participation in supervised exercise rehab., where available. Unless contraindicated, people with well-compensated, clinically stable CVD should progress over time to the recommended physical activity dose incl. light-moderate resistance activities. Those with advanced CVD or severely impaired functional capacity may have to aim for a lesser amount.	Specific online factsheet guideline available. Easy to follow.
No formal guidelines identified	(Bull & Expert Working Groups, 2010)	UK	Disability		No formal recommendations identified	Recommendations made on the priority need for the UK to establish process for the development of PA guidelines for adults, young people and children with non-communicable disease (e.g. cardiovascular disease, diabetes, cancer, mental health conditions). Physical disability not mentioned.

U.S. Department of Health and Human Services	Guidelines based on: (Rimmer & Chen, 2009; U.S. Department of Health and Human Services, 2008)	USA	DISABILITY	≥6	Adults with disabilities, who are able, should do >150 mins/wk of moderate-intensity, or 75 mins/wk of vigorous-intensity aerobic activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity episodes >10mins, preferably spread through wk. muscle-strengthening activities on ≥2 d/wk working all major muscle groups When adults with disabilities are not able to meet the guidelines, they should engage in regular physical activity according to their abilities and should avoid inactivity. Adults with disabilities should consult their health-care provider about the amounts and types of physical activity that are appropriate for their abilities.	Acknowledgement that disparity exists between the level of PA participation among people with disabilities compared to those without a disability (U.S. Department of Health and Human Services, 2008) Promoting health guidelines requires a coordinated effort among public health professionals and federal agencies in identifying evidence-based interventions that have documented success for improving key outcomes in select disability groups (Rimmer & Chen, 2009) NCHPAD website contains factsheets describing various disabilities and health conditions, as well as physical activity, exercise, and overall health considerations and recommendations. Comprehensive and specific section on exercise prescription for trainers working with amputees (National Center on Health Physical Activity and Disability, 2017).

Note. A conceptual model was developed in the Netherlands entitled Physical activity for people with a disability to improve participation in PA and health outcomes (van der Ploeg, van der Beek, van der Woude, & van Mechelen, 2004)

In clinical populations such as those with type 2 diabetes, additional elements of the physical activity guidelines could be condition-specific and beneficial if incorporated into daily and weekly routines (Armstrong & Sigal, 2015). This review article describes the importance of emphasising elements of the guidelines such as resistance training and the emerging evidence around the negative effects of sedentary behaviour when promoting physical activity. The same message is derived from another study of a convenience sample of people (N = 1100) who were interviewed about their perceptions of recommended physical activity doses contained in the physical activity guidelines. The sample was 50% female, 28% was > 65 years old, and 41% was overweight (Knox, Webb, Esliger, Biddle, & Sherar, 2014). The analysed responses showed that the current guideline of 150 minutes/week of moderate-vigorous physical activity might be perceived as being unattainable and impractical for those with low levels of physical activity. The researchers also reported that reinforcement of the guideline physical activity doses might be less encouraging than promoting any increase in physical activity irrespective of the level. Repeating the current guideline levels rather than varying the content of the message could act as a barrier for engaging in physical activity participation, particularly for those in poorer health who may otherwise benefit greatly from becoming more physically active.

Physical activity guidelines for individuals with limb absence

Evidence-based clinical guidelines exist for the physiotherapy management of adults with lower limb amputation, and professional standards and guidelines on amputation rehabilitation recognise physical activity as being an important component of pre- and post-operative rehabilitation (British Association of Chartered Physiotherapists in Amputee Rehabilitation, 2012; British Society of Rehabilitation Medicine, 2003). Furthermore messaging and guidance on participation in group physical activity for established prosthesis users is also provided in non-peer reviewed literature such as online media (Amputee Coalition, 2017; Limbless Association, 2017). However, to date, there are no published recommendations on how much physical activity people with limb absence should do to maintain and improve health. This may be due to the fact that characteristically, people with lower limb absence could be considered as being physically and physiologically different. For example, an evaluation was conducted of the records of 229 patients at a Veteran Affairs hospital (n = 221 were male and n = 8 were female). Consecutive major lower extremity amputations (119 above-knee amputations and 177 below-knee amputations) were performed over a period of 86 months (Cruz, Eidt, Capps, Kirtley, & Moursi, 2003). The researchers concluded that most patients undergoing major lower extremity amputations have much comorbidity; hence morbidity and mortality rates are high, with the most common causes of death being cardiac and respiratory in nature. These data suggest that major lower extremity amputations highlight a very high-risk population with only 39% survival at 7 years post-amputation. Of the known causes of death, 21 resulted from myocardial infarction, 22 from congestive heart failure, 14 from respiratory failure, 13 from cancer, 10 from sepsis, 7 from stroke, and 6 from renal failure. Based on the known causes of death following limb amputation, it could be feasible to draw upon physical activity guidelines which exist for other conditions such as cardiovascular disease and diabetes for adults with lower limb absence (as described in Table 1). It is an area worthy of further attention in order to determine whether guidelines for people with limb absence are specifically required. It may help to prevent duplication of effort and minimise resource outlay if similar medical conditions could be grouped together and a guideline created for these populations.

Physical activity promotion for the general population, for clinical populations, and for individuals with limb absence

Promotion of physical activity is a public health priority and improvements to promotional strategies continue to be explored. For instance, Draft 2 of a global action plan on physical activity 2018–2030 was submitted for feedback in January 2018 by the World Health Organisation. Formal implementation of the action plan will provide a global opportunity to refocus and renew efforts at promoting physical activity (World Health Organization, 2017b). At a national level, the United Kingdom Government has produced guidance on how all adults can be more active daily, yet unlike the American guidance, there are no timescales for delivery of the guidance nor measurable outcomes such as health improvement stated (Public Health England, 2016). Further, the Active Scotland Outcomes Framework describes

Scotland's ambitions for sport and physical activity (Scottish Government, 2017). Active Scotland Outcomes contribute to the delivery of National Outcomes and the framework describes the key outcomes desired for sport and physical activity in Scotland over the next ten years.

In the United States, the Healthy People 2020 initiative provides a comprehensive set of 10-year, national goals and objectives for improving the health of all Americans (U.S. Department of Health and Human Services, 2014). The development of the National Health Promotion and Disease Prevention Objectives is a work in-progress until 2030 (https://www.healthypeople.gov/). Physical activity may be promoted in several ways for example: through delivery of personalised advice by healthcare professionals; by the provision of formal or informal written materials; or referral to an exercise program designed and facilitated by qualified personnel. A combination of these promotional strategies may also be possible however it may be simplistic to assume that these strategies will have the same aims and objectives. This again demonstrates a need for international parity in delivering public health messages. A key United Kingdom public health example of reporting on physical activity for health is a publication from the Chief Medical Officers of the four home countries (Department of Health, 2011). This document shows how the public health community can encourage people to make healthier lifestyle choices. A United States example of written guidance is a document detailing 10 effective strategies on how to increase physical activity (U.S. Department of Health and Human Services, 2011). Strategies may be individually tailored, school-based or community-wide, or a combination of all.

Building on strategies to promote physical activity, more recently electronic technology has played a role in the delivery of physical activity promotion (Middelweerd, Mollee, van der Wal, Brug, & Te Velde, 2014). Health and fitness applications (apps) have gained popularity in interventions to improve physical behaviour outcomes. A systematic review examined 27 studies to assess the efficacy of interventions that use apps to improve physical behaviour outcomes in children and adults (Schoeppe et al., 2016). The review provided evidence that app-based interventions to improve physical behaviour outcomes can be effective. Most studies featured in the review were randomised controlled trials (N = 19; 70%). One such randomised control trial detailed the recruitment of 110 adults with a mean age of 35.6 years (standard deviation 12.4) who received access to a 50-day online social networking physical activity intervention which included self-monitoring, social elements, and pedometers (Maher et al., 2015). Assessments were undertaken online at baseline, 8 weeks, and 20 weeks. The primary outcome measure was self-reported weekly moderate-to-vigorous physical activity (MVPA). Secondary outcomes were weekly walking, vigorous physical activity time, moderate physical activity time, overall quality of life, and mental health quality of life. Results stated that intervention participants had significantly increased their total weekly MVPA by 135 minutes relative to the control group (p = .03). This was due primarily to increases in walking time. High levels of engagement with the intervention, and particularly the self-monitoring features were observed. Another randomised controlled trial was conducted to evaluate the effectiveness of a smartphone app to increase physical activity in primary care (Glynn et al., 2014). The intervention group was provided with an app and detailed instructions on how to use it to achieve these goals. Measurement of daily step count between baseline and follow-up provided the outcome of change in physical activity. 78 provided baseline data (intervention = 37; control = 41) and 77 provided outcome data (intervention = 37; control = 40). The mean increase in daily step count from a baseline of 4365 steps a day for the intervention group from week 1 to week 8 inclusive was 1029 steps per day (95% confidence interval 214 to 1843). Improvements in physical activity in the intervention group were sustained until the end of the 8-week trial. The benefits of smartphone apps over other intervention delivery modes such as websites, face-to-face counselling and group sessions may partially explain the efficacy of app interventions. Understanding the best modes of delivering interventions can be supported by qualitative focus group data. These data show that convenient access to health behaviour change programs that provide information and advice, real-time self-monitoring, feedback, reinforcement, social support, and instant reward are regarded as important aspects of any app intervention by students in two studies conducted in the United Kingdom and the Netherlands (Dennison, Morrison, Conway, & Yardley, 2013; Middelweerd et al., 2015).

Physical activity promotion for clinical populations

The focus of exercise and physical activity guidelines has evolved from recommending structured, vigorous exercise, to recommending moderate-intensity physical activity which can be incorporated into daily routines (Richards, 2015). This is a positive trend based on recommendations in Warburton's 2016 critical review which described the negative consequences of promoting possibly over-ambitious threshold-based messages related to physical activity and health (Warburton & Bredin, 2016). For instance, promotional materials have emerged that state explicitly that individuals "must" attain 150 minutes per week of moderate to vigorous physical activity to achieve health benefits. This has the potential effect of creating a significant barrier for physical activity participation, particularly for those who would benefit greatly from becoming more physically active. Additional messages state that participating in vigorous intensity physical activity for less time is an alternative to attaining 150 minutes per week of MVPA. Yet this message also implies that health benefits cannot be accrued at lower volumes of activity, such as a participating in a gentle walking programme. Campaigns based on threshold messages may be also be limited when promoting small physical activity increases towards a population and dispelling the negative consequences of this type of promotion is also important. This is supported by a study which examined the perception of health benefits after exposure to physical activity messages that did and did not state a threshold on activity duration (Knox et al., 2014). A convenience sample of adults (N = 1100) received: a threshold message (150 min/week MVPA); a message that presented the threshold as a minimum; a generic message; or no message. Participants rated perceived health effects of seven physical activity durations. Those who were given all three messages held more positive perceptions of >150 min/week of MVPA relative to those not receiving any message. For MVPA durations <150 min/week, the generic PA message group perceived the greatest health benefits. Those receiving the threshold message tended to have the least positive perceptions of durations <150 min/week. The researchers concluded that threshold messages were associated with lower perceived health benefits for shorter durations.

Those with clinical conditions may have the perception that by increasing physical activity levels, personal health may be put at risk, and poor health may be exacerbated further (McAuley, Szabo, Gothe, & Olson, 2011). These clinical circumstances must be managed with care and caution to minimise risk of health deterioration due to over-participation. The effect of any condition on an individual's ability to participate in physical activity must be considered prior, during and following activity (van der Ploeg, van der Beek, van der Woude, & van Mechelen, 2004). To facilitate this, there are guidelines for clinical populations such as those with diabetes or cardiovascular disease (Nagi & Gallen, 2010; National Institute for Health and Care Excellence, 2014). The clinical setting can promote stronger adherence by providing a consistent, supportive, and positive environment. Adherence is greater when patients perceive a strong, collaborative relationship with healthcare providers (Miller, 1997).

In considering primary care interventions which examine how the benefits of physical activity are communicated, a systematic review and meta-analysis of randomised controlled trial of sedentary adults was conducted (Orrow, Kinmonth, Sanderson, & Sutton, 2012). There were two review objectives, to determine whether trials of physical activity promotion showed sustained effects on physical activity or fitness in sedentary adults, and whether exercise referral interventions were more effective than other intervention strategies. 15 trials were included in the review (N = 8745). In terms of the participants, the researchers did not define the description of sedentary. It was concluded that promotion of physical activity leads from small to medium improvement in self-reported physical activity at 12 months (odds ratio 1.42, 95% confidence interval 1.17 to 1.73; standardised mean difference 0.25, 0.11 to 0.38). The number needed to treat with an intervention for one additional sedentary adult to meet internationally recommended levels of activity at 12 months was 12 (7 to 33). Insufficient evidence was found to recommend exercise referral schemes over advice or counselling interventions. The authors acknowledged that longer follow-up and the use of objective measures of outcome would enhance their findings. This was due to self-report measurements often being different than direct measurement levels of physical activity. This poses a problem for reliance on and precision of self-report measures, and for attempts to correct for self-report (Prince et al., 2008).

Research has also been carried out to determine the effectiveness of exercise referral schemes. This randomised control trial compared the effect of two communication styles with a non-intervention control group on self-reported physical activity at 12 months (Hillsdon, Thorogood, White, & Foster, 2002). Methods involved advice or counselling given face-to-face or by phone (or both) on multiple occasions with middle-aged men and women (N = 1658). Results were compared with those from a no-intervention control group on self-reported physical activity at 12 months. The researchers concluded that physical activity promotion in primary care was not effective. Findings suggest that patients whose health may benefit from increased physical activity could benefit from 20–30 minutes of brief negotiation to increase physical activity. The recommendation was made that further research be conducted to derive the most effective way of increasing physical activity in primary care.

This was supported by results from the 2011–2012 National Health and Nutrition Examination Survey (NHANES). Participants were asked if they had ever been told by a doctor or health professional during the past 12 months to increase physical activity or exercise in order to lower the risk for certain diseases (Centers for Disease Control and Prevention, 2011). Some 36.3% of adult Americans reported that they had been told by a health care professional to be physically active. Among adults reporting no exercise during a typical week (including no work, transportation, or recreational exercise), only 44.9% had been told by a health care professional to increase their exercise (Loprinzi & Beets, 2014).

Conversely, results of a systematic review conducted to assess physical activity promotion by community health workers within specific interventions suggested that improvements are being made in communicating the message of being more active (Costa, Guerra, Santos, & Florindo, 2015). Descriptive synthesis was carried out on 26 studies, with 24 studies being carried out in the United States. One study evaluated physical activity using an objective measurement of a pedometer. The remaining 25 studies utilised either questionnaire or self-report tools to assess physical activity promotion. Women predominated in all studies comprising mixed gender samples (*n* = 18, 69.2%), while six studies (23.1%) included women participants only. Successful interventions were most commonly conducted over a period of 6.5 months, and aimed at women, individuals older than 30 years, specific ethnic groups and at-risk or clinical groups. Results may suggest a positive trend towards increased promotion and subsequent positive promotional effects and outcomes of interventions. However, as women predominated in most studies, the conclusions are gender biased and may not be representative of the whole population. Further research therefore should focus on males.

Physical activity promotion for individuals with limb absence

Physical activity promotion and the implementation of clinical interventions to improve health have been well-researched and documented for both general and clinical populations. It was also considered important to explore if and how physical activity is being promoted in the population of adults with lower limb absence. A literature search concluded that these questions have not been addressed in the peer-reviewed literature specifically for this population. Another aim of this particular section of the literature review was to ascertain who is tasked with promoting physical activity in adults with lower limb absence. A search did not reveal any literature in relation to this question. However, the majority of available online literature suggests that the overarching promotion of physical activity is delivered by the World Health Organisation, filters through governmental agencies such as the Department of Health in the United Kingdom, and to societies supporting specific clinical populations such as Diabetes UK (Department of Health, 2011; Diabetes UK, 2017; World Health Organization, 2017a).

Objective measurement of physical behaviour

Accurate and reliable assessment of physical activity is important but can be challenging for epidemiologists, exercise scientists, clinicians, and behavioural researchers (Troiano, 2006). Measurement techniques can be categorised as follows: direct observation; subjective reporting; and objective devices such as accelerometers. In order to be specific to the population of interest and the type of objective measurement tool used, this literature search was conducted encompassing accelerometry, and only adult populations (not children and adolescents). The ranking of methods for the assessment of habitual physical activity on six different parameters, where 1 denotes the highest and 5 the lowest rank are summarised in Table 2 taken from an article by Westerterp in 2009 who critically appraised the assessment of physical activity (Westerterp, 2009). The comparative description of the separate methods shows that using motion sensors is the most viable option for researchers and participants. This is a belief supported by Aparicio-Ugarriza et al. who discussed the merits and shortcomings of various modes of measuring physical activity (Aparicio-Ugarriza et al., 2015). For example, accelerometers save information about intensity and frequency of physical activity, but not about the type of physical activity.

Table 2 Ranking of methods for the assessment of habitual physical activity

	Subject interference	Subject effort	Contextual information	Activity structure	Objective data	Observer time/cost
Behavioural observation	5	1	1	2	4	5
Questionnaire diaries interviews	4	5	2	4	5	2
Heart rate monitoring	3	4	4	3	3	3
Motion sensors	2	3	3	1	2	1
Doubly labelled water	1	2	5	5	1	4

Note. Table contents from Westerterp, K. R. (2009). Assessment of physical activity: A critical appraisal. *European Journal of Applied Physiology, 105*, 823-828. 1 = high ranking 5 = low ranking

Measurement can be challenging due to lack of consensus in best measurement practice. Articles such as those written by Ward and colleagues have presented informative descriptions to help researchers in the selection and use of accelerometers (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). More recently, Edwardson and colleagues have described considerations when using the activPAL™ monitor which is a useful, device-specific resource for researchers (Edwardson et al., 2016). This will be described later in the chapter.

The benefits of objective monitoring techniques over subjective self-reporting methods is supported by comprehensive research conducted using data from the 2003-2004 National Health and Nutritional Examination Survey (Troiano, Berrigan,

& Dodd, 2008). For the subjective component of the research a representative sample of 9643 United States individuals were interviewed and examined by survey teams. For the objective component of the research, those assessed as ambulatory from the subjective component (*n* = 6329) provided at least one day of accelerometer data having worn an ActiGraph accelerometer (ActiGraph, LLC; Ft. Walton Beach, FL) for 7 days). Four or more days of accelerometer data were provided by 4867 participants. Results showed that males are more physically active than females. Physical activity declines dramatically across age groups between childhood and adolescence and continues to decline with age. Among adults, adherence by participants to the stated recommendation of achieving 30 minutes per day of physical activity was less than 5% of the cohort. This was in comparison to subjectively self-reported adherence of 51% who accumulated 150 minutes of physical activity in the form of household, recreational and transportation activity per week. In conclusion, objective and subjective measures of physical activity gave qualitatively similar results regarding gender and age patterns of activity. However more importantly, adherence to physical activity recommendations according to accelerometer-measured activity was substantially lower than according to self-reported activity. Interpreting self-report activity should be performed cautiously as bias in self-reporting can lead to imprecise conclusions. Hence, the assumption is that objective measurements through accelerometry can yield more truthful and accurate estimates over participants over-estimated perceptions of their physical activity levels (Duncan, Sydeman, Perri, Limacher, & Martin, 2001). Another group of researchers appraised the suitability and role of accelerometers for large scale population-level physical activity monitoring (Pedisic & Bauman, 2015). Their findings suggested however that accelerometers have limitations regarding generalisability, validity, comprehensiveness, simplicity, affordability, adaptability, between-study comparability and sustainability. In short, accelerometer data can only be interpreted and reported consistently and accurately if data collection and processing methods are appropriate and standardised both nationally and internationally.

Accelerometer reliability and validity studies

Using reliable and valid measurement devices is a crucial component of research quality (Kimberlin & Winterstein, 2008). It is important to select an accelerometer which is within researchers' budget, has established reliability, and has been validated in the population to be assessed (Berlin, Storti, & Brach, 2006). Variables derived from accelerometer data include accelerometer or step counts, counts per minute, energy expenditure, and minutes spent in various intensity categories. Researchers should compare the unit of measurement for each study establishing reliability and validity. For example, if bouts of standing or sitting/lying are to be assessed then reliability and validity should be determined for the accelerometer in recording these bouts. Trost and colleagues reported in 2005 that definitive evidence did not exist which indicated that one make and model of accelerometer is more reliable and valid than another (Trost, McIver, & Pate, 2005). Since then, a systematic review has been conducted to evaluate the measurement tools used in interventions to increase physical activity among older adults (65+ years), including both self-report measures and objective measures (Falck, McDonald, Beets, Brazendale, & Liu-Ambrose, 2016). In addition, the implications of different measurement tools on study results were evaluated and discussed. Of the 44 studies included, 32 used self-report measures, nine used objective measures and three studies used both measures. 29% of studies used a measure that had neither established validity nor reliability, and only 63% of measures in the interventions had established both validity and reliability. Only 57% of measures had population-specific reliability and 66% had population-specific validity. The majority of intervention studies to help increase older adult physical activity participation used self-report measures, even though many have little evidence of validity and reliability. Another review presented similar statistics on the reporting of validity (Cervantes & Porretta, 2010). This review examined the literature on physical activity measurement among individuals with disabilities utilising Yun and Ulrich's view on measurement validity (Yun & Ulrich, 2002). Individuals with disabilities in this review were classified as those identified in the Public Law 108–446 Individuals with Disabilities Educational Improvement Act (IDEIA) of 2004. Included in the 13 stated conditions were autism, deaf-blindness, hearing impairments, and orthopaedic impairment. From 28 studies reviewed, findings revealed that self-report and accelerometers were the most common approaches to measuring physical activity, and 17 studies (61%) reported validity and reliability evidence. Regarding the specific use of accelerometers among individuals with disabilities, all eight of the studies in this review reported criterion-related validity which is the extent to which a measure is related to an outcome. The reporting of criterion-related validity in these studies should be treated with caution as some researchers failed to determine an appropriate criterion and subgroups of rather than the whole representative sample of the population were used.

Identification of whether available accelerometers have been appropriately validated for use in assessing physical activity (energy expenditure) was carried out through systematic review (Van Remoortel et al., 2012). 134 papers were reviewed; 40 studies were conducted in a field setting (validation against doubly labelled water), 86 studies in a laboratory setting (validation against a metabolic cart, metabolic chamber) and eight in field and laboratory settings. Pedometers, accelerometers (uniaxial, biaxial and triaxial designs) and multisensor systems featured in the selected research articles. Multisensor systems combine accelerometry with other sensors which capture body responses to exercise (e.g. heart rate or skin temperature) to optimise physical activity assessments. Correlation coefficients between accelerometer outcomes and energy expenditure by the criterion method (doubly labelled water and metabolic cart/chamber) and percentage mean differences between energy expenditure estimation from the monitor and energy expenditure measurement by the criterion method, were extracted. Most validation studies had been performed in healthy adults ($n = 118$), with few carried out in patients with chronic diseases ($n = 16$). For total energy expenditure, correlation coefficients were significantly lower in uniaxial compared to multisensor devices. Uniaxial devices tended to underestimate total energy expenditure (−12.07% (95% CI; -18.28 to −5.85) compared to triaxial (−6.85% (95% CI; -18.20 to 4.49), $p = .37$) and were statistically significantly less accurate than multisensor devices (−3.64% (95% CI; -8.97 to 1.70), $p < .001$). Total energy expenditure was underestimated during slow walking speeds in 69% of the laboratory validation studies compared to 37%, 30% and 37% of the studies during intermediate, fast walking speed and running, respectively. For active energy expenditure, correlations were slightly but not significantly lower in uniaxial compared to triaxial and multisensor devices. The study conclusions were that triaxial devices tend to be more valid monitors, accelerometers are less accurate at slow walking speeds, and information about validated activity monitors in chronic disease populations is scarce. Validation studies in these populations are required prior to their inclusion in clinical trials in order to provide valid results.

A commercially-available accelerometer, the activPAL™ triaxial monitor, is of relevance to the PhD line of research. Therefore, it was important to gain an understanding of reliability and validity studies carried out using the activPAL. Table 3 details the studies revealed from the search, and reports on the reliability and validity results. In reviewing the literature and compiling the table of results, it became clear that different methods of reporting results are being used, with some of the studies presenting only validity results, or only reliability results. There was also variability in the types of validity being reported. For example, the Dowd, Harrington and Donnelly 2012 article reports on concurrent validity between the activPAL versus the ActiGraph accelerometers for sitting, standing and slow walking (Dowd, Harrington, & Donnelly, 2012). In contrast, other authors reported validity results in terms of percentage agreement (Grant, Dall, Mitchell, & Granat, 2008; Grant, Ryan, Tigbe, & Granat, 2006). This inconsistency in reporting methods may lead to challenges for researchers in extracting consistent variables from reliability and validity data in order to be able to design robust objective measurement studies. The following key points can be summarised from Table 3:

1. reporting of research results can be inconsistent.
2. study researchers do not always establish a criterion reference and reporting of intra- or inter-rater reliability can be variable.
3. study researchers often report on reliability or validity, but usually not both.
4. all participants in the 10 studies were adults suggesting there is a lack of evidence on reliability and validity of the activPAL in children.
5. the mean number of participants across the 10 studies was 20 (range 1- 43) suggesting robust results are being reported.

Table 3 activPAL accelerometer reliability and validity studies

Study	Sample	Validity measures activPAL	Reliability measures activPAL
(Buis et al., 2014)	*n* = 1 Healthy adult with unilateral transtibial amputation Two activPAL monitors per participant	Not reported	Inter-device reliability for step count *ICC* = .99
(Dahlgren, Carlsson, Moorhead, Hager-Ross, & McDonough, 2010)	*N* = 18 Healthy adults One activPAL monitor/adult placed on prosthesis shin	Not reported	Intra-device reliability Walking *ICC* = .69 (95% CI = .35-.87). Jogging *ICC* = .81 (95% CI = .57-.93). Cycling 45rpm *ICC* = .27 (95% CI = -.21-.65). Cycling 75rpm *ICC* = .55 (95% CI = .12-.80)

Study	Sample	Validity measures activPAL	Reliability measures activPAL
(Dowd, Harrington, & Donnelly, 2012)	*N* = 30 Healthy females One activPAL monitor One ActiGraph monitor One Cosmed K4B2	Criterion validity R^2 = .93 (*SE* = 1.20 when compared with METs across 7 activities. Concurrent validity activPAL vs ActiGraph $r = .96$, $p < .01$ Agreement for sitting, standing, stepping for activPAL and ActiGraph were 100%, 98.2%, 99.2% and 100.0%, 0%, 100% respectively	Not reported
(Grant, Ryan, Tigbe, & Granat, 2006)	*N* = 18 Healthy adults Three activPAL monitors One on each thigh, and third attached atop first monitor	Percentage agreement between observer and activPAL 95.9% for walking	Inter-observer reliability *ICC* > .97 sitting, standing and walking Inter-device reliability *ICC* = .79 - .99 for standing, sitting and walking

Study	Sample	Validity measures activPAL	Reliability measures activPAL
(Grant, Dall, Mitchell, & Granat, 2008)	*N* = 21 (11 female, 10 male) Adults with cardiovascular disease, or osteoporosis One activPAL monitor Two pedometers (NL-2000 SW-200) One monitor attached participant's thigh	Percentage error <1% for treadmill and outdoor conditions step number and cadence	Not reported
(Kanoun, 2009)	*N* = 43(33 females, 10 males) Healthy adults One activPAL monitor attached to participant's thigh	Underestimated steps taken by < 1% at 0.67, 0.90 and 1.33m.s^{-1}, and by 3.5% at 0.45m.s^{-1}	Not reported
(Larkin, Nordgren, Brand, Fraser, & Kennedy, 2015)	*N* = 20 (17 female, 3 male) Adults with a diagnosis of rheumatoid arthritis	Percentage difference Steps 25.9% Transitions 36.0% Sedentary time – 3.1% Standing and light activity time -7.6% Walking 4.5%	Inter rater reliability Step number *ICC* = .70 (95% CI = -.06 - .93) Transitions: not reported Sedentary time *ICC* =.75 (95% CI = .46 - .89) Standing and light activity *ICC* =.84 (95% CI = .64 - .94) Walking *ICC* =.92 (95% CI = .82 - .97)

Study	Sample	Validity measures activPAL	Reliability measures activPAL
(McGuckin, Sealey, Leicht, & Barnett, 2015)	*N* = 10 Healthy adults Two monitors attached to one thigh only	Not reported	Sitting *ICC* = .93 Standing *ICC* = .85 Walking *ICC* = .85
(Ryan, Grant, Tigbe, & Granat, 2006)	*N* = 20 (12 female, 8 male) Healthy adults Two monitors each placed on each participant's thigh (four in total)	Percentage error < 1.11% for step number and cadence	Inter-device reliability for step number and cadence *ICC* ≥ .99
(Salih, Peel, & Burgess, 2016)	*N* = 21 (6 female, 15 male) Adults in prosthetic rehabilitation with transtibial or transfemoral limb absence. Two activPAL monitors placed on each thigh	Limits of agreement Limb absent side = -.43 - .66 Sound side = -.09 - .10 Sensitivity Limb absent side = 86% Sound side = 90.5%	Not reported

The use of accelerometers in objectively measured free-living studies

Many objective measurement devices shown to be reliable and valid in laboratory settings are also appropriate for field studies and clinical settings (Aparicio-Ugarriza et al., 2015). There is a wealth of evidence to support the use of accelerometers in free-living studies on the general population and many clinical populations (Healy et al., 2011; Healy et al., 2007).

A systematic review was carried out on the use of accelerometry as an objective measure to assess physical activity in adults (Bento, Cortinhas, Leitao, & Mota, 2012). This review of 18 articles evaluated a total of 19,848 participants. Methodological approaches were scored for each of the studies and awarded points for reporting the following: a minimum of four days of data collection; hours of data collection (waking hours, sleep); the minimum number of monitoring hours per day to be considered as a valid day of data collection; the epoch used in data collection; use of an activity log along with the accelerometer; calibration method of the devices; the software used to analyse data; and how the authors accounted for non-wear time. Outcome measures were also extracted and analysed. The outcomes of interest were time spent at activities of different levels, and mean and total daily activity (most commonly reported outcome). As was described earlier in this chapter, the recurring theme of inconsistent presentation of reliability and validity data by researchers was evident. Articles selected for review had different methodological approaches, analyses, and results, which prevented study comparisons. From this review it was concluded there is a need to standardise study methods for data reporting to allow comparisons of results across studies and monitor population variations and changes. In addition, these data can inform research design for physical behaviour studies which include older people, and designs which report on findings for men and women separately.

More recently, research has been conducted to derive methodology standards for clinical trials through a review of research studies on free-living physical activity in patients with chronic obstructive pulmonary disease (Byrom & Rowe, 2016). To understand methods used and outcomes measured when utilising an activity monitor in this population, 76 studies were reviewed. The article summarised current practice and provided recommendations for implementation and data management standards. Included in the proposed standards were the methodology item, the activity monitor type; number of days the monitor was to be worn; and a valid day definition. For each methodology item, a proposed approach with rationale was presented. Confidence in each of the recommendations was summarised based on three levels: high consensus in the performed review; a reasoned approach where different approaches were reported; or more research and evaluation required to provide a standard for future research. The authors concluded that a set of standard methodologies need to be proposed and agreed for activity monitoring in clinical trials, providing a comprehensive template on which future studies can be designed and implemented. Another review of studies was designed to objectively evaluate physical activity following spine surgery (Rao et al., 2016). The researchers concluded that a key advantage of using accelerometers in clinical populations is the collection of standardised objective measurements across studies.

A third review of note is a study which reviewed published work in the measurement of sedentary behaviour to make recommendations for sedentary behaviour measurement in clinical studies (Byrom, Stratton, McCarthy, & Muehlhausen, 2016). Although the authors did not specifically describe the strategy adopted in searching for evidence, they described preliminary recommendations on accelerometer properties and outcome measure selection when studying sedentary behaviour. Outcome measures such as total sedentary time, maximum sedentary bout length, and the number of postural transitions should be included with the caveat that the second and third recommendations are researched and evaluated further in order to provide a standard for future research. Further, the authors recommend that accelerometers should be triaxial and provide raw acceleration data to enable post processing where necessary. Thigh-worn accelerometers are recommended to enable robust estimation of posture in addition to physical activity, with postural changes to be defined using a minimum sitting/upright period of 10 seconds in adults. In conclusion, the authors of each of all three of these review articles agree that devices should be selected for use in experimental studies based on validation evidence, and accelerometry data should be validated.

The previously-described review by Edwardson et al. related to considerations when using the activPAL monitor is probably one of the most relevant and comprehensive pieces of work on the topic of physical activity monitoring in free-living studies (Edwardson et al., 2016). More than 55 studies were reviewed in order for the researchers to summarise key issues when considering the activPAL for use in field-based research. Pre-data collection decisions, monitor preparation and distribution, data collection considerations, and manual and automated data processing possibilities were presented using examples from current literature and experiences from two research groups from the UK and Australia. For experienced and early-career researchers alike, this review is considered an invaluable resource which provides recommendations on the following:

- wearing protocol of 24 hours.
- deployment of activPAL accelerometer for at least 7 days.
- supply of comprehensive verbal, visual and written instruction for participants.
- provision of diary for participant recording of sleep and wake time.
- event files to be used for data provision.
- classify non-wear in waking time against external source such as a diary.
- transparency should prevail when reporting activPAL collection and processing methods.

The evidence from experimental studies that examine free-living physical behaviour is extensive. A study examining free-living physical activity in people with intermittent claudication is of relevance to the population of adults with lower limb absence, and draws on the work around validation of the activPAL accelerometer (Clarke, Holdsworth, Ryan, & Granat, 2013). This study featured 7-day continuous monitoring of 30 individuals using an accelerometer in order to objectively quantify the fragmented nature of walking bouts. The activPAL was the accelerometer of choice. The authors described an event-based claudication index which corresponds to the classic stop/start walking pattern which is universally displayed by people with intermittent claudication. The index provides an objective, functional outcome specifically tailored to impairments experienced by people with intermittent claudication. The index could significantly enhance the clinicians' ability to objectively determine the effectiveness of interventions in both clinical and research environments. Another study examining the same cohort used event-based analysis to characterise the distribution of duration and cadence of walking events (Granat, Clarke, Holdsworth, Stansfield, & Dall, 2015). An age-matched control group (*n* = 30) provided activPAL data for comparison with the data from the intermittent claudication group (*n* = 30). Both groups had similar number of walking events per day (392 ± 117 vs 415 ± 160), however the control group accumulated a greater proportion of their walking at higher cadences and 32% of their steps were taken at a cadence above 100 steps per minute. For the intermittent claudication group this was 20%. This is an important piece of evidence on which to draw due to the characteristics of the intermittent claudication population when compared to those with lower limb amputation. The majority of people with limb amputation have vascular compromise (United National Institute for Prosthetics Orthotics Development, 2011-2012). This study therefore provides useful comparison data for this PhD.

A search of the literature did not yield any evidence to help researchers gain an understanding of the free-living physical behaviour and patterns of those with lower limb absence. However, a study (Buis et al., 2014) compared the daily number of steps taken by two groups of participants with transtibial amputation each group wearing a different prosthetic socket prescription. Participants had to have worn their prosthesis daily for 6 months. Each subgroup had 24 participants (20 male, 4 female, mean age 50.4 and 60.54 years respectively) who wore the activPAL monitor for a maximum of 6 days with a 24 hour wear protocol. The activPAL was attached to the anterior shin tube of the prosthesis at the level of the ankle. The researchers showed the average number of steps taken daily was different for each group (9130 steps, *SD* = 4420, and 7383 steps, *SD* = 4383). The percentage of daily time spent in walking activity was 7.5%, *SD* = 3.7%, and 6.1% *SD* = 3.3%). The highest percentages of the total number of daily steps taken for both groups were shown to be in the cadence band of 100-110 steps/minute. The total number of steps taken for each group in all cadence bands at or above 100 steps/minute could not be determined as this data was not specifically reported. Other outcomes variables such as activity bouts, sit-to-stand transitions, time periods of bouts, and physical behaviour patterns were not investigated in this study.

Summary of Chapter 2, limitations of the evidence and the research questions

The aim of this literature review was to review and understand the evidence around five key areas in order to derive the research questions. The first area was the motivations and barriers to physical activity participation in general and relevant clinical populations and in those with limb absence. Included were the benefits of participating in physical activity and a rationale was presented for physical activity being promoted to people with disabilities. From this, it was apparent that this is a well-researched area in the general population and specific clinical populations. However, it is an under-researched one with regards to those with limb absence which led to research question 1:

What are the under-researched areas in relation to motivations and barriers to physical activity, exercise and sport participation in people with limb absence?

The second area was physical activity guidelines designed for the general population, relevant clinical populations, and for those with limb absence. Again this is a well-researched area with guidelines produced for general population and for specific clinical populations such as cardiovascular disease, cancer and diabetes. Guidelines have not been produced for people with limb absence. With this being the case, it was thought relevant to question if those working in prosthetic rehabilitation have any awareness and knowledge of the available guidelines. The third area was the promotion and implementation of physical activity. From the literature, little is known about prosthetic healthcare professionals knowledge of physical activity guidelines and if and how physical activity is promoted to those with limb absence. A review of the literature in these two areas gave rise to research question 2:

What is the demographic profile, the awareness and knowledge of prosthetic rehabilitation healthcare professionals in relation to physical activity guidelines, and what are the current and desirable practices of prosthetic rehabilitation healthcare professionals in relation to physical activity promotion?

The fourth key area was objective measurement of physical behaviour. A review of the evidence on reliability and validity studies in the general population, clinical populations and in the limb absent population was carried out. There is an abundance of robust research related to reliability and validity of the activPAL accelerometer in healthy adults and many clinical populations. However, there are few studies which have established interrater reliability of observed stepping and reclining nor examined reliability and validity in those with limb absence. This again suggests that this is an under-researched area. Therefore, research question 3 asks:

Is the activPAL accelerometer a reliable and valid measurement tool for use in testing adults with lower limb absence?

Finally, free-living studies which featured accelerometers in the methodologies were the fifth key area under examination. Again there is an abundance of free-living studies on the general population and some clinical populations which use the activPAL accelerometer to measure free-living physical behaviour. However, this is an under-researched area in people with limb absence. In addition, there are no studies which compare the free-living physical behaviours of this clinical group with those of the healthy population. This led to research question 4:

What is the free-living physical behaviour of adults with lower limb absence and how does their physical behaviour compare to that of a healthy matched control group?

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Appendix A Literature review: Abbreviated summary of subject headings and keywords

Subject population (people with limb absence)		Physical activity		Subject population (allied health professionals)		Guidelines (physical activity)		Promotion (physical activity)		Measurement		Reliability and validity		Motivations and barriers	
Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword	Subject Heading	Keyword
Amputees Artificial Limbs exp Prosthesis Design Prosthesis Fitting	amput* prosthe* limbless* trans-femoral trans-tibial above-knee below-knee	Motor activity Locomotion Physical Exertion	physical activity	Health Professional Public Health Professional Public Health Education Allied Health Personnel Medical Staff Nursing Staff Therapy Rehabilitation	health W/1 profession* therap* physio* prosthetist occupational therapist doctor nurse rehab*	Health Planning Guidelines Practice Guideline Health Policy	guideline* practice* policy	Health Promotion	promot* campaign* wellness wellbeing	Measurement Outcomes Monitors	measure* outcome* monitor*	Reliability Validity	reliability validity	Motivation Attitude Body Image	motiv* barrier*

Sedentary behaviour	
Subject Heading	Keyword
Sedentary Lifestyle	sedent* lifestyle factors inactive*

Note. Databases searched - Ovid Medline (1946 to June Week 2 2017), Google Scholar, The Cochrane Library, Journal of Prosthetics and Orthotics (hand searched)
Limits applied - English language, review articles, humans

Chapter 3 Study 1: A systematic review of the motivations and barriers to prosthesis users' participation in physical activity, exercise and sport

Chapter overview

This chapter presents a published systematic review of the motivations and barriers to participation in physical activity, exercise and sport by people with limb absence. This systematic review was conducted in 2011 one year before London hosted the Paralympic Games, and before Glasgow hosted the 2014 Commonwealth Games. The subjects of sport and exercise were topical, especially around those who were regarded as elite athletes with a disability. The literature review was conducted in the early phases of PhD study and before the research scope was narrowed from encompassing sports and exercise, to focussing on physical behaviour. However, conducting a systematic review on physical activity, exercise and sport in relation to people with limb absence allowed the author to understand and appreciate the evidence base around all the aspects of physical activity in this group of the population. The review is presented as published within the journal Prosthetics and Orthotics International in 2012.

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Background

The Paralympic Games will take place in London, England in the summer of 2012. In addition, the Commonwealth Games are to be hosted by Glasgow in Scotland in 2014 providing an exciting and unique opportunity to profile physical activity, exercise and sports for the able-bodied and those with a disability. In 2002 the Commonwealth Games introduced Elite Athletes with a Disability (EAD) to the events. This was repeated in 2010 in Delhi and will be the case in 2014 in Glasgow. All generations will be exposed to the obvious media coverage surrounding these events.

In this Prosthetics and Orthotics International special edition, much emphasis is placed on the elite para-athlete performer. However, the purpose of this particular review is to learn from the literature on how to promote physical activity, exercise and sport in non-elite, everyday prosthesis users. Although elite athletes form only a small proportion of the population, countless people with a sedentary lifestyle are encouraged to view them as role-models who will inspire them to become physically active. This is also true for elite athletes with a disability who may inspire their less active peers. The Glasgow Legacy Framework for the forthcoming 2014 Commonwealth Games suggest that Scottish sporting champions can be role models to inspire people to become more physically active (Glasgow City Council, 2012). The desired outcome following the Commonwealth Games is to encourage a cultural change in the people of Glasgow and increase their participation in physical activity and sport (Glasgow City Council, 2012). Both the Paralympics in 2012 and the Commonwealth Games in 2014 will be platforms for the celebration of sport and personal achievement. Preceding the Glasgow event, the United Kingdom (UK) Government has responsibility for maximising an increase in participation at community and grassroots level in all sport and across all groups following the Paralympics (House of Commons, 2007). A second ambition of both events is to increase the capacity of the sports infrastructure through improved facilities, club formation and development and coaching training and education (Glasgow City Council, 2012; House of Commons, 2007). However, a recent review of the impact of major sports events on health found little evidence for uptake of activity in populations around major events (McCartney et al., 2010). The review concluded that the available evidence is not sufficient to confirm or refute expectations about the health or socioeconomic benefits for the host population of previous major multi-sport events. The forthcoming Paralympic Games and Commonwealth Games, cannot be expected to automatically provide health benefits yet a healthier more active population are certainly desirable legacies after the events. The inclusion of the limb absent population in these legacies to their benefit should be a priority for those involved in their rehabilitation and care despite this contradictory evidence (Glasgow City Council, 2012; House of Commons, 2007; McCartney et al., 2010).

Importantly, the UK population with limb amputation is predominantly elderly and there are low levels of fitness and activity within this group (Davies & Datta, 2003). Despite an increase in opportunities for people with limb absence to participate in competitive sports due to better prosthetic components and the growth and development of sports organisations for the disabled, the numbers of prosthetic sports limb users also remain relatively low (Ruddell & Shinew, 2006). In the authors experience, for those more able users, a gentle walking rehabilitation goal such as that undertaken by a large proportion of the UK limb absent population, can be limiting. Because of the generally sedentary and elderly amputee patient demographic in the UK, it is more usual for those in a rehabilitation program to achieve a level of physical functioning which may not challenge the person to move beyond a basic walking goal. It is believed that by raising the awareness of practitioners through research and education, participation in physical activity, exercise and sport can be encouraged with resulting sustained health benefits for those with amputation. In an example, the evidence which examines walking interventions shows the benefits of tailored interventions delivered in group-based or individual settings (Ogilvie et al., 2007; Seligman, 2002). There is a suggestion that those with limb absence could and should engage in physical activity to improve their health and social inclusion (Webster, Levy, Bryant, & Prusakowski, 2001). This type of upstream intervention is required to reduce the alarming figures on the low levels of physical activity in the United Kingdom: only 40% of men and 28% of women meet the minimum recommendations for physical activity in adults (National Health Service, 2008). Indeed, in Scotland "72% of women and 59% of men are not active enough for health", making physical inactivity the most prevalent risk factor for coronary heart disease, and more prevalent than obesity and smoking (Scottish Government, 2003).

This review originated from the idea that it might be possible to make a difference to the lives of those with amputation who were motivated to become recreational or elite athletes. Against a backdrop of preparation for the elite international sports events of the next three years and beyond, the authors wish to promote the idea that sport is accessible to those who are athletically inclined. The authors also recognise the importance of the majority being able to maintain basic levels of daily physical activity; adults of age 19-64 years should aim to be active daily even if they do not wish to participate in sport. Over a week, activity should add up to at least 150 minutes of moderate intensity activity in bouts of 10 minutes or more (Department of Health, 2011). The limb absent population is no exception to these guidelines.

In a bid to understand the motivations and barriers in the general population, the authors examined evidence from a general population survey known as the Allied Dunbar National Fitness Survey conducted during the early 1990's (Sports Council, Health Education Authority, & Allied Dunbar, 1992). This large descriptive UK survey suggests several motivations for participation in physical activity. These include the physical and emotional concepts suggesting people wish 'to feel in good shape physically', 'to improve or maintain health', and 'to feel a sense of improvement'. Similarly, the same study reported barriers to physical activity uptake such as physical ('I'm too old'), emotional ('I'm not the sporty type'), and motivational ('I haven't got the energy').

Following on, the authors' were keen to understand if similar principles applied to those with limb absence who have low levels of physical fitness due to a combination of a sedentary lifestyle and underlying pathologies. These include disease processes such as peripheral arterial disease and diabetes. In aligning the authors research objectives with those already applied to the able-bodied population, two areas of outcome were soon identified; the first was to encourage those who didn't require high performance prostheses to become more active by participating in daily physical activity; and the second to enable those who were already physically fit to realise their potential through the various levels of competition sport from school and community level sports to international level competition. It is recognised that this second outcome may or may not require standard or higher performance prostheses to participate.

This background led to the initiation of this comprehensively structured review of the available literature. The authors were keen to understand the following: Are people with amputation participating in physical activity, exercise and sports? Are these people participating at the same level as they did before their amputation? And what are their motivations and barriers to participation? The aim was to gather data, and provide conclusions on what motivates or is a barrier to participation in physical activity, exercise and sport for those with lower limb absence. The authors were also curious about the thematic groups which could emerge from the relevant literature which might describe the behaviour of those currently engaged in physical activity and whether these themes were related in any way to the motivations and barriers to participation.

Methodology

During 2011, a literature review was systematically performed by a prosthetic and physical activity for health research team based at the University of Strathclyde. The review covers all peer reviewed and non-peer-reviewed, non-published works such as those appearing in reports, conference proceedings and standards. The following bibliographic databases were searched using a combination of keywords and subject headings: ASSIA (Applied Social Sciences Index and Abstracts); CINAHL (Cumulative Index to Nursing and Allied Health Literature); Embase (Biomedical database using Emtree); Medline (uses Medical Subject Headings); Sport Discus (sports and sports medicine); PsycINFO (behavioural and social sciences), AMED (Allied and Complementary Medicine); and the COCHRANE Library (systematic reviews in healthcare). Secondary references from selected articles were also searched for any key literature not previously identified.

A summary of the subject headings and keywords used in combination in the Medline search is presented in Appendix B. This search strategy formed the basis for the other databases, although each database has unique thesaurus terms. Studies were considered eligible for inclusion if they met the authors agreed criteria. Sensing that the topic field could be narrow, the authors were keen to minimise the overuse of exclusion criterion in order to broaden the search scope. The obvious inclusion criterion was people having acquired amputation or congenital absence. For sensitivity, the search aimed to identify studies on the limb absent population. However, to be included in the review, the study participants had to be users of prosthetic devices. For example, studies which researched swimming when the users were not wearing a prosthesis were excluded (Osborough, Payton, & Daley, 2010). 'Walking' was excluded as a search term within 'Sports', but included within the subject heading of 'Physical Fitness'.

Although there was an initial desire to examine the population of only lower limb prosthesis users, studies describing those with upper limb absence were included in order not to exclude key works. Studies testing mixed populations with disabilities were excluded unless amputee-specific data and findings could be extracted. This did exclude otherwise relevant papers but focuses the review on the experiences of the prosthesis user (Crocker & Bouffard, 1990; Hanrahan, 1995; Hopper & Santomier, 1984). No date restrictions were put on the search and studies were included regardless of participant numbers. No language restrictions were placed on the search but studies were only included if they were available in English or via translation.

Results from the completed literature search were downloaded to reference management software and the duplicates removed. During the review process, article abstracts were scanned for relevance by four reviewers. Full text copies of all potentially relevant studies were obtained. These articles were then considered for inclusion by at least two reviewers. Any disagreement between reviewers following consideration of the inclusion and exclusion criteria was resolved by discussion with a third reviewer. Figure 1 details the stages of the screening and independent reviewing processes involved in deriving the definitive number of articles.

The quality of the evidence included in the 12 articles selected for final review is important to note. As the articles were of survey design, a grading of 2- or lower according to the SIGN Grading System was given (Harbour & Miller, 2001). This justified the use of a simple standardised data extraction form developed to summarise information from the eligible articles. The form was developed from the Narrative Synthesis in Systematic Reviews (Kars, Hofman, Geertzen, Pepping, & Dekker, 2009) project and piloted on a selection of the articles (Popay et al., 2006). The form enabled reviewers to document the author and year; country of origin; study type; methodology; intervention; participants; context; outcomes; and results. In addition, the process of data extraction led to the identification of themes and the focussed recommendations for the completed review.

Results

697 articles were identified from the literature and once the duplicate papers had been removed, 684 papers were comprehensively scanned for relevance. The aforementioned inclusion and exclusion criteria were applied, 89 references appeared to meet the criteria, and the full text versions were sourced. Of these, 12 met all of the inclusion criteria and were included in the review (Couture, Caron, & Desrosiers, 2010; Deans, McFadyen, & Rowe, 2008; Kars et al., 2009; Kegel, Carpenter, & Burgess, 1978; Kegel, Webster, & Burgess, 1980; McAuley & Rudolph, 1995; Pasek & Schkade, 1996; Sousa, Corredeira, & Pereira, 2009; Tatar, 2010; Wetterhahn, Hanson, & Levy, 2002). Table 4 provides an overview of the 12 included studies using the headings from the data extraction form.

Nine of the articles have been published since 2000 (Couture et al., 2010; Deans et al., 2008; Dyer, Noroozi, Sewell, & Redwood, 2011; Gallagher, O'Donovan, Doyle, & Desmond, 2011; Kars et al., 2009; Sousa et al., 2009; Tatar, 2010; Walker, Coburn, Cottle, Burke, & Talwalkar, 2008; Wetterhahn et al., 2002). The other papers were published in 1978, 1980, and 1996 (Kegel et al., 1978; Kegel et al., 1980; Pasek & Schkade, 1996). All of the articles originate in developed world countries and all studies are survey designs. Seven of the articles feature those with lower limb absence (Couture et al., 2010; Deans et al., 2008; Dyer et al., 2011; Gallagher et al., 2011; Kars et al., 2009; Tatar, 2010; Wetterhahn et al., 2002). Two articles featuring those with upper limb absence (Sousa et al., 2009; Walker et al., 2008). Ten articles describe participants with mixed aetiologies stated as vascular, trauma, oncology and congenital (Couture et al., 2010; Deans et al., 2008; Kars et al., 2009; Kegel et al., 1978; Kegel et al., 1980; Pasek & Schkade, 1996; Sousa et al., 2009; Tatar, 2010; Walker et al., 2008; Wetterhahn et al., 2002). Two articles do not describe the reason for limb absence (Dyer et al., 2011; Gallagher et al., 2011).

Upon further scrutiny of the 12 papers, clear themes emerged. The authors agreed that four themes represented the article content and acknowledged that individual articles could be included in more than one group. These themes were: prosthetic components; functional and rehabilitation outcomes; body image, mastery and empowerment; and motivations and barriers to physical activity, exercise and sport (please see Table 4). All of the articles describe the recreational and sporting pursuits of the participants. Since this was a focus of the literature review and a prerequisite for articles to be included, it was felt this descriptor would not feature as a standalone thematic group.

Figure 1 Consort diagram showing stages of screening and independent reviewing processes

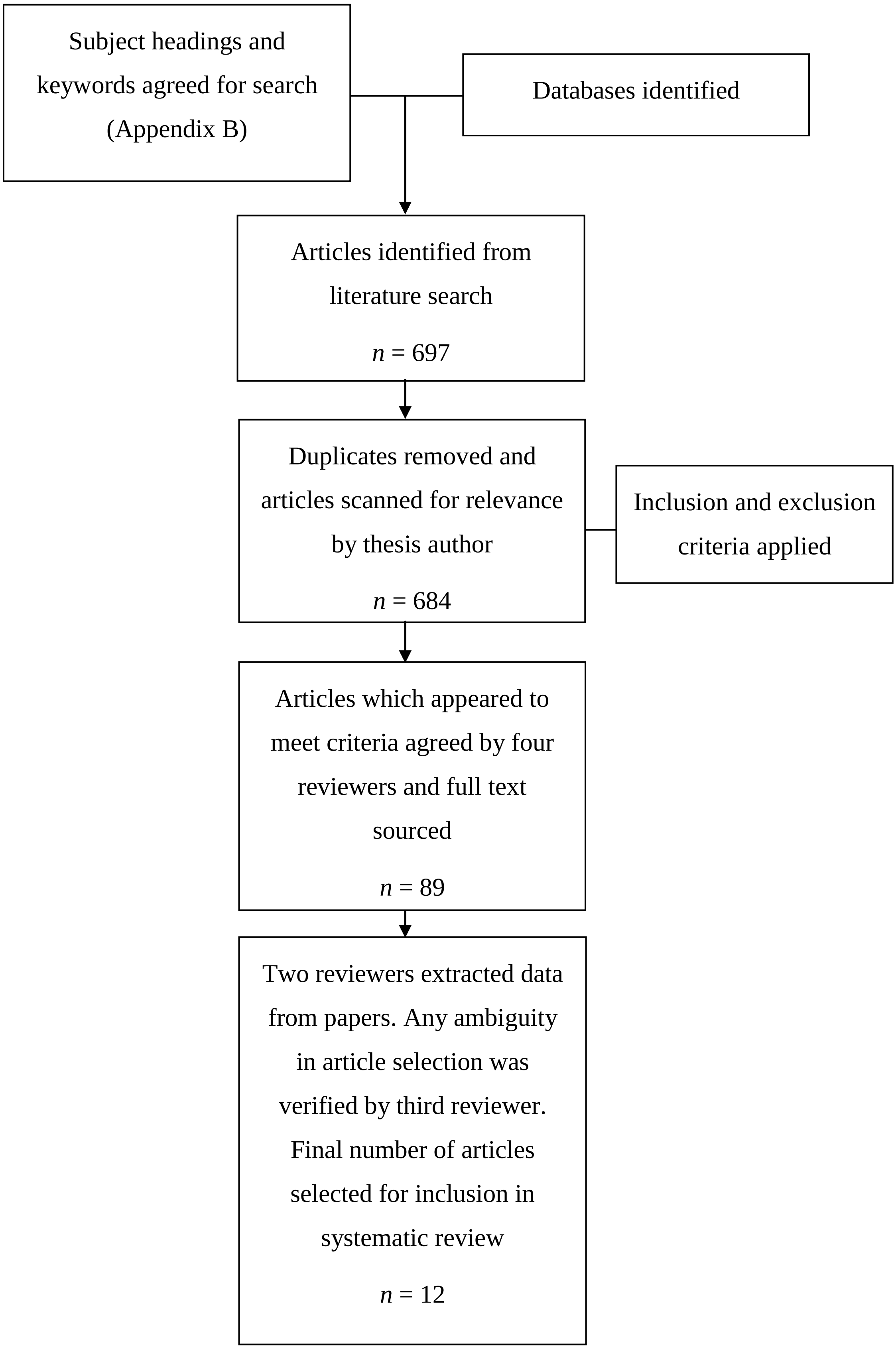

Table 4 Summary of 12 included articles

Author, year	Country	Study type	Aim/s, intervention/s and outcome/s	Study participant profile (number, level, gender, mean age, aetiology)	Context	Results	Thematic group/s
1. Coutour et al., 2010	Canada	Survey	Describe leisure activities, satisfaction and constraints following LLA Qnn (ILP) and SSI	Qnn *N* = 15 [1TT, 4TF (8M, 7F)] SSI n=8 [6TT, 2TF (6M, 2F)] MA = 65y Vascular disease	Hospital and community based LLAs in Sherbrooke, Quebec, 2-3m following discharge	Decrease in leisure activities following LLA, although satisfaction remained high	2
2. Deans et al., 2008	UK	Survey	Investigate relationship between PA and QoL in LLAs Qnn (TAPES and WHOQOL-Bref)	*N* = 25 [22TT, 3TF (20M, 5F)] MA = 66y Mixed aetiology	Community based LLA in West central Scotland, >2y post amputation	Low levels of PA do not impact negatively on QoL. LLAs place high importance on social relationships rather than being physically active	2 and 4

3. Dyer et al.; 2011	UK	Survey (consensus-based)	Investigate expert opinion on role of LLRP and stakeholders perceptions of fairness 3 rounds of Qnn (Iterative) by email	*N* = 22 (level, gender, MA, aetiology not specified)	Expert panel from UK-wide locations	The appropriate limit of a LLRP would be determined by the performance not exceeding a naturally defined level	1
4. Gallagher et al.; 2011	Ireland	Survey (secondary data analysis)	Investigate barriers, participation restriction and functioning levels in LLAs and ULAs	*N* = 148 [LLP = 65; ULP = 17; LLP and ULP = 1; prosthesis type not specified = 65; (110M, 38F)] MA not specified Aetiology not specified	Data extracted from MAP module of NPSDDI	Environmental barriers, activity limitations and participation restrictions can inform evidenced based management and planning of care	2 and 4

5. Kars et al.; 2009	Nether-lands	Survey	Investigate five areas related to the sports participation habits of LLAs Qnn (self-constructed)	*N* = 105 [H = 1; HD = 5; TF = 27; KD = 13; TT = 58; AD = 0 (71M, 31F; 3 missing values)] MA (sports) = 55.5y MA (non-sports) = 60.2y Mixed aetiology (vascular, trauma, oncology)	Community living LLAs in Province of Drenthe	Older LLAs participating more than anticipated; and likelihood of participation in sport is increased if participated pre-amputation; level and aetiology were not predictors of participation	2
6. Kegel et al.; 1978	USA	Survey (retro-spective)	Investigate the relationship between age, amputation level and cause to functional outcome in LLAs Qnn (design not stated)	*N* = 134 [HD=5; TF=19; KD=3; TT=81; AD=5; PF=1; BiL=20; (103M, 31F)] MA=45y Mixed aetiology (vascular, trauma, oncology, congenital)	Community based LLAs in Seattle area, > 6m post discharge	LLAs do not resume same lifestyle post-amp. Activities were swimming, fishing. Running walking long distances challenging for LLA, although desirable	2 and 4

7. Kegel et al; 1980	USA	Survey	Evaluate the interest and participation in recreational activities of LLAs, difficulties encountered, and need for further education and development of resources. Information was also sought from Prosthetists and Physical Therapists Qnn (three self-constructed; one for LLAs; one for prosthetists; one for physical therapists)	*N* = 100 (amputees) [*n* = 60 (active); *n* = 40 (non-active); BK = 58; AK = 25; BiL = 17; (85M, 15F)] MA = 45y Mixed aetiology (vascular, trauma, oncology, congenital)	Community based LLAs (> 3m post discharge), Prosthetists and Physical Therapists. Location not stated although authors Seattle-based	Younger LLAs involved in more recreation. Gender and amputation level did not influence activity. Those with trauma and congenital absence aetiologies were more active than those with vascular and oncology aetiologies Group support important Improvements in prosthetic design recommended Education for prosthetists and physios on recreation is important	4

8. Pasek and Schkade, 1996	USA	Survey and Cohort	Investigate whether components of mastery and self-esteem could be identified in LLAs and ULAs Observation	*N* = 14 (7M, 7F) MA = 14.4y Mixed aetiologies (not specifically stated)	6-day skiing trip for teenage users at NSCD, Winter Park, Colorado	Subjects mastery over fears, limb deficiencies and physical environment led to increased self-esteem	3 and 4
9. Sousa et al.; 2009	Portugal	Survey	To compare how those with LLA and ULA and either involved or not involved in sport view their bodies and perceive how others view them SSIs	*N* = 14 (9M, 5F) MA = 29.4y Mixed aetiologies (not specifically stated)	Community-based LLAs and ULAs in Porto	Those involved in sport are more positive about their body The importance of being recognised and treated as a person not a person with a disability	2, 3 and 4

10. Tatar, 2010	Turkey	Survey Qnn - two questionnaires; ABIS and self-constructed Qnn to assess demo-graphics and issues on prosthesis use	Investigate whether LLAs who do participate in exercise and sport have a different body image to those who do not	*N* = 37 [TF = 19; TT = 18; (25M, 12F)] MA not stated Mixed aetiologies (trauma, other, vascular, frost bite, oncology)	LLAs attending rehabilitation centre at Marmara University and sports clubs in Istanbul with > 3y prosthesis use	Participation in exercise and sports positively influence body image	3
11. Walker et al.; 2008	USA	Survey (two approaches retro-spective and SSI)	Determine how effective recreational terminal devices are for children	*N* = 11 [TR=7; WD=2; PH=2; (9M, 2F)] MA=10.1y Aetiology congenital=10, other=1	11 paediatric ULAs attending SHCLH, Kentucky	The function of children participating in weightlifting and violin enhanced by bespoke devices. Families to consider device expense against level and length of interest	1 and 3

12. Wetterhahn et al; 2002	USA	Survey Qnn (MBSRQ and ABIS) Also to examine correlations between two body image assessments	Determine if a relationship exists between body image and level of participation in exercise and sport	*N* = 56 [TF=22; TT=34; (36M, 20F)] MA not stated Mixed aetiologies (trauma, vascular, oncology, other)	LLAs from amputee support groups' prosthetic facilities, VA Hospital amputee clinic, local sports camp and Paralympic competition across five states and Canada	Positive relationship found between regular participation in exercise and body image among LLAs	3

Note. Legend
LLA=Lower limb amputation; Qnn=Questionnaire/s; ILP= Individual Leisure Profile; n=number; MA=Mean age; y=years; LLAs=Lower limb amputees; m=months; SSI=Semi-structured interview/s; M=Male; F=Female; TT= Transtibial; TF=Transfemoral; UK=United Kingdom; WHOQOL-Bref= World Health Organisation Quality of Life Scale -Brief Version; TAPES=Trinity Amputation and Prosthesis Experience Scale; PA=Physical activity; QoL=Quality of Life; LLP=Lower limb prosthesis; ULP=Upper Limb Prosthesis; MAP= Measure of Activity Participation; LLP= Lower limb prosthesis; ULP= Upper limb prosthesis; ULAs- Upper limb amputees; NPSDDI= National Physical and Sensory Disability Database in Ireland; USA=United States of America; BiL=Bilateral; NSCD=National Sports Centre for the Disabled; ABIS=Amputee Body Image Scale; TR=Trans radial; WD=Wrist disarticulation; PH=Partial hand; SHCLH=Shriner's Hospital for Children – Lexington Hospital; MBSRQ=Multidimensional Body-Self Relations Questionnaire; VA=Veteran's Affairs
Thematic Groups
1. Prosthetic components 2. Functional and rehabilitation outcomes 3. Body image, mastery and empowerment
4. Motivations and barriers related to physical activity, exercise and sport

Discussion

This review of 12 studies that comprise this literature review focuses on a number of themes.

As reported in a Dutch study, the results indicate that people are generally inactive (68% of the amputee population), which is a greater level of inactivity than their non-disabled peers (40% of the general population) (Kars, Hofman, Geertzen, Pepping, & Dekker, 2009). There are no other known epidemiological studies which report on the physical activity, exercise and sports involvement of limb absent people and this should be pursued. It is reported that there is a decrease in the level of leisure activity following lower limb amputation, although people's satisfaction with their changed physical status remains high (Kegel, Carpenter, & Burgess, 1978). This is echoed in a 2008 United Kingdom-based study suggesting that people place more importance on maintaining social standing and prioritising relationships rather than adopting a level of physical functioning which may be entirely unfamiliar (Deans, McFadyen, & Rowe, 2008). The authors suggest that healthcare practitioners can help their patients understand the importance of social support and facilitate ways of providing this support. The study by Kars et al. found that the likelihood of participating in physical activity, exercise and sport following amputation increased if they participated prior to amputation (Kars et al., 2009). Generally, people who do return to leisure or sports activities opt for less strenuous activities such as swimming and fishing where either a prosthesis is not required or the person is not functionally dependent on a prosthesis to participate (Wetterhahn, Hanson, & Levy, 2002). The authors believe that if pre-amputation motivations to exercise can be captured and recreated in the post-amputation period, the negative effects of a sedentary lifestyle could be reversed. Further investigation on this theory is required.

Physical activity may be influenced by psychological function through an increased perception of mastery. The mastery hypothesis is derived from social-cognitive theory (Gallagher, O'Donovan, Doyle, & Desmond, 2011) and proposes that improved affect following physical activity is due to an increased sense of mastery or accomplishment. It follows, that with a sense of mastery of their prosthesis, a person with lower limb absence may increase their self-efficacy, thereby increasing prosthetic use and ultimately increasing their physical activity levels. The converse of this may also follow that by encouraging physical activity pre-operatively, and with reinforcement of physical activity post-operatively, self-worth and self-efficacy are increased. This theory is supported by a narrative review on the able-bodied population, which suggests there is a relationship between physical activity and the emotional function component of quality of life (Dyer, Noroozi, Sewell, & Redwood, 2011). Lessons can be learned from the field of motivation and barriers to physical activity in the able-bodied population which could serve as a comparison and exemplar to the population with amputation. This work is in early stage but should be progressed.

Five of the 12 included articles discuss the concept of body image related to limb loss (Pasek & Schkade, 1996; Sousa, Corredeira, & Pereira, 2009; Tatar, 2010; Walker, Coburn, Cottle, Burke, & Talwalkar, 2008; Wetterhahn et al., 2002). All of the studies show that those people who are involved in sport have more positive feelings about their bodies, with a positive relationship being reported between regular sport participation and body image. However, in the Tatar study it cannot be differentiated whether exercise and sport positively influence body image, as those who have a pre-existing positive body image participated in sport (Tatar, 2010). The use of a case-control study design is a positive feature of this study, a design type which also features in the Sousa study (Sousa et al., 2009). The authors welcome this case-control type of prosthetic research and the data it yields. This is opposed to those types which rely on purely subjective observational data on what may be construed as an impressionable study group as featured in the Pasek study (Pasek & Schkade, 1996).

Findings based on the general population state that physical limitations and a lack of confidence can be barriers to becoming more active, stating older and overweight adults can find participation physically demanding as well as embarrassing (Gallagher et al., 2011; Sports Council, Health Education Authority, & Allied Dunbar, 1992). There is perhaps an underestimation in the field on how strong the link is between amputation, body image and physical activity participation. As discussed previously, the social environment in motivating someone to exercise is important. There is again the suggestion that the rehabilitation environment plays a role in helping people overcome fears and anxieties with regards to participation. In this way, longer term commitment and adherence to regular physical activity may be achievable. The article by Gallagher et al. addresses the environmental barriers which exist for people and recommends greater understanding in order to implement bespoke management at many levels of care (Gallagher et al., 2011). These barriers include services, attitudes, climate, the physical environment and income.

Two of the included studies discuss prosthetic components and their use in leisure time and sports activities (Dyer et al., 2011; Walker et al., 2008). Dyer used the Delphi method to investigate the role of running prostheses and stakeholders perceptions of fairness in the context of disability sport. Whilst this article does not focus on motivations and barriers within the limb absent population, it is compelling to compare the findings from this work with the authors' own clinical experiences of prostheses for sport. It is our belief there could be poor perceptions within the prosthesis user community that participation in sport is only possible with specialised, high performance prosthetic technology. This perception may be true of participation at a competitive sports level, yet the majority of prostheses correctly prescribed in UK clinics today are functionally advanced enough to satisfy the majority of recreational sports user requirements. The study by Walker et al. recommends that bespoke terminal devices for children with upper limb absence be prescribed upon individual consideration of children's motivations to participate in recreational activities such as weightlifting and violin playing (Walker et al., 2008).

Finally, due to the relevance of a research study, mention should be made of an unpublished article (Berbrayer, 2004). The article appears only in abstract and poster form which was uncovered during the literature search. The authors appreciate that this is an exceptional case, but as the research topic base is clearly narrow and this particular study mirrors the authors' area of interest, it is felt discussion of the article is justified. The hypothesis was to examine motivation, access and barriers to sports for adults with amputation and this was done by semi-structured interview of 10 people who had sustained traumatic amputation of either upper or lower limbs and who were established prosthesis users. Questions posed included those on pain, health status, current and previous activities, mentors, domestic support and barriers to participation. Two types of motivation for doing sports were identified; universal which included health benefits, social interaction and stress relief; and unique benefits which included increasing self-esteem and improving body image. The subjects reported three types of barriers to participation: 1) physical issues such as stump pain; 2) psychosocial issues including embarrassment; and 3) societal issues stating work hours and cost for example. It was concluded that for participation in sport to be positive, the user should have a personal history of sport involvement, they should have mentors and accessible facilities. Organised sports need to be established, sport should be including in the working day, and future studies should examine the topic of addressing depression. Further, with psychological well-being being closely linked with physical activity participation (Biddle & Mutrie, 2001), there is a clear need to investigate this avenue of research.

In terms of possible shortcomings of the review and the studies in question, the twelve included articles were all survey designs representative of the special population in question and allowing generalised observations to be made. The significance of the data from the studies was perhaps too broad in order to be specifically relevant to what motivates or precludes someone from being involved in physical activity. However, the broad ranging concepts which have been presented have prompted the authors to question theories which can be investigated more fully in their future research. Data collection methods used by Kegel et al could be repeated to inform us of current trends in user involvement in physical activity, exercise and sports (Kegel et al., 1978; Kegel, Webster, & Burgess, 1980). With regards to the relatively small samples sizes which tend to feature in prosthetic research, efforts to recruit greater limb absent populations to participate in studies will always lead to more robust research findings. Finally, and as mentioned in the methodology section, the authors would have included four other relevant and robust works were it not for the fact that the study populations had mixed disability conditions (Mastro, Burton, Rosendahl, & Sherrill, 1996). It is important that data on the limb absent subjects is extracted, defined and reported separately from that of people with different conditions in order that conclusions and recommendations can be clearly gleaned for each special population.

Conclusions

There is a paucity of literature related to the topic area in question. This review has found that people with limb absence are not participating in physical activity conducive to health benefits, and only a minority participate in exercise and sports. Participation following amputation does not mirror that of pre-amputation levels, and more barriers than motivations exist to adopting or maintaining a physically active lifestyle. Studies which explore concepts such as mastery of physical activity, exercise and sports skills, and body image related to self-esteem, can be drawn upon to further the work for the mutual benefit of prosthesis users and healthcare professionals. The authors would like to capitalise on the extensive physical activity for health research focussed on the general population and use the findings to investigate similar concepts in the limb absent population who have underlying health issues. Where participation in events such as the Paralympics and Commonwealth Games may be an inspirational reality for a select few, achieving a level of daily physical functioning conducive to health benefits should be a daily reality for all.

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Summary of Chapter 3

There were three main findings derived from conducting this systematic review. At that time there was a small number of publications (N = 12) covering the topics of the motivations and barriers to physical activity, exercise and sports in people with limb absence. Most of these papers focussed on exercise and sports participation, rather than free-living physical behaviour of people with limb absence. All 12 of the papers used a survey approach in the data collection methodology, and the number of participants in the studies ranged from $N = 11$ to $N = 148$ ($M = 57$). These three main findings influenced the design of the remaining three studies in this thesis. First, it was determined that research on the physical behaviour of people with limb absence in a free-living setting would be novel and a useful addition to the evidence base. Aligned to this, it was also important to establish the reliability and validity of an appropriate method to measure physical behaviour in this group of the population. Furthermore, gaining an understanding of the role a prosthetic healthcare professional has in promoting physical activity for health benefits would be informative. Therefore, the broad reaching nature of this systematic review was of benefit in that the researcher could be guided towards focussing the future studies which will be presented in this thesis.

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Appendix B Study 1: Abbreviated summary of subject headings and keywords

Subject population		Physical activity, exercise and sport		Motivations and barriers	
Subject headings	Keywords	Subject headings	Keywords	Subject headings	Keywords
Amputees Artificial Limbs exp Prosthesis Design Prosthesis Fitting	amput* prosthe* limbless*	exp Sports (but 'walking' excluded) exp Exercise Athletes Physical Fitness exp Exercise Therapy exp Physical Education and Training	sport* exercis*	exp Motivation exp Attitude Body Image Self Concept exp Health Behavior exp Life Style	motiv* barrier*

Note. exp – the subject heading was expanded to include narrower terms within the hierarchical structure of MeSH terms.

Chapter 4 Study 2: Physical activity guidelines and promotion: An online survey for prosthetic rehabilitation healthcare professionals

Chapter overview

This chapter describes the design and implementation of an online survey, specifically designed for a sample of United Kingdom prosthetic rehabilitation team professionals. The study findings present a demographic profile of UK healthcare professionals who care for people who have limb absence. The survey was designed with the aims of exploring healthcare professionals' awareness and knowledge of current physical activity recommendations. An understanding of healthcare professionals' current and desirable practice towards physical activity promotion was also explored.

Introduction

Prosthetic rehabilitation is an important process for people with limb absence in supporting their achievement of short- and long-term rehabilitation goals. The multidisciplinary team will comprise of rehabilitation consultants, prosthetists/orthotists, physiotherapists, occupational therapists, clinical psychologists and nurses. These healthcare professionals will be involved at specific stages throughout the patient-centred rehabilitation process in decision making, goal setting, and treatment. Within their dedicated scope of practice, each healthcare professional will provide treatment for the patient, delivering expert attention and advice (Limbless Association, 2017).

The majority of people who undergo amputation of a lower limb do so following a previous diagnosis of peripheral arterial disease (Selvin & Erlinger, 2004; United National Institute for Prosthetics Orthotics Development, 2011-2012). Risk factors include, age, gender, cardiovascular disease, smoking, hypertension, obesity, and lack of physical activity. It may be the formal or informal role and responsibility of many of the aforementioned healthcare professionals to discuss how lifestyle-related health might be improved during the rehabilitation process, including advice on the importance of maintaining or increasing physical activity levels, and reducing sedentary behaviour. Formal or informal physical activity advice may be offered routinely, sporadically or not at all during clinical practice. Often healthcare professionals appreciate the importance of promoting a physically active lifestyle to patients where the rehabilitation focus is to increase mobility. Yet whilst the desire to promote physical activity may be omnipresent, perhaps knowledge barriers exist for the healthcare professionals trying to offer the advice. The creation of an online survey was underpinned by a need to explore healthcare professionals' awareness and knowledge of current physical activity recommendations. In addition, an understanding of healthcare professionals' current and desirable practice towards physical activity promotion was explored.

People who engage in physical activity have a lower risk of developing diseases such as heart disease, Type 2 diabetes, cerebrovascular disease, and some cancers (U.S. Department of Health and Human Services, 2011). Evidence has shown over a 40-year period that participation in regular physical activity is related to a reduction in all-cause mortality and longer life (Warburton, Nicol, & Bredin, 2006). In line with this, the number of physical activity interventions for both non-clinical and clinical populations has increased (Kahn et al., 2002). For example, placing signage as point-of-decision prompts to encourage stair use can be effective (Sallis, Bauman, & Pratt, 1998). Yet research into intervention effectiveness has also demonstrated only modest success in healthy, ageing and clinical adult populations (Conn, Hafdahl, & Mehr, 2011). It is also known that certain groups of the population are less knowledgeable about physical activity guidelines (Knox, Esliger, Biddle, & Sherar, 2013). In this study, men with lower education and employment status, and older adults were less likely to have knowledge of physical activity guidelines. This is also supported by a statement from the British Heart Foundation that "physical activity levels also vary by household income. In England in 2012, 76% of men in the highest income quintile reached recommended levels, compared to 55% of men in the lowest income quintile" (Townsend, Wickramasinghe, Williams, Bhatnagar, & Rayner, 2015). Policy approaches are required to reduce the low levels of physical activity in the United Kingdom in all populations. Self-report data on physical activity levels of people in England and Scotland in 2012 identified that 67% of men over the age of 16, and 55% of women over 16 met the guidelines, with a physically active lifestyle declining with age (Townsend et al., 2015). Seventy per cent of boys and 61% of girls reach the recommended 60 minutes of moderate-intensity physical activity a day (Miles, 2007). Yet by later life, 20% of men and 17% of women aged between 65 and 74 years achieved the recommended activity levels of 5 or more days of moderate-to-vigorous activity. From the age of 75 years onwards, 9% of men and 6% of women meet the recommended guidelines (Townsend et al., 2015). These levels of participation could be interpreted as being positive yet should be cautiously accepted; self-report data can contain inaccuracies because respondents' memory recall can be fallible (Schacter, 1999).

The amount of time spent being active on a daily and weekly basis depends on age. The UK's Chief Medical Officer advises that adults of 19-64 years of age should participate in at least 150 minutes moderate intensity physical activity per week (Department of Health, 2011). Muscle strengthening activities should also be included on two or more days of the week, and the time spent being sedentary (sitting) for extended periods should be minimised (Department of Health, 2011). Other versions of physical activity guidelines include the recommendation to participate in flexibility exercises on two or more days of the week (Garber et al., 2011). Walking briskly would be an example of moderate intensity physical activity. Vigorous intensity might elicit a more laboured breathing during and following participation. Comparable health benefits can be achieved by accumulating at least 75 minutes of vigorous intensity activity over a week (Department of Health, 2011). Without exclusion, all sections of the population should aim to be as active as possible.

These guidelines exist to support the general population to lead a more active lifestyle. Yet it is questionable whether the active living message is being communicated effectively enough for adults to make sense of, heed and implement the recommendations. Research states that American adults had knowledge about how to be physically active, yet this knowledge alone was not sufficient to prompt engagement in physical activity sufficient for health benefits (Morrow, Krzewinski-Malone, Jackson, Bungum, & Fitzgerald, 2004). Clinicians and healthcare professionals could be engaged in promoting regular physical activity and to discourage an inactive lifestyle amongst their patients. Indeed, a systematic review of physical activity promotion by community health workers summarised that 61.5% of the papers reported that community-based physical activity strategies and interventions were successful (Costa, Guerra, Santos, & Florindo, 2015). In this paper 26 articles were selected for descriptive synthesis, with 12 of the studies reporting an increase in the total volume of physical activity in minutes or days per week, higher energy expenditure, higher scores in physical exercises and increase in the proportion of individuals who enhanced their level of physical activity. Although success is reported, not every healthcare professional engages in physical activity promotion as part of their routine clinical practice. Other studies report low rates of engagement in the practice, and numerous barriers to promotion including lack of awareness, lack of knowledge of the content, and lack of time (Matthews, Kirk, & Mutrie, 2014).

Guidelines have been published to support health professionals working with clinical populations such as those who have multiple sclerosis (Dixon-Ibarra, Nery-Hurwit, Driver, & MacDonald, 2016), and those who have diabetes (Kirk, Barnett, & Mutrie, 2007; Scottish Intercollegiate Guidelines Network, 2010). There are no known published physical activity guidelines for healthcare professionals working with patients with limb absence. Further, evidence shows that people with physical disability experience difficulty with physical activity participation due to factors such as the primary disabling condition, secondary complications, programme factors, and personal and environmental factors (Lui & Hui, 2009). Furthermore, following amputation, patients place a high level of importance on maintaining strong relationships with family, friends and their peers. This can be perceived as a more achievable goal, rather than trying to achieve a level of physical activity to which they perhaps cannot relate (Deans, McFadyen, & Rowe, 2008).

Importantly, the UK population with limb absence is predominantly older and there are low levels of fitness and activity within this group (Davies & Datta, 2003). During 2011-2012, 5906 people were referred to regional prosthetic rehabilitation services in the United Kingdom. The majority were male (n = 4121). 5389 of those referred had lower limb absence, and almost 70% were referred due to compromised vascular causes (impaired circulation). 70% of these people were over 54 years of age (United National Institute for Prosthetics Orthotics Development, 2011-2012). Against this backdrop, it would be reasonable to think that there may be low levels of physical fitness and physical activity participation in people with lower limb amputation (Gable, Chang, & Krull, 2007). Another factor which may contribute to low physical activity levels in this population is the rise in the number of transfemoral amputations being performed. With the loss of a person's anatomical knee joint, mobility is compromised further and energy expenditure increases (Goktepe, Cakir, Yilmaz, & Yazicioglu, 2010). This could further reduce motivation towards participation in physical activity.

Much of the literature around physical activity for people with limb absence has focussed primarily on sports (Bragaru, Dekker, Geertzen, & Dijkstra, 2011; Deans, Burns, McGarry, Murray, & Mutrie, 2012). There has been an increase in opportunities for people with limb absence to participate in competitive sports due to better prosthetic components and the growth and development of sports organisations for people with disabilities. One study stated that 32% of people with amputation participated in sports in the Netherlands (Kars, Hofman, Geertzen, Pepping, & Dekker, 2009). However, the proportion of people with limb absence participating in sports is likely to be much less when age, aetiology, socio-economic and geographical locations are considered. The clinical population of those with limb absence is older and has vascular complications (United National Institute for Prosthetics Orthotics Development, 2011-2012). With these vascular complications, even a gentle walking rehabilitation goal could be challenging for the majority of the limb absent population. Practitioners involved in the care of people with limb absence may therefore have an important but challenging role to play in supporting their patients to participate in physical activity.

Based on this, the aims of this study were to:

1. Present a demographic picture of rehabilitation healthcare professionals caring for people with limb absence.
2. Explore prosthetic healthcare professional awareness and knowledge of physical activity guidelines.
3. Investigate current and desired practice of promoting physical activity to people with limb absence.

Methodology

The following describes a quantitative research approach to the collection and analysis of data collection from an online survey completed by prosthetic healthcare professionals.

Participants

Participants were rehabilitation medicine consultants, prosthetists, orthotists, physiotherapists, occupational therapists, nurses, and clinical psychologists. Potential participants, working nationally in clinically related fields, were identified from a number of sources including: open-access online health-related databases; secure databases held at the University of Strathclyde; and the author's professional networks. The number of people estimated to be working in the UK prosthetic rehabilitation environment at the time of recruitment was thought to be in the region of 370. This figure is based on information supplied by the British Association of Prosthetists and Orthotists (J. McGlinchey, personal communication, December 14, 2016).

The following groups and individuals were contacted in the four UK home countries by email or by post:

- UK Disablement Service Centre Managers (*N* = 53).
- Private prosthetic service providers (*N* = 6).
- Professional associations of allied healthcare professionals, specifically the British Association of Prosthetists and Orthotists (BAPO); the Royal Society of Rehabilitation Medicine (RSRM); the British Association of Chartered Physiotherapists in Amputee Rehabilitation (BACPAR); and the Scottish Physiotherapy Amputee Research Group (SPARG).
- Organisations involved in the support of people with limb absence, specifically the British Limbless Ex-Serviceman's Association (BLESMA), Finding Your Feet, The Limbless Association, and

Prosthetics and Orthotics Rehabilitation Technology - Education and Research (PORT-ER).

- Health and social care contacts held on the secure National Centre for Prosthetics and Orthotics (NCPO) database, University of Strathclyde. These contacts had previously given permission for their details to be held on file and contacted with details of research studies and continuing professional development opportunities.
- NHS Lanarkshire Allied Health Professional (AHP) Director with an invitation to disseminate information and details of the survey around their professional networks.

In addition, relevant allied health media such as Assistive Technologies Magazine and BAPOMag were asked to market the survey with an advertisement based on a recruitment postcard, flyer and poster. A web link on the author's work-related webpage was also provided to aid in recruitment. The survey was marketed through established University and departmental social media accounts. Recruitment postcards and flyers were also distributed at the 2014 British Association of Prosthetists and Orthotists national annual conference. Appendix C contains the ethical approval which was granted for the study by the University of Strathclyde Ethics Committee (approved 08 October 2013). All participants gave written informed consent prior to participation. A covering letter, participant information sheet and a recruitment postcard, flyer and poster were circulated to introduce the survey, provide information on the survey, and to invite potential respondents to participate (please refer to Appendix D).

The online survey

A 40-item online survey distributed to UK health and social care professionals involved in the routine clinical care of people with limb absence. The specific aims and objectives of the survey were to:

1. provide information on those who completed the survey in order to create a demographic sample of UK prosthetic rehabilitation healthcare professionals.
2. explore knowledge and understanding of physical activity guidelines.

3. investigate the current and desirable practice of UK healthcare professionals in relation to physical activity promotion for people with limb absence.

4. explore UK healthcare professionals views on physical activity guidelines promotion for people with limb absence.

Specific survey questions were developed by the author and informed by previously published research that examined the beliefs and behaviours of general practitioners regarding promotion of physical activity. The questionnaire items addressed: the role of the general practitioner in the areas of screening and recording patients' levels of physical activity; the use of various strategies for the promotion of exercise; confidence in advising patients on exercise; the details and type of physical activity recommended by the general practitioners; and knowledge of the barriers to participation by patients in physical activity.

The survey was designed, edited and distributed using Qualtrics®, allowing collected data to be stored securely on the host server (www.qualtrics.com). The online survey design allowed for cost effective and time efficient distribution of the survey to the target population around the UK and helped optimise the response rate. Hard copy versions of the survey were available to participants on their request however no one selected this option. Appendix E contains the survey as it appeared online to participants. In developing the survey, sensitivity to potential respondents' working environments, working practices and inter-professional relationships were important considerations. It was also important that test validity was not affected by compromised readability (Benson, 1981). Reliability and validity testing of the questionnaire was not completed as part of this work and is acknowledged as a limitation.

A link within the online survey version directed potential participants to a study information sheet and consent form. A check box at the beginning of the survey indicated that the information sheet had been read and consent given to participate in the study. The survey contained the following elements:

- Part I had 15 questions designed to evaluate healthcare professionals' awareness and existing knowledge of current weekly UK physical activity guidelines using multiple choice style questions.
- Part II contained 11 questions designed to seek healthcare professionals' views on their current practice of physical activity promotion. These items were scored on a five-point Likert scale and were Always, Most of the Time, Sometimes, Rarely, Never.
- Part III contained seven questions about healthcare professionals' attitudes and beliefs on what they consider to be desirable in the practice of physical activity promotion. The items were scored on a five-point Likert scale and were Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree.
- Part IV had seven demographic questions related to respondents' professional title; gender; age; years qualified; years working in clinical practice; and geographical location of usual workplace. The final item was an open-ended, optional question to offer respondents an opportunity to comment on relevant topics not covered elsewhere in the survey (please see Appendix E and Table 18).

Contextual statements preceded each of the four survey parts designed to help focus the respondents' minds on the type of questions being asked within the section. Multiple choice formatting was used in Part I rather than open-ended items for brevity and to avoid response fatigue. Likert format was used in the range of responses for Part II and III of the survey to capture the intensity of respondents' feelings for a given item (Likert, 1932). Finally, respondents were invited to enter their email contact details if they wished to be entered into a draw to win a personal music player. Email details were not linked to the participant's survey data ensuring data anonymity.

Piloting the survey

As recommended by Stone (1993), pilot testing of the survey was conducted with 20 volunteers who collectively had expertise in prosthetics and orthotics rehabilitation, physical activity behaviour, physical activity measurement, and survey design (Stone, 1993). These volunteers were recruited from the author's professional network. Feedback from pilot testing prompted adjustments to be made to improve survey continuity, logic and readability. The content of certain questions pertaining to exercise intensity was also reworded. The time taken to complete the questionnaire was noted (from the online software output) to be on average around 10 minutes.

Survey data collection, storage and security, data analysis rationale and data screening and analysis

The survey was available from 14 October 2013 until 20 March 2014 to allow for marketing and distribution of the survey, and to maximise on the return of completed surveys. Data from completed and partially completed electronic surveys were stored on the secure Qualtrics® platform and then exported to IBM SPSS Version 22 (IBM Corp., Armonk, NY). Responses from surveys in progress for more than one week were deleted with respondents deemed to have effectively withdrawn themselves and their data from the project. Data were coded and handled only by the principal investigator and one member of the research team. Neither the raw or cleaned data contained identifying information. The data were stored on an encrypted and password protected University server.

Descriptive statistics were calculated on respondents' professional title; gender; age; years qualified; years working in clinical practice; and geographical location of usual workplace. Professional titles reported by the respondents were simplified into three groups to allow a sufficient sample for comparison analysis. These were Prosthetists/Orthotists, Physiotherapist and Other.

Chi-square tests were used to explore differences across professional groups in awareness of the existence and content of the physical activity guidelines, and the source of respondents learning of the content of the guidelines. Where low cell counts were present, the Fisher Exact Test was used (Yates, Moore, & McCabe, 1999).

A knowledge score was calculated to look at how well informed the respondents were about the content of the physical activity guidelines, and what they understood from the guidelines. This score was constructed from the responses to 11 of the 15 questions in Part 1 of the survey. One-way analysis of variance (ANOVA) tests were used to compare the three professional groups with follow up Fisher's Least Significant Difference (LSD) post-hoc testing used to indicate which of the comparisons were significant.

Independent samples t-tests were used to compare the awareness of the existence and content of the guidelines with the respondents' knowledge of the guidelines. A Pearson correlation analysis evaluated the influence that the respondents' age, years qualified, and years in clinical practice had on the knowledge score. Again, ANOVA was used to analyse the differences in respondents' views of current and desired practice of promoting physical activity. Lastly, the unstructured text entry statements given by respondents were categorised to derive commonality and respondent-driven interest.

Results

A total of 106 respondents completed the survey. The majority of responses were received in the first six weeks from the survey being available (49.5% of responses received in October 2013, and 46.7% received in November 2013). Data from 106 respondents were analysed.

Participant characteristics

A breakdown of the original responses is shown in Table 5 along with their percentage contribution to the simplified grouping. 10.5% of respondents (n = 11) declared their professional title was something other than the six options available. These were coach (n = 1) occupational therapist (n = 3), podiatrist (n = 3), senior lecturer (n = 1), student orthotist (n = 1) and surgeon (n = 2). These professions along with the other groupings with small sample sizes were combined into three simplified professional groupings; Prosthetist/Orthotist (comprising prosthetist/orthotists, prosthetists and orthotists); Physiotherapists; and Other (comprising medics, nurses and those declaring another professional title). Demographics in Tables 5 through 9 are reported using this simplified profession grouping. One respondent did not declare their professional title.

As shown in Table 6, 67.0% of respondents were female (n = 71), with 33.0% being male (n = 35). However, there was a wide variation in the gender make up by profession notably, 90.9% of Physiotherapists were female compared to a much lower number of Prosthetist/Orthotist female respondents (53.7%).

The age distribution of Prosthetists/Orthotists and Physiotherapists was similar. However, there was a tendency to older respondents in the Other professional grouping (please see Table 7).

Table 5 Professional affiliation of survey participants

Response	All		Prosthetist/ Orthotist		Physiotherapist		Other	
	*N**	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Prosthetist/Orthotist	34	32.4	34	63.0				
Prosthetist	19	18.1	19	35.2				
Orthotist	1	1.0	1	1.9				
Physiotherapist	33	31.4			33	100.0		
Medic	3	2.9					3	16.7
Nurse	4	3.8					4	22.2
Other	11	10.5					11	61.1
Missing	1							
Total	106	100.0	54	100.0	33	100.0	18	100.0

Note. *One respondent did not declare their professional title

Table 6 Gender of survey participants

Response	All		Prosthetist/ Orthotist		Physiotherapist		Other	
	*N**	%	*n*	%	*n*	%	*n*	%
Male	35	33.0	25	46.3	3	9.1	6	33.3
Female	71	67.0	29	53.7	30	90.9	12	66.7
Total	106	100.0	54	100.0	33	100.0	18	100.0

Note. *One respondent did not declare their profession

Table 7 Age of survey participants

Response (years)	All		Prosthetist/ Orthotist		Physiotherapist		Other	
	*N**	%	*n*	%	*n*	%	*n*	%
20-30	19	17.9	11	20.4	5	15.2	2	11.1
31-40	34	32.1	17	31.5	13	39.4	4	22.2
41-50	29	27.4	14	25.9	11	33.3	4	22.2
≥51	24	22.6	12	22.2	4	12.1	8	44.4
Total	106	100.0	54	100.0	33	100.0	18	100.0

Note. *One respondent did not declare their profession

Just over one-quarter (26.7%) of the sample had been qualified for 10 years or less. The most common number of years qualified was between 11-20 years (40.0%) while the remaining one-third (33.3%) had been qualified for 21 years or more.

Table 8 Years qualified of survey participants

Response (years)	All		Prosthetist/ Orthotist		Physiotherapist		Other	
	N	%	*n**	%	*n*	%	*n*	%
0-10	28	26.7	15	28.3	9	27.3	3	16.7
11-20	42	40.0	20	37.7	13	39.4	9	50.0
21-30	23	21.9	11	20.8	10	30.3	2	11.1
31-40	12	11.4	7	13.2	1	3.00	4	22.2
Missing	1		1					
Total	106	100.0	54	100.0	33	100.0	18	100.0

Note. *One Prosthetist/Orthotist did not declare the number of years qualified

The proportion of the sample which worked in clinical practice for 10 years or less was 29.5%. The most common number of years in clinical practice was between 11-20 years (38.1%). 21.0% of the sample had been in clinical practice for 21-30 years while a further 11.4% had been in clinical practice for 31-40 years.

Experience was similar between Prosthetists/Orthotists and Physiotherapists up to 20 years of practice. However, there was a much higher percentage (13.0%) of Prosthetists/Orthotists with 31-40 years of experience compared to only 3.0% of Physiotherapists. The Other grouping tended to have the most experience in general with 22.2% with 31-40 years.

Table 9 Years working in clinical practice of survey participants

Response (years)	All		Prosthetist/ Orthotist		Physiotherapist		Other	
	N	%	***n***	%	***n***	%	***n****	%
0-10	31	29.5	18	33.3	9	27.3	3	17.7
11-20	40	38.1	20	37.0	12	36.4	8	47.1
21-30	22	21.0	9	16.7	11	33.3	2	11.8
31-40	12	11.4	7	13.0	1	3.0	4	23.5
Missing	1						1	
Total	106	100.0	54	100.0	33	100.0	18	100.0

Note. *One respondent did not declare the number of years working in clinical practice

Just under half (48.0%) of respondents were in England with a further 46.1% located in Scotland. There was a slightly higher percentage of Physiotherapists located in England (59.4%), while the Other grouping of respondents were more likely to be in Scotland (66.7%) than the other home countries (please see Table 10).

Table 10 Geographical location of usual place of work of participants

Response	All		Prosthetist/ Orthotist		Physio-therapist		Other	
	N*	***%***	***n******	***%***	***n*ǂ**	***%***	***n***	***%***
England	49	48.0	24	47.1	19	59.4	5	27.8
Northern Ireland	2	2.0	1	2.0	1	3.1		
Scotland	47	46.1	24	47.1	11	34.4	12	66.7
Wales	4	3.9	2	3.9	1	3.1	1	5.6
Missing	4		3		1			
Total	106	100.0	54	100.0	33	100.0	18	100.0

*Note.**One respondent did not declare their profession
ǂ One Physiotherapist did not declare their geographical location
*** Three Prosthetist/Orthotists did not declare their geographical location

Knowledge and understanding of physical activity guidelines

Awareness of the existence of physical activity guidelines (question 1) and awareness of the content of the guidelines are shown in Table 11 (question 2). Overall, 60.4% of all respondents were aware of the existence of the guidelines. However, there was a considerable difference based on the profession of the respondent. 78.8% of Physiotherapists were aware of the existence of the guidelines, compared to only 51.9% of Prosthetists/Orthotists. The Other group of respondents showed similar awareness of the existence at 55.6%.

Only those who indicated they were aware of the content guidelines and recorded a response regarding the source of their awareness were regarded as valid entries for the purposes of the analysis. Of those who were aware of the guidelines, 68.8% of all respondents were aware of the content of the guidelines. 73.1% of Physiotherapists were aware of the content of the guidelines compared to 60.7% of Prosthetists/Orthotists. The Other professions showed the highest level of awareness of the content (80.0%) albeit with a much smaller sample available (*n* = 10).

The difference across professional groups in awareness of guideline existence and content of the guidelines was explored using Chi-Square or Fisher Exact Test. A significant difference was identified between the three groups ($t_{(2)} = 6.51$, $p = .039$) in terms of guideline existence. No significant difference could be detected between the groups in terms of awareness of the guideline content. Responses to question 3 related to the source of respondents' awareness (online learning, higher education course etc.) and are also presented in Table 11. The most common source of awareness of the content of the guideline was self-directed learning (25%). There were also no significant differences detected between the different professions regarding their sources of awareness using the Fisher's Exact Test ($p > 0.05$). For those who responded 'Other' to their source of awareness, most described obtaining their awareness and knowledge from media sources, or from national and regional professional seminars and conferences.

The final 11 questions in Part I of the survey sought to examine how well-informed the respondents were about the content of the physical activity guidelines, and what they understood of the guidelines. The correct answer to each question was based upon the UK Government recommendations for adults in the general population aged 19-64 years (Department of Health, 2011). A knowledge score was constructed from the responses with each correct answer increasing the respondents score by a single point. Answers of brisk walking and jogging were awarded a point for each of the questions asking which constituted moderate and vigorous intensity physical activity. In this instance, allowance was made for the respondents who may have been considering their own patients' capabilities of what could be achieved in terms of physical activity intensity. Respondents might have been technically correct in giving any answer of two or more days for the questions which asked on how many days in a week muscle strengthening and flexibility activities should be performed. However, a point was only awarded if the respondent chose the answer of two days thereby reducing the element of risk that the respondent may have guessed the answer. The questions and their correct answers are shown in Table 12.

Descriptive statistics for the sample overall are displayed in Table 13. On average respondents scored 6.42 out of 11, with some variation within the groups. Physiotherapists scored, on average, 7.00 out of 11 while Prosthetists/Orthotists scored 6.24 and Other 5.89. The result indicates a significant overall difference ($F_{(2,102)} = 4.32$, $p = .016$) with post-hoc comparisons indicating a significant differences between Prosthetist/Orthotists and Physiotherapists, as well as Physiotherapists and the Other grouping.

Table 11 Awareness of the existence of and awareness of the contents of physical activity guidelines, and the source of awareness

Question	Statistic	Prosthetist /Orthotist		Physiotherapist		Other		NA	*df*	*t*	*p*	*Fisher's Exact Prob.*
		Yes	No	Yes	No	Yes	No					
Q1 Are you aware there are physical activity guidelines?	*N*	28	26	26	7	10	8		2	6.51	.039*	.041
	%	51.9	48.2	78.8	21.2	55.6	44.4					
Q2 Are you aware of the content of physical activity guidelines?	*N*	17	11	19	7	8	2	41	2	1.66	.437ǂ	.509
	%	60.7	39.3	73.1	26.9	80.0	20.0					
Q3 Source: On-line learning	*n*	6	22	7	19	3	7	41	2	0.38	.829	.795
	%	21.4	78.6	26.9	73.1	30.0	70.0					
Q3 Source: Higher education course	*n*	4	24	3	23	0	10	41	2	1.56	.458	.665
	%	14.3	85.7	11.5	88.5	0.0	100.0					
Q3 Source: Work-based seminar	*n*	5	23	1	25	0	10	41	2	4.34	.114	.154
	%	17.9	82.1	3.9	96.2	0.0	100.0					
Q3 Source: Self-directed learning	*n*	7	21	11	15	1	9	41	2	4.14	.126	.157
	%	25.0	75.0	42.3	57.7	10.0	90.0					
Q3 Source: Published articles	*n*	6	22	7	19	4	6	41	2	1.31	.521	.520
	%	21.4	78.6	26.9	73.08	40.0	60.0					
Q3 Source: Other	*n*	5	23	2	24	2	8	41	2	1.50	.473	.497
	%	17.9	82.1	7.7	92.3	20.0	80.0					

Note * significant difference between groups in awareness of guideline existence
ǂ no significant difference between professional groups in awareness of guideline content

Table 12 Correct answers to items examining respondents' knowledge and understanding of the UK physical activity guidelines

Item	Correct answer
Q5 What is the minimum number of days per week a person must be physically active in order to improve or maintain overall health?	5 days/week
Q6 What is the minimum intensity of physical activity necessary to maintain or improve overall health?	Moderate
Q7 If a person does only moderate intensity physical activity, for how many minutes should this total per week in order to maintain or improve health?	150 minutes
Q8 Which one of the following constitutes moderate intensity physical activity?	Brisk walking (or jogging)
Q9 Which one of the following constitutes vigorous intensity physical activity?	Jogging (or brisk walking)
Q10 When compared to moderate intensity physical activity, do you think comparable health benefits can be achieved through vigorous intensity activity?	Yes
Q11 For how many minutes over a week do you think vigorous intensity physical activity should be performed in order to achieve comparable health benefits to performing moderate intensity physical activity?	At least 75 minutes
Q12 Do you think people should undertake physical activity to maintain or improve muscle strength?	Yes
Q13 On how many days a week do you think people should participate in muscle strengthening activities?	2 days/week
Q14 Do you think people should undertake physical activity to maintain or improve joint flexibility?	Yes
Q15 On how many days a week do you think people should participate in flexibility activities?	2 days/week

Table 13 Total Knowledge level (score) by profession

Statistic	Overall	Prosthetist/ Orthotist	Physio-therapist	Other	*df**	*F*	*p*	Post-hoc Tests (LSD) Pros/Orth compared to Physio.	Pros/ Orth compared to Other	Physio. Compared to Other
M	6.42	6.24	7.00	5.89						
SD	1.49	1.44	1.54	1.23	2, 102	4.32	0.016	*		*
n	105	54	33	18						

Note. *M* = Mean, *SD* = Standard Deviation, * = Between groups, within groups

Further analysis was conducted to investigate if there were differences between awareness and knowledge of the content of the physical activity guidelines and the knowledge scores achieved. The hypothesis being that knowledge of the guidelines would improve the respondents' knowledge score. Table 14 shows the data and output from results of the independent samples t-test.

Results illustrated that participants who were aware of the guidelines had higher knowledge scores. This was found for All ($t_{(104)} = 5.24$, $p < .000$), in Prosthetist/Orthotists ($t_{(52)} = 3.89$, $p = .0003$) and Physiotherapists ($t_{(31)} = 2.73$, $p = .011$). However no significant difference was detected in the Other professions ($t_{(16)} = .80$, $p = .433$).

For those who were aware of the guidelines, the level of knowledge was tested to compare between those who said they were aware of the content and those who said that they were not. None of the comparisons reached significance with the exception of the Other professional group which was due to small sample sizes.

To explore how respondents' age, years qualified and years working in clinical practice influenced the level of knowledge found in healthcare professionals, correlational analysis was conducted. Results in Table 15 show that there were negative correlations between knowledge and age ($r = -.23$, $p = .019$), knowledge and years qualified ($r = -.16$, $p = .104$), and knowledge and years working in clinical practice ($r = -.19$, $p = .057$). Knowledge level was found to be significantly correlated with age at the 0.05 level for All respondents. The results indicate that as age, years qualified and years working in clinical practice increase, knowledge of physical activity guidelines decreases. Knowledge level was not found to be significantly correlated with experience at the 0.05 level in any of the measures for

Prosthetist/Orthotists although, as with the results for All respondents, the correlations were negative.

The correlation analysis for Physiotherapists indicated negative correlations between knowledge and age (*r*=-0.205, *p*=0.254), knowledge and years qualified (*r*=-0.179, *p*=0.318), and knowledge and years working in clinical practice (*r*=-0.166, *p*=0.355). Despite the correlation coefficients being stronger in this analysis than in the overall analysis, the results were not found to be significant due to the smaller sample size. Again, knowledge level was not found to be significantly correlated with experience in any of the measures for the Other professional group although, as with the results found overall and for Prosthetist/Orthotists and Physiotherapists, the correlations were negative.

Table 14 Knowledge score: Independent samples t-test

Q1: Are you aware there are physical activity guidelines?

Group	Statistic	Yes	No	*df*	*t*	*p*
	M	6.95	5.57			
All	*SD*	1.36	1.27	104	5.24	.000
	n	64	42			
	M	6.89	5.54			
Prosthetist/Orthotist	*SD*	1.34	1.21	52	3.89	.000
	n	28	26			
	M	7.35	5.71			
Physiotherapist	*SD*	1.32	1.70	31	2.73	.011
	n	26	7			
	M	6.10	5.63			
Other	*SD*	1.20	1.30	16	.80	.433
	n	10	8			
Q2: Are you aware of the content of physical activity guidelines?						
	M	7.16	6.50			
All	*SD*	1.36	1.28	62	1.83	.072
	n	44	20			
	M	7.06	6.64			
Prosthetist/Orthotist	*SD*	1.39	1.29	26	.81	.427
	n	17	11			
	M	7.58	6.71			
Physiotherapist	*SD*	1.30	1.25	24	1.51	.143
	n	19	7			
	M	6.38	5.00			
Other†	*SD*	1.19	0.00	7	3.27	.014
	n	8	2			

Note. All variances were tested with Levene tests and found to be equal ('Other' ignored)
†'No' group only contains two members so test results are likely to be unreliable.

Table 15 Pearson correlations: Knowledge, age, years qualified and years working

Measurement	Statistic	Total knowledge level	Q36 What is your age?	Q37 For how many years have you been qualified?	Q38 For how many years have you been working in clinical practice?
All respondents					
Total knowledge level	*r*	1.00			
	p				
	n	106			
Q36 What is your age?	*r*	-.23*	1.00		
	p	.019			
	n	106	106		
Q37 For how many years have you been qualified?	*r*	-.16	0.84**	1.00	
	p	0.104	.000		
	n	105	105	105	
Q38 For how many years have you been working in clinical practice?	*r*	-.19	0.79**	0.94**	1.00
	p	.057	.000	.000	
	n	105	105	104	105
Prosthetist/Orthotist					
Total knowledge level	*r*	1.00			
	p				
	n	54			
Q36 What is your age?	*r*	-.193	1.00		
	p	.162			
	n	54	54		
Q37 For how many years have you been qualified?	*r*	-.160	.903**	1.00	
	p	.252	.000		
	n	53	53	53	
Q38 For how many years have you been working in clinical practice?	*r*	-0.222	.816**	.912**	1.00
	p	.107	.000	.000	
	n	54	54	53	54

Note *Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Physiotherapist					
Total knowledge level	*r*	1.00			
	p				
	n	33			
Q36 what is your age?	*r*	-.205	1.00		
	p	.254			
	n	33	33		
Q37 For how many years have you been qualified?	*r*	-.179	.811**	1.00	
	p	.318	.000		
	n	33	33	33	
Q38 For how many years have you been working in clinical practice?	*r*	-.166	.780**	.979**	1.00
	p	.355	.000	.000	
	n	33	33	33	33
Other					
Total knowledge level	*r*	1.00			
	p				
	n	18			
Q36 What is your age?	*r*	-.424	1.00		
	p	.079			
	n	18	18		
Q37 For how many years have you been qualified?	*r*	-.156	.68	1.00**	
	p	.536	.0019	.000	
	n	18	18	18	
Q38 For how many years have you been working in clinical practice?	*r*	-.130	.68**	1.00**	1.00
	p	.618	.003	.000	
	n	17	17	17	17

Note *Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Current physical activity promotion practice

Part II of the survey examined respondents' current practice in promoting physical activity in the prosthetic rehabilitation setting. The data was checked and confirmed as having a normal distribution and therefore ANOVA was used as the appropriate statistical test.

One-way analysis of variance tests were used to compare between the three professional groups. The Likert scales were originally coded with 1 being the highest answer and 5 being the lowest. To make the results more easily interpretable, the scales were reversed before testing meaning higher scores indicated the respondent would be more engaged in the practice of promoting physical activity. Table 16 displays the results ~~of the ANOVA~~ for all questions related to healthcare professionals' current practice in promoting physical activity. In summary, Physiotherapists:

- promoted physical activity to patients more than both Prosthetist/Orthotists and Other professions ($F_{(2, 101)} = 10.32$, $p < .000$).
- were more likely to state that they had adequate knowledge to promote physical activity to patients than Prosthetist/Orthotists ($F_{(2, 101)} = 8.65$, $p = .0003$).
- were more likely to state that they were confident in promoting physical activity to patients than Prosthetist/Orthotists ($F_{(2, 101)} = 8.25$, $p = .0005$)
- were more likely to have undertaken pre-qualification ($F_{(2, 100)} = 16.95$, $p < .000$) and post-qualification ($F_{(2, 99)} = 6.65$, $p = .0019$) learning on the topic of physical activity promotion.

Prosthetist/Orthotists were significantly less likely to say that workplace management expected them to promote physical activity than both Physiotherapists and Other professions ($F_{(2, 101)} = 11.66$, $p < .0001$). Prosthetist/Orthotists were also the least likely group to say that their professional association encourages them to promote physical activity ($F_{(2, 101)} = 28.39$, $p < .0001$). Physiotherapists were significantly more likely than either of the other two professional groupings to say that their professional association encouraged them to promote physical activity.

It is noteworthy that significance was close in questions 17 and 18 '*I enjoy promoting physical activity to patients*' ($F_{(2, 101)} = 2.74$, $p = .0693$) and '*I have time to promote physical activity to patients*' ($F_{(2, 100)} = 2.67$, $p = .0741$). Again, both results tended to indicate higher levels of engagement in promoting physical activity amongst Physiotherapists. Importantly, one question in this group showed no significant differences between groups: '*I discuss physical activity promotion with other health & social care professionals'* ($F_{(2, 100)}$ = 1.49, p = .2295). Therefore, this suggests that levels of discussion about physical activity promotion between professions are similar.

Views on desirable physical activity promotion practice

Part III of the questionnaire examined attitudes and beliefs towards what healthcare professionals considered to be desirable practice in promoting physical activity to people with limb absence. The results are presented in Table 17. To analyse differences in responses between professional groups, one-way analysis of variance was conducted. Again, Likert scales were reversed in order that the most positive answer indicated a higher score and therefore in this case more agreement with the statement. Physiotherapists were more likely than the other two professional groups to feel that:

- physiotherapists should promote physical activity to patients ($F_{(2, 102)}$= 4.48, p = .0136),
- workplace management should expect physiotherapists to promote physical activity to patients ($F_{(2, 101)}$ = 5.71, p = .0045).
- their professional association should encourage physiotherapists to promote physical activity to patients ($F_{(2, 102)}$ = 11.83, p < .0001).
- continuing professional development (CPD) courses should exist on patient physical activity promotion ($F_{(2, 102)}$ = 5.82, p = .0040).

It is notable that the majority of results in the table are significant. As with the results in Part II on current practice of physical activity promotion, the results in Part III tended to indicate higher levels of positive responses from Physiotherapists than from Prosthetists/Orthotists or those in the Other professional group.

Finally, 29 respondents provided further personal views through text entry statements in an open-ended, unstructured question. Table 18 summarises the themes and the statements captured from the respondents. An indication of each respondent's profession is also provided.

Table 16 Current practice related to physical activity promotion for people with limb absence

Question	Statistic	All	Prosthetist/Orthotist	Physio-therapist	Other	*df* between, within groups	*F*	*p*	Post-hoc Tests (LSD)		
									Pros/Orth compared to Physio.	Pros/Orth compared to Other	Physio compared to Other
Q16 I promote physical activity to patients	*M*	3.91	3.57	4.48	3.88						
	SD	0.99	0.98	0.62	1.11	2, 101	10.32	<.000	*		*
	n	104	54	33	17						
Q17 I enjoy promoting physical activity to patients	*M*	3.97	3.78	4.24	4.06						
	SD	0.93	0.92	0.75	1.14	2, 101	2.74	.0693	*		
	n	104	54	33	17						
Q18 I have time to promote physical activity to patients	*M*	3.57	3.52	3.82	3.25						
	SD	0.86	0.91	0.58	1.06	2, 100	2.67	.0741			*
	n	103	54	33	16						
Q19 I have adequate knowledge to be able to promote physical activity to patients	*M*	3.70	3.43	4.15	3.71						
	SD	0.85	0.84	0.57	0.99	2, 101	8.65	.0003	*		
	n	104	54	33	17						
Q20 I am confident about promoting physical activity to patients†	*M*	3.83	3.52	4.27	3.94						
	SD	0.91	0.88	0.63	1.09	2, 101	8.25	.0005	*		
	n	104	54	33	17						
Q21 Other health and social care professionals should promote physical activity to patients	*M*	4.21	4.19	4.24	4.22						
	SD	0.72	0.70	0.75	0.73	2, 102	0.07	.9347			
	n	105	54	33	18						

Table 16 (continued) Current practice related to physical activity promotion for people with limb absence

Question	Statistic	Overall	Prosthetist/Orthotist	Physio-therapist	Other	*df* between, within groups	*F*	*p*	Post hoc Tests (LSD)		
									Pros/Orth compared to Physio.	**Pros/Orth compared to Other**	**Physio compared to Other**
Q22 I discuss physical activity promotion with other health & social care professionals	*M*	**3.17**	**3.04**	**3.25**	**3.47**						
	SD	0.95	0.95	0.88	1.07	2, 100	1.49	.220			
	n	103	54	32	17						
Q23 My workplace management expects me to promote physical activity to patients	*M*	**3.37**	**2.85**	**4.06**	**3.65**						
	SD	1.28	1.19	1.03	1.32	2, 101	11.66	.000	*	*	
	n	104	54	33	17						
Q24 My professional association encourages me to promote physical activity to patients	*M*	**3.53**	**2.80**	**4.67**	**3.65**						
	SD	1.39	1.28	0.60	1.37	2, 101	28.39	.000	*	*	*
	n	104	54	33	17						
Q25 I have undertaken pre-qualification learning on the topic of physical activity promotion†	*M*	**1.93**	**1.41**	**2.91**	**1.76**						
	SD	1.33	0.88	1.47	1.30	2, 100	16.95	.000	*		*
	n	103	54	32	17						
Q26 I have undertaken or am undertaking post-qualification learning on the topic of physical activity promotion†	*M*	**2.01**	**1.58**	**2.63**	**2.18**						
	SD	1.36	1.05	1.45	1.63	2, 99	6.65	.002	*		
	n	102	53	32	17						

Note. †Indicates significant Levene test indicating variances (standard deviations) are not equal.

Table 17 Desired practice related to physical activity promotion for people with limb absence

Question	Statistic	Overall	Prosthetist/ Orthotist	Physio-therapist	Other	*df* *between, within groups*	*F*	*p*	Post-Hoc Tests (LSD): Pros/Orth compared to Physio.	Post-Hoc Tests (LSD): Pros/Orth compared to Other	Post-Hoc Tests (LSD): Physio compared to Other
Q27 I should promote physical activity to patients	*M*	**4.45**	**4.31**	**4.70**	**4.39**						
	SD	0.60	0.58	0.53	0.70	2, 102	4.48	0.0136	*		
	n	105	54	33	18						
Q28 My workplace management should expect me to promote physical activity to patients	*M*	**4.22**	**4.07**	**4.59**	**4.00**						
	SD	0.79	0.70	0.67	1.03	2, 101	5.71	0.0045	*		*
	n	104	54	32	18						
Q29 My professional association should encourage me to promote physical activity to patients	*M*	**4.28**	**4.02**	**4.73**	**4.22**						
	SD	0.73	0.71	0.52	0.73	2, 102	11.83	<.0001	*		*
	n	105	54	33	18						
Q30 Other health and social care professionals should promote physical activity to patients	*M*	**4.36**	**4.28**	**4.55**	**4.28**						
	SD	0.59	0.53	0.62	0.67	2, 102	2.39	0.0969	*		
	n	105	54	33	18						
Q31 Pre-qualification health and social care students should be educated at higher education level on patient physical activity promotion	*M*	**4.18**	**4.09**	**4.42**	**4.00**						
	SD	0.79	0.77	0.75	0.84	2, 101	2.45	0.0914			
	n	104	53	33	18						
Q32 Continuing professional development (CPD) courses should exist on patient physical activity promotion	*M*	**4.30**	**4.13**	**4.58**	**4.28**						
	SD	0.62	0.62	0.50	0.67	2, 102	5.82	0.0040	*		
	n	105	54	33	18						
Q33 I would attend patient physical activity promotion CPD courses if they were available	*M*	**4.01**	**3.91**	**4.27**	**3.83**						
	SD	0.80	0.71	0.63	1.20	2, 102	2.73	0.0698	*		
	n	105	54	33	18						

Table 18 Categorised text entry responses to open survey question

Category/theme	Statement
Respondents' acknowledgement of the levels of physical activity within their own health professional community and Healthcare professionals as role models	• I think much depends on the clinician's individual participation in exercise - it would be interesting to ask how much and what sort of exercise they complete each week (physiotherapist) • It might be interesting to see how much physical activity practitioners themselves partake in. Do we practise what we preach? (physiotherapist) • I try and promote physical activity with my patients with limb loss but accessibility and motivation are often a problem (physiotherapist) • Most health care workers don't follow 'the guidelines'! (prosthetist/orthotist) • I do enforce with patients the importance of activity and exercise but realise that for many, many patients it is a difficult challenge even getting in and out of bed unassisted (prosthetist/orthotist) • I think my own inactivity has held me back from fully engaging in promoting physical activity to prosthetic limb users. I feel I could have been more confident in this if I was more active myself (prosthetist/orthotist)
Comorbidity in people with limb absence	• One barrier to my confidence in promoting physical activity is concern about exercise adversely affecting any condition the patient may have (prosthetist) • Promoting physical activity with not only limb loss but multi-pathologies including heart conditions can be difficult, if they have been advised by other health professional to take things easy. Also family members often still believe that physical activity may detrimental (physiotherapist) • Many elderly patients lack the mental capacity too to take on board the importance of keeping on the move. Many people STOP activity when their heart rate is increased, because they FEAR it - some will have had angina or heart problems previously (prosthetist/orthotist) • Many of our patients have other comorbidities that it is very difficult to lecture them on exercise when they have such reduced mobility (prosthetist) • Clearly for most individuals exercise is essential to maintain or increase health but we do have patients whose vascular systems are severely compromised and therefore should have medical advice prior to commencing exercise. For these individuals very careful advice is required (prosthetist) • In some cases where there are other complications e.g. cardio-vascular implications or safety concerns/other pathologies, it may even be necessary to reduce a patient's activity expectations. Understanding this is just as important if not more, than promotion of exercise (prosthetist/orthotist) • Obviously amputees, like other sections of the community, can have

	special needs/considerations to take into account, but please don't isolate amputees (or orthotic users etc.) from the wider population (prosthetist/orthotist) • Pushing a wheelchair is a hard enough challenge for the vast majority of patients that we may see (prosthetist/orthotist)
Prosthetic prescription	• Imperfect prosthetic provision will also contribute to patients' ability to be more mobile (prosthetist/orthotist) • I feel there is a lack of activity options for lower limb amputees who are not limb fitted (physiotherapist) • The NHS does not support the provision of specific leisure of sport activity limb. Arguably many activities may be pursued without the need for a specifically designed prosthesis (prosthetist/orthotist) • The other drawback is prosthetic prescription for the more active patients. With budgetary restrictions, it is more difficult to provide a prosthesis for recreational use (such as swimming) which would help increase/improve patients' fitness (prosthetist/orthotist)
Respondents' views on the role/s of other healthcare professionals	• I feel that the GP has a better overall view of the patient's health and therefore is in a better position to promote physical activity within the patient's limitations (prosthetist) • Healthcare and social care professionals should only give advice re physical activity if they have the relevant experience and background knowledge. Not ALL exercises are suitable for ALL of the population and incorrect advice/exercise can be unbeneficial or in extreme cases cause injury/damage (physiotherapist) • Promoting physical activity with not only limb loss but multi-pathologies including heart conditions can be difficult, if they have been advised by other health professional to take things easy. Also family members often still believe that physical activity may detrimental (physiotherapist) • Not enough emphasis placed on prevention and personal responsibility by large proportion of general population and/or medical profession (physiotherapist) • Promotion of physical activity is/should be one of the central pillars of physiotherapy treatment (physiotherapist) • The NHS however has no HCP [healthcare professional] group charged with delivering this message and as such is reliant on individuals. Some professional groups pretend to be the experts but rarely have the level of training to deliver in this area (medic) • I am also an amputee so I talk to my patients about the type of exercise that works for me, hoping it will encourage my patients (prosthetist/orthotist) • There is a GP [General Practitioner] exercise referral scheme available which some patients do access (prosthetist/orthotist) • Clinical professionals could effectively work with sports coaches etc to promote physical and emotional health (coach in rehabilitation)

Discussion

This study aimed to answer three research questions.

Demographic profile of prosthetic rehabilitation healthcare professionals

The first question was asked to yield a demographic profile about UK healthcare professionals providing care for people with limb absence, and to explore similarities and differences in responses across different professional groups. This research explores topics similar to other notable UK studies on attitudes, beliefs, and current and desired practice in physical activity promotion (McKenna, Naylor, & McDowell, 1998; McKenna & Vernon, 2004; Searle et al., 2012). An Australian-based research group also conducted similar work (Bull, Schipper, Jamrozik, & Blanksby, 1995, 1997). These studies examined the specific healthcare professional grouping of general practitioners, the nature of their profession being the treatment of people who present with many and varying medical conditions. Treatment episodes engaged in by general practitioners tend to be more irregular with less opportunity to positively reinforce the benefits of participating in physical activity for health maintenance or improvement. Conversely, this particular survey study examined three professional groups comprising the prosthetic rehabilitation team and treating rehabilitation issues specific to people with limb absence. Although the demographic profile of the members of the prosthetic rehabilitation team was representative of the UK demographic (Working Party of British Society of Rehabilitation Medicine, 2003), it was difficult to draw exacting comparisons with the study populations in these works. Similarities lay in age profile but not in gender, with the majority of respondents to this survey being female. There is a gender bias to more females working in the field of physiotherapy in the UK, and slightly fewer female prosthetists than male working in prosthetics (Health and Care Professions Council, 2016).

Awareness and knowledge of physical activity guidelines

The second question sought to explore knowledge and understanding of physical activity guidelines. All members of the multidisciplinary team were aware of the presence of the guidelines and content, and had varying degrees of knowledge of the physical activity guidelines. Specifically, Physiotherapists were most aware of the presence of the guidelines and better informed about the content than Prosthetists/ Orthotists and Other members of the multidisciplinary team. This may be attributed to the requirement that within the prosthetic multidisciplinary team, the role of the Physiotherapist is to include exercise therapy in the immediate post-operative therapy period of rehabilitation.

Respondents were more aware of the existence and the content of the guidelines and as a result their knowledge score performance increased. Physiotherapists achieved overall higher scores, out-performing Prosthetists/Orthotists and other members of the multidisciplinary team. The knowledge questions which were most problematic for all respondents were those enquiring about the number of minutes that moderate and vigorous activities should be performed over a week. Respondents underestimated the number of minutes. Conversely, respondents overestimated the number of days that people should engage in muscle strengthening and flexibility activities. This suggests that confusion remains around important more detailed elements of the guidelines. This could be further complicated by the ongoing update and changes to existing published international or national guidelines. Table 1 in Chapter 2 details physical activity guidelines for clinical populations that serves to reinforce a mixed-message and possibly confusing approach. A case may be made for creating dedicated guidelines specifically for people with limb absence which includes guidance on how to advise those with complex conditions. This is supported by the text-entry comments in Table 18, the majority of which suggest professionals have anxiety in communicating physical activity benefits to patients living with comorbidity. A survey respondent noted “One barrier to my confidence in promoting physical activity is [my] concern about exercise adversely affecting any condition the patient may have”.

The source of the survey respondents’ awareness of the existence and content of the guidelines appears to be of an ad-hoc, self-directed nature. Therefore, there is an argument for a formalised approach to dissemination of recognised guidelines for post-qualification professionals. This could take the form of position statements from Professional Associations, or bespoke continuing professional development courses delivered in the work-place, online, or from external educational sources. Canadian-based research points to coordinated and well-funded approaches being adopted to reach the desired clinical and professional populations (Cameron, Craig, Bull, & Bauman, 2007). Taking this further, there may be a case for including the topic of physical activity promotion in the BACPAR 2012 guidelines (British Association of Chartered Physiotherapists in Amputee Rehabilitation, 2012). The Amputee and Prosthetic Rehabilitation Standards could also include the recommendation of promoting physical activity (Working Party of British Society of Rehabilitation Medicine, 2003).

The knowledge score detailed in Tables 12-15, was used effectively to examine how age, experience and time since qualification influenced the level of knowledge found in professionals. The results of this kind of analysis can often be counterintuitive as the guidelines surrounding current best practice often change following professional qualification. Therefore, even though a professional may be highly experienced, his or her knowledge of the latest guidelines may be more limited than someone who was recently qualified. In the case of this survey, as age, experience and time since qualification increased, knowledge levels about current best practice reduced. It is therefore possible that these results could again lend some support to the idea that refresher courses could be beneficial in keeping experienced professionals who have longer tenure up to date with the latest clinical developments and practices. This is supported by historical work which examined general practitioners' and nurses' knowledge of physical activity in primary care (Gould, Thorogood, Iliffe, & Morris, 1995). Here, knowledge gaps were identified in particular those related to specific health benefits of physical activity. It is also evident that despite a lack of pre-qualification education on physical activity for health in UK prosthetic/orthotic students, prosthetists obtain information and advice on physical activity recommendations from a variety of informal sources. However, the sources of this information are vague and are not particularly well known. It is also acknowledged that those with a personal interest in physical activity for health may be more motivated to carry out self-directed learning on the topic.

The notion that implementing pre- and post-qualification education and training on physical activity guidelines and promotion is straightforward may prove misguided however. There is evidence on the success or otherwise of medical and physiotherapy undergraduate curricula which considered the design, implementation and preparation of students (O'Donoghue, Doody, & Cusack, 2011; Weiler, Chew, Coombs, Hamer, & Stamatakis, 2012). The former describes the need for the re-evaluation of physical activity education programmes in Irish physiotherapy teaching due to the lack of explicit content in relation to lifestyle-related disease. The second paper describes the omission in medical school teaching of basic elements such as the Chief Medical Officer's recommendations. Further, some physical activity training, particularly around aerobic guidelines, was provided in 13 of 15 Australian medical schools sampled. However, less than half (42.9%) reported the training was sufficient even though 41.2% of medical students reported no barriers to implementing physical activity training in their curricula (Strong et al., 2017).

Current and desirable practice in relation to physical activity promotion

The third research question sought to determine current and desired practice of healthcare professionals in promoting physical activity. It is a positive outcome of this study to learn that members of the multidisciplinary team are promoting physical activity to people with limb absence and feel they have the knowledge to do so. That said, most survey respondents (90.4%) felt they had the knowledge to advise patients on physical activity, yet respondents only achieved a knowledge score of 58.4%. Similar results were seen in a study of general practitioners, whereby more than three quarters of respondents felt they had sufficient knowledge to advise patients on physical activity, yet actual knowledge levels suggested they had less knowledge than believed (Lawlor, Keen, & Neal, 1999).

The accuracy, consistency and frequency with which patients are receiving guidance and information have to be questioned based on the responses to questions in these sections. To support this, the results of a Swedish project state that despite supposed good knowledge of health-related issues, healthcare professionals were not prone to promote healthier lifestyle habits to their patients (Jonsdottir, Börjesson, & Ahlborg, 2011). Similar outcomes were reported from a UK study that examined health visitors and nurses views in promoting physical activity in primary care settings (Douglas et al., 2006). In this study, high levels of enthusiasm for promoting physical activity were evident, yet reasons for not giving advice included lack of time and lack of education and educational materials both for healthcare professionals and patients. Positively, Finnish research has shown that uptake of supervised physical activity is increased if healthcare advice is given by professionals (Hirvensalo, Heikkinen, Lintunen, & Rantanen, 2003).

In this survey, physical activity promotion is indeed regarded to be a cornerstone of physiotherapists' scope of practice, and the results demonstrate that they are the professional group most likely to promote physical activity. A number of optional answers given at the end of the survey demonstrated mixed results on respondents' views on the role of other healthcare professions in advice-giving. Some thought the general practitioner should be responsible "I feel that the GP [general practitioner] has a better overall view of the patient's health and therefore is in a better position to promote physical activity within the patient's limitations" whilst another suggested the role was one for physiotherapists "Promotion of physical activity is/should be one of the central pillars of physiotherapy treatment". Yet considering the impermanent nature of physiotherapists' caregiving, one should question whether other healthcare professionals could be as equally well-placed to take a greater role and responsibility for delivering the active living message. There could be a case for prosthetists incorporating physical activity promotion into their everyday clinical practice. It is known that by including physiotherapy in the immediate post-amputation weeks, prosthetic fitting can be achieved sooner (Woodburn, Sockalingham, Gilmore, Condie, & Ruckley, 2004). This means the opportunity for reinforcement of the importance of exercise and/or physiotherapy could be reduced for the physiotherapist. Yet, this could be an opportunity for prosthetists to engage with the patient about health improvement strategies much earlier in the rehabilitation process when the patient might be receptive to change (Bandura & Adams, 1977). Prosthetists could also be well-placed over the course of the patient's rehabilitation lifetime to be able to offer this advice.

In addition to determining whose role it might be to promote physical activity, there is the question of whether healthcare professionals identify themselves as role models in the positive delivery of health promotion. There is acknowledgement that they personally may not be meeting the physical activity recommendations. One respondent noted “I think my own inactivity has held me back from fully engaging in promoting physical activity to prosthetic limb users. I feel I could have been more confident in this if I was more active myself” (please refer to Table 18). This is reflected in personal opinion where the belief is held that unhealthy behaviour may influence clinical practice (While, 2015). Respondents in another study echoed similar views on how their appearance and attitudes could positively or negatively influence behaviour (Matthews, Kirk, & Mutrie, 2014). These insights from health professionals on physical activity promotion within diabetes care could be helpful in making similar comparisons and recommendations in prosthetic care.

Overall, there seems to be a lack of formal guidance on appropriate physical activity levels for people with limb absence. Should specific guidelines be established for use in prosthetic rehabilitation, these should be updated regularly. Consistency in delivering messages on content of guidelines is also important. Training on the implementation of the guidelines should also be current, with the possibility of pre-qualification and post-qualification continuing professional development courses being established. All healthcare professionals working with people with limb absence should be motivated to understand the content of physical activity guidelines with careful consideration of complex clinical presentations. The findings show that by bringing clarity, simplicity and specificity to existing guidelines, this might better support healthcare professionals in effectively communicating the content to patients.

Two of the aims of this study were to research and report on current and desirable practice in prosthetic rehabilitation team professionals. The focus of this work was to examine differences between professional groups in their responses to category items. This is dissimilar to other works which examined differences and similarities between self-reports of current practice and perceived desirable practice in the promotion of physical activity by doctors (Bull et al., 1995, 1997). That said, similar conclusions are drawn insomuch as healthcare professionals should receive skills training in detailed rather than general aspects of physical activity for health. Advice to patients with specific conditions should be increased (in this case people with limb absence) whilst acknowledging a need to avoid overloading individuals with information (Matthews et al., 2014).

Strengths, limitations and future work

At the time of writing, awareness and knowledge of physical activity guidelines of the prosthetic multidisciplinary team had not been researched. The current and desirable practices of this group are also an under-researched area. Therefore the current research has made an original contribution to knowledge in addressing these areas.

Limitations of the methodology could have compromised the results. The survey was designed with prescriptive questions which led the participant through focussed survey sections. This may have prompted recall rather than the participant answering with completely independent thought. Positively, there was a small section at the end of the survey which allowed the participant free thought to comment, and designing research using a qualitative approach might yield more free-ranging, deeper and unpredictable responses. A further limitation could have been with the scoring system used for the knowledge score which was constructed from the responses to questions as detailed in Table 12. It is acknowledged that respondents were rewarded one point only for each absolute correct answer which may not have reflected any general knowledge around physical activity guidelines content that the individual professional groups may have had. In addition, Questions 25 and 26 may have been better served by Yes/No responses meaning that the Likert scale responses could have been heavily weighted to either end of the 1 to 5 scale. Because of this the data was not normally distributed. It may not have been appropriate to describe the answers to these questions using a point based system.

The response rate of 30% is regarded as being an average response rate for online surveys (Nulty, 2008). Improvements in the response rate might be achieved by traditional postal mailing. In addition, drop-out rate was very low and nonresponse bias was not considered. That said, not all the views of professionals working with people with limb absence were captured, and it would be reasonable to assume that those who did respond may have been interested and more motivated towards participating in and promoting physical activity for health.

Further, the survey was designed to capture the views of all healthcare professionals specifically working in prosthetic rehabilitation. The reason for this was to explore which professional grouping might be best placed to promote physical activity, and a wish to maximise responses. However, this broader based recruitment strategy created challenges in aligning and comparing the results with other studies which explore similar clinical topics, yet focussed on only one professional grouping for example general practitioners (Searle et al., 2012).

Building on this work, future research could have two strands. The first would be to survey post-qualification prosthetists, and undergraduate prosthetic and orthotic students on the preferred mode of knowledge exchange on the topics of physical activity for health and sedentary behaviour. Within this, prosthetists could also be consulted on what might be the best approaches for designing and implementing a physical behaviour intervention specifically designed for patients with limb absence in a clinical and/or community setting. The second work strand could include the piloting of an intervention on the effectiveness of physical activity promotion by prosthetists. Alternatively, creating referral pathways for patients from the prosthetic rehabilitation environment to a dedicated physical activity support service could be examined. At the very least, it could be beneficial to create a prosthetic-focussed guideline for the multidisciplinary team to draw upon which might empower the prosthetist to propel the physical activity for health agenda to the forefront for the betterment of those with limb absence. There appears to be a lack of training on how healthcare professionals should deliver physical activity advice especially for prosthetists who, of all the members of the prosthetic rehabilitation team, have the most involved and prolonged contact with their patients. Future work may address these issues.

To help inform researchers on how physical activity interventions may be designed, it is important to understand the behaviour of the population for whom the intervention is being designed. With little evidence available to inform researchers, it seems like a natural progression to objectively study free-living physical behaviour in people with limb absence. Accurate objective measurement of physical behaviour requires careful selection of a measurement instrument. Evidence of instrument reliability and validity must also be available or established before any robust measurement study is conducted. Future work could include objective measurement of physical activity in those with limb absence, providing evidence for healthcare service providers and professionals, and the research community.

Summary of Chapter 4

A survey was developed to examine healthcare professionals' awareness of the presence and knowledge of the content of the physical activity guidelines. The survey also provided data on respondents' views on their current desirable practice with regards to physical activity promotion. A demographic profile of a sample of healthcare professionals who care for people with limb absence has also been

This study has demonstrated that physiotherapists have adequate knowledge to deliver advice on physical activity at an early and important stage in an individual's prosthetic rehabilitation. However, results have shown that prosthetists and other members of the prosthetic rehabilitation team also have awareness and knowledge of physical activity guidelines. It is proposed that prosthetists could, with the correct guidance and support, formally promote physical activity for health over the long-term course of prosthetic care. It may be possible that with education and training, and the support of employers and professional agencies prosthetists could build physical activity promotion into their routine clinical practice for the benefit of established patients with limb absence. At the very least prosthetic rehabilitation professionals could be able to identify when physical activity might benefit their patients leading to an informed referral decision to be made.

Little is known about physical behaviour in the population of people with limb absence. It is sensible to research this in more detail and future work could focus on this area. Without this evidence, there is a risk of promoting physical activity to a clinical group who are sufficiently active. Objectively measuring physical behaviour and understanding the results could ultimately lead to the design of bespoke clinical interventions as proposed in this particular study of healthcare professionals. In the longer term, interventions may contribute to overall patient health and well-being improvements for the patient with limb absence.

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Appendix C Study 2: University ethics and sponsorship approval

Sarah Deans

From:	Susan Rasmussen
Sent:	08 October 2013 14:50
To:	Sarah Deans
Cc:	David Rowe; James Baxter; HaSS Research and Knowledge Exchange
Subject:	Deans & Rowe ethics (school of psychological sciences and health). Type 1
Attachments:	4 App 4 Postcard and Advert DEANS V2 FINAL.docx; 5 App 5 Info Sheet & Consent DEANS V3 FINAL.docx; Ethics Application ROWE DEANS V4 FINAL.docx; 1 App 1 TEST SURVEY DEANS V5 FINAL.docx; 2 App 2 Managers Cover Letter DEANS V3 FINAL.docx; 3 App 3 AHPs Cover Letter DEANS V3 FINAL.docx

Dear Sarah,

The ethics committee has now approved your study entitled 'UK health and social care professionals and the rehabilitation of people with limb absence: their knowledge, beliefs and behaviours regarding physical activity (PA) promotion', and your application has been forwarded to the faculty for sponsorship approval. You will receive another email when this approval has been given. Please bear in mind that you may not begin your study until you have received sponsorship approval.

Best of luck with the study,
Susan

Dr Susan Rasmussen
CPsychol, Health Psychologist
Senior Lecturer
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building, Room 680
40 George Street Glasgow G1 1QE

Email: s.a.rasmussen@strath.ac.uk
Phone: 0141 548 2575
http://www.strath.ac.uk/humanities/courses/psychology/staff/rasmussensusandr/

2012 THE AWARDS
UK University of the Year

From: Sarah Deans
Sent: 08 October 2013 10:42
To: Susan Rasmussen
Cc: David Rowe
Subject: RE: Ethics Sarah deans PhD

Dear Susan,

Please find attached the following final version documents:

- Ethics Application Form
- 1 Appendix 1 Test Survey

1

Sarah Deans

From: HaSS Research and Knowledge Exchange
Sent: 09 October 2013 15:12
To: David Rowe; Sarah Deans; Alison Kirk; Anthony McGarry
Cc: Susan Rasmussen
Subject: Type 1 Ethics Application : Approval.

Type 1 Ethics Application - Approval

Our ref: 360 08-Oct-13

Dear All

UK health and social care professionals and the rehabilitation of people with limb absence: their knowledge, beliefs and
behaviours regarding physical activity (PA) promotion.

I can now confirm full ethical and sponsorship approval for the above study.

Regards

Gail

Gail Henry, Administrative Assistant
(Research and KE support team)
Faculty of Humanities and Social Sciences
University of Strathclyde | Room 340, Level 3, Lord Hope Building | 141 St James Road | Glasgow | G4 0LT
T: 0141 444 8418 | E: gail.henry@strath.ac.uk

2012 THE AWARDS
UK University of the Year

Appendix D Participants covering letter, participant information sheet and consent, and recruitment postcard

Participants' covering letter

Dear Professional Colleague (name here),

Research study title: UK health and social care professionals and the rehabilitation of people with limb absence: their knowledge, beliefs and behaviours regarding physical activity promotion.

I am writing to you about a project which aims to support people living with limb absence to make healthier lifestyle choices. The work is supported by the School of Psychological Sciences and Health, and the National Centre for Prosthetics and Orthotics, both departments of the University of Strathclyde in Glasgow. It is on-going doctoral work in the area of physical activity for health which has been given full ethical approval by the School of Psychological Sciences and Health Ethics Committee at the University of Strathclyde. I do hope you will consider being involved.

About this project

We are keen to find about the level of knowledge of physical activity guidelines of those who care for people with limb absence. We would also like to understand health professionals' current practice in relation to physical activity promotion and whether they feel they should engage in routine promotion of physical activity. The results will be disseminated at national and international prosthetic/orthotic conferences and in a relevant rehabilitation medicine journal.

Your involvement

If you are a healthcare and social care professional caring for those with limb absence and over 21 years of age, you are warmly invited to complete the enclosed survey. You can also complete this online at either http://www.bit.ly/16gt212 or https://hass.eu.qualtrics.com/SE/?SID=SV_6P8rsQIqkf8u8OF

The survey should take about ten minutes to complete. It is your decision whether or not to take part in the investigation or not. You do not have to participate. Data from completed and partially completed surveys will be stored and analysed only after the survey has been submitted by the participant. Responses from surveys in progress will be deleted after one week, and participants will have effectively withdrawn themselves and their data from the project. Because your responses will always be anonymous, your data cannot be used to identify you. As such, you will not be able to withdraw your data should you choose to withdraw personally from the study.

You are also very welcome to pass the survey your healthcare professional colleagues currently caring for those who have limb absence. Your colleague may be a Nurse, Physiotherapist, Prosthetist or Rehabilitation Consultant. All would be welcome to participate if they are involved in amputee rehabilitation in any way.

Background and the issue

Regular physical activity, in addition to a balanced diet and other positive lifestyle behaviours such as not smoking and limiting alcohol, is well established as an important part of maintaining good health and a good way to reduce the risk of many diseases. Yet low levels of physical activity are prevalent; only 40% of men and 28% of women in the UK meet the minimum recommended physical activity levels. We believe the limb absent population could also be more physically active and hope this study is able to inform us about the ways in which this could be achieved.

I hope you will consider supporting this work by completing the short survey and please contact me if you would like any further information. Thank-you.

With kind regards,

Sarah A. Deans
Prosthetist/Orthotist & Teaching Fellow
Department of Biomedical Engineering
National Centre for Prosthetics and Orthotics
Curran Building
131 St James Road
Glasgow, G4 0LS, UK
E: sarah.deans@strath.ac.uk
T: +44 (0)141 548 3929

Supervisor:
Dr David Rowe
Reader
School of Psychological Sciences of Health
GH533 Graham Hills Building
50 George Street
Glasgow, UK
E: david.rowe@strath.ac.uk
T: +44 (0) 141 548 4069

University of Strathclyde Humanities & Social Sciences

Participant information sheet and consent

Name of department: School of Psychological Sciences and Health, Faculty of Humanities and Social Sciences

Title of the study: United Kingdom (UK) health and social care professionals and the rehabilitation of people with limb absence: their knowledge, beliefs and behaviours regarding physical activity (PA) promotion.

Introduction

A research team from the School of Psychological Sciences and Health at the University of Strathclyde are conducting a project which focusses on two groups of people: those who have limb absence, and the healthcare professionals who look after them. The work is part of part-time doctoral study being undertaken by Sarah Deans who is a Teaching Fellow at the Department of Biomedical Engineering incorporating the National Centre for Prosthetics and Orthotics (NCPO), also at the University of Strathclyde.

What is the purpose of this investigation?

Background

Regular physical activity (PA), in addition to a balanced diet and other positive lifestyle behaviours such as not smoking and limiting alcohol, is well established as an important part of maintaining good health and a good way of reducing the risk of many diseases. Yet low levels of physical activity are prevalent; only 40% of men and 28% of women meet the minimum recommended physical activity levels. We believe the limb absent population could also be more physically active and hope this study is able to inform us about the ways in which this could be achieved.

We are keen to find about the level of knowledge of UK physical activity guidelines in those who have a clinical responsibility for people with limb absence. The team would also like to understand current and desired practices of physical activity promotion by health and social care professionals.

Do you have to take part?

It is your decision whether or not to take part in the investigation or not. You do not have to participate. If you begin the survey you can decide not to submit the answers and your responses will not be recorded. Data from completed and partially completed surveys will be stored and analysed only after the survey has been submitted by the participant. Responses from surveys in progress will be deleted after one week, and participants will have effectively withdrawn themselves and their data from the project.

What will you do in the project?

Having read the information sheet and consented to participate in the project by ticking the box at the beginning of the online survey, you are warmly invited to complete an online survey by accessing either http://www.bit.ly/16gt212 or https://hass.eu.qualtrics.com/SE/?SID=SV_6P8rsQIqkf8u8OF The survey should take about ten minutes to complete. There are 39 questions and your responses will be collected anonymously so you will not be identifiable. For this reason, it will not be possible for the data you provide to be withdrawn once it has been submitted.

If you prefer, the survey is also available to complete in hard copy by contacting the researcher Sarah Deans using her details below.

Why have you been invited to take part?

The researchers are keen to understand UK health professionals' knowledge, beliefs and behaviours about physical activity promotion. You have been invited to complete the survey because you are a healthcare professional which has a role and responsibility for caring for people who have limb absence. If you are over 21, a post-qualification health and social care professional, and have experience of working with people who have limb absence, then you are eligible to participate in this study.

What happens to the information in the project?
All of the information you provide will be anonymous and cannot be identifiable with you.

The information you provide will be stored in a secure University of Strathclyde office location. It may also be held within a password protected and encrypted University of Strathclyde virtual environment. All records including paper records and computer files will be held for approximately five years in correct conditions for the storage of personal information at the University of Strathclyde.

The data will be stored until the research findings have been disseminated or presented at meetings and conferences with the aim of helping others; data presented in this way will also be anonymised. Data is normally stored for around a period of five years.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

What happens next?
If you wish to be involved in the project, then you will be asked to tick the appropriate box at the beginning of the online survey to indicate you have read this information sheet and consent to taking part.

If you choose not to be involved, then please accept our thanks for taking the time to read this information.

Has the study been ethically approved?

This investigation was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee at the University of Strathclyde.

If you wish to contact an independent person to whom any questions may be directed or further information sought from, please contact:

Dr Susan Rasmussen, School Ethics Committee Convenor

6.80 Graham Hills Building,

50 George Street,

Glasgow, UK E: s.a.rasmussen@strath.ac.uk T: +44 (0)141 548 2575

Who can you contact if you have any questions/concerns, before, during or after the investigation?

You can contact the following people:

Researcher

Mrs Sarah Deans

Teaching Fellow

National Centre for Prosthetics and Orthotics

Department of Biomedical Engineering

Curran Building

131 St James Road

Glasgow, G4 0LS, UK

E: sarah.deans@strath.ac.uk

T: +44 (0) 141 548 3929

Chief Investigator

Dr David Rowe

Reader in Exercise Science

School of Psychological Sciences and Health

GH533 Graham Hill Building

50 George Street

Glasgow, UK

E: david.rowe@strath.ac.uk

T: +44 (0) 141 548 4069

Consent

You will be required to give your consent to participate in this investigation. You can do this at the beginning of the online survey by ticking Yes.

Name of Department: School of Psychological Sciences and Health

Title of the study: UK health and social care professionals and the rehabilitation of people with limb absence: their knowledge, beliefs and behaviours regarding physical activity promotion.

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction if I have required them to do so.
- I understand that my participation is voluntary and that I am free choose not to participate, without having to give a reason and without any consequences.
- I understand that any information recorded in the investigation will remain confidential and no information provide can be identifiable with me
- I understand that the study data is anonymous and therefore data cannot be identifiable with me.
- I understand that I cannot withdraw my data from the study once I have submitted the survey, as the data I provide cannot be identifiable with me.
- I understand that by ticking the 'Yes' box at the beginning of the survey, I consent to taking part in the study.

Recruitment postcard (double-sided)

UK Health Professionals and Physical Activity (PA) Promotion Survey

A team of researchers from the University of Strathclyde are keen to understand if and how physical activity for health could be promoted in people with limb absence.

To take the survey or simply find out more, you can follow this link:

bit.ly/16gt212 The survey will take about 10 minutes to complete

If you would like to have the information or complete the survey in a different format please contact:
E: sarah.deans@strath.ac.uk
T: 0141 548 3929
National Centre for Prosthetics and Orthotics, G4 0LS, UK

Survey participants will have an opportunity to enter their details into a random draw to win an iPod Shuffle.

Appendix E Definitive online survey version

Survey Title
UK health professionals who care for people with limb absence:
their knowledge, beliefs and behaviours regarding physical activity promotion.

Thank you for your interest in this survey. Understanding your knowledge of physical activity guidelines and your views on physical activity promotion is extremely important to us.

The survey focuses on physical activity for maintaining or improving health in people who have limb absence.

Please keep in mind the idea of physical activity for maintaining or improving health rather than for sports participation or fitness benefits.

The survey should take ten minutes to complete and there is an opportunity for you to be entered into an optional free prize draw to win an iPod Shuffle on completion of the survey.

The survey covering letter and participant information sheet can be viewed by clicking on the links below.

Survey covering letter   Participant information sheet

If you have read the covering letter and information sheet, please tick whether you would like to take part in our survey.

- ◯ Yes, I would like to take part
- ◯ No, I've decided not to take part

Part I is about your current knowledge and understanding of physical activity guidelines for the general population.

Please answer the questions to the best of your knowledge.

Q1. ARE YOU AWARE THERE ARE PHYSICAL ACTIVITY GUIDELINES? (please select one)

- ◯ Yes (if you know the name of the guideline and/or country of publication, please note it here)
- ◯ No

Q2. ARE YOU AWARE OF THE CONTENT OF PHYSICAL ACTIVITY GUIDELINES? (please select one)

- ◯ Yes
- ◯ No

Q3. FROM WHICH SOURCE DID YOU LEARN ABOUT PHYSICAL ACTIVITY GUIDELINES? (please select all that apply)

- ☐ On line learning
- ☐ Higher education course
- ☐ Work based seminar
- ☐ Self directed learning
- ☐ Published articles
- ☐ Other (please describe optional)

Q4. DO YOU THINK BEING PHYSICALLY ACTIVE IS NECESSARY TO MAINTAIN OR IMPROVE OVERALL HEALTH? (please select one)

- Yes
- No

Q5. WHAT IS THE MINIMUM NUMBER OF DAYS PER WEEK A PERSON MUST BE PHYSICALLY ACTIVE IN ORDER TO IMPROVE OR MAINTAIN OVERALL HEALTH? (please select one)

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

Q6. WHAT IS THE MINIMUM INTENSITY OF PHYSICAL ACTIVITY NECESSARY TO MAINTAIN OR IMPROVE OVERALL HEALTH? (please select one)

- Very light
- Light
- Moderate
- Vigorous
- Very vigorous

Q7. IF A PERSON DOES ONLY MODERATE INTENSITY PHYSICAL ACTIVITY, FOR HOW MANY MINUTES SHOULD THIS TOTAL PER WEEK IN ORDER TO MAINTAIN OR IMPROVE HEALTH? (please select one)

- At least 60
- At least 75
- At least 90
- At least 105
- At least 120
- At least 135
- At least 150

Q8. WHICH ONE OF THE FOLLOWING CONSTITUTES MODERATE INTENSITY PHYSICAL ACTIVITY? (please select one)

- Casual walking
- Brisk walking
- Jogging
- Running
- Sprinting
- None of the above

Q9. WHICH ONE OF THE FOLLOWING CONSTITUTES VIGOROUS INTENSITY PHYSICAL ACTIVITY? (please select one)

- Casual walking
- Brisk walking
- Jogging
- None of the above

Q10. WHEN COMPARED TO MODERATE INTENSITY PHYSICAL ACTIVITY, DO YOU THINK COMPARABLE HEALTH BENEFITS CAN BE ACHIEVED THROUGH VIGOROUS INTENSITY ACTIVITY? (please select one)

- Yes
- No

Q11. FOR HOW MANY MINUTES OVER A WEEK DO YOU THINK VIGOROUS INTENSITY PHYSICAL ACTIVITY SHOULD BE PERFORMED IN ORDER TO ACHIEVE COMPARABLE HEALTH BENEFITS TO PERFORMING MODERATE INTENSITY PHYSICAL ACTIVITY? (please select one)

- At least 60
- At least 75
- At least 90
- At least 105
- At least 120
- At least 135
- At least 150

Q12. DO YOU THINK PEOPLE SHOULD UNDERTAKE PHYSICAL ACTIVITY TO MAINTAIN OR IMPROVE MUSCLE STRENGTH? (please select one)

- Yes
- No

Q13. ON HOW MANY DAYS A WEEK DO YOU THINK PEOPLE SHOULD PARTICIPATE IN MUSCLE STRENGTHENING ACTIVITIES? (please select one)

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

Q14. DO YOU THINK PEOPLE SHOULD UNDERTAKE PHYSICAL ACTIVITY TO MAINTAIN OR IMPROVE JOINT FLEXIBILITY? (please select one)

- Yes
- No

Q15. ON HOW MANY DAYS A WEEK DO YOU THINK PEOPLE SHOULD PARTICIPATE IN FLEXIBILITY ACTIVITIES? (please select one)

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

PART II is about your current practice related to physical activity promotion for people with limb absence (referred to here as patients).

Please tick one answer to indicate the extent to which you agree with the following statements.

Q16. I PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q17. I ENJOY PROMOTING PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q18. I HAVE TIME TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q19. I HAVE ADEQUATE KNOWLEDGE TO BE ABLE TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q20. I AM CONFIDENT ABOUT PROMOTING PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q21. OTHER HEALTH AND SOCIAL CARE PROFESSIONALS SHOULD PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q22. I DISCUSS PHYSICAL ACTIVITY PROMOTION WITH OTHER HEALTH & SOCIAL CARE PROFESSIONALS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q23. MY WORKPLACE MANAGEMENT EXPECTS ME TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q24. MY PROFESSIONAL ASSOCIATION ENCOURAGES ME TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q25. I HAVE UNDERTAKEN PRE-QUALIFICATION LEARNING ON THE TOPIC OF PHYSICAL ACTIVITY PROMOTION (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

Q26. I HAVE UNDERTAKEN OR AM UNDERTAKING POST-QUALIFICATION LEARNING ON THE TOPIC OF PHYSICAL ACTIVITY PROMOTION (please select one)

- Always
- Most of the Time
- Sometimes
- Rarely
- Never

PART III is about your attitudes and beliefs towards what you consider to be desirable practice in promoting physical activity to people with limb absence (again referred to here as patients).

Please tick one answer to indicate the extent to which you agree with the following statements.

Q27. I SHOULD PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q28. MY WORKPLACE MANAGEMENT SHOULD EXPECT ME TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q29. MY PROFESSIONAL ASSOCIATION SHOULD ENCOURAGE ME TO PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q30. OTHER HEALTH AND SOCIAL CARE PROFESSIONALS SHOULD PROMOTE PHYSICAL ACTIVITY TO PATIENTS (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q31. PRE-QUALIFICATION HEALTH AND SOCIAL CARE STUDENTS SHOULD BE EDUCATED AT HIGHER EDUCATION LEVEL ON PATIENT PHYSICAL ACTIVITY PROMOTION (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q32. CONTINUING PROFESSIONAL DEVELOPMENT (CPD) COURSES SHOULD EXIST ON PATIENT PHYSICAL ACTIVITY PROMOTION (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

Q33. I WOULD ATTEND PATIENT PHYSICAL ACTIVITY PROMOTION CPD COURSES IF THEY WERE AVAILABLE (please select one)

- Strongly agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

And finally, PART IV of the survey has six quick questions about you.

Q34. WHAT IS YOUR PROFESSIONAL TITLE? (please select all that apply)

- Prosthetist/Orthotist
- Prosthetist
- Orthotist
- Consultant in Rehabilitation Medicine
- Physiotherapist
- Nurse
- Another health and social care professional (please describe – optional)

Q35. WHAT IS YOUR GENDER? (please select one)

- Male
- Female

Q36. WHAT IS YOUR AGE? (please select one)

- 20-30
- 31-40
- 41-50
- 51-60
- Over 60

Q37. FOR HOW MANY YEARS HAVE YOU BEEN QUALIFIED? (please select one)

- 0-10
- 11-20
- 21-30
- 31-40
- Over 40

Q38. FOR HOW MANY YEARS HAVE YOU BEEN WORKING IN CLINICAL PRACTICE? (please select one)

- 0-10
- 11-20
- 21-30
- 31-40
- Over 40

Q39. WHAT IS THE GEOGRAPHICAL LOCATION OF YOUR USUAL PLACE OF WORK? (please select one)

- England
- Northern Ireland
- Scotland
- Wales

Q40. We appreciate you may have other thoughts, ideas, opinions and views which we haven't covered elsewhere in the survey.

We would be very interested in these and would really like you to note them down in the following space.

Thank you so much for taking the time to complete this survey. We are grateful for your responses which will always be treated confidentially.

By way of a thank–you for completing the survey you are invited to enter into our free draw to win an iPod Shuffle. Please enter your email address here if you wish to be entered into the draw.

We're sorry that you have chosen not to take part in the survey but thanks for considering it anyway.

Chapter 5 Study 3: Reliability and validity of the activPAL™ accelerometer during simulated lifestyle activities

Chapter overview

This chapter focuses on the measurement of physical behaviour in adults with lower limb absence. The chapter describes a study conducted in a laboratory setting designed to test the reliability and validity of the activPAL™ accelerometer.

Introduction

This introduction provides an evidenced-based review of studies which describe measurement tools used in the subjective and objective measurement of activity and sedentary behaviour in clinical populations. The chapter will also discuss the importance of selecting reliable and valid measurement tools.

The importance of physical activity for health

A level of physical activity lower than that recommended in published guidelines has been identified as the fourth leading risk factor for global mortality and six percent of deaths globally can be attributed to a lack of physical activity (Lim et al., 2012). Adults who are insufficiently physically active have a 20−30% increased risk of all-cause mortality compared to those who do at least 150 minutes of moderate-intensity physical activity per week, or the equivalent (World Health Organization, 2011). Physical activity is one of the most important components of successful health promotion and has long been a priority for public health, rising to greater prominence with the publication of the global recommendations on physical activity for health (World Health Organization, 2011). Increasing physical activity and reducing sedentary behaviour among those with mobility limitations has also been shown to improve health outcomes and control the economic and social burden of lifestyle-related disease (Loprinzi, Sheffield, Tyo, & Fittipaldi-Wert, 2014). Measuring physical behaviour in population samples is necessary to identify those at risk, and where and how best to direct physical behaviour interventions. Outcomes of physical behaviour interventions must be evaluated to determine effectiveness, and measurement is an important aspect of evaluation (Sallis, 2010). Selection of an appropriate measurement tool is multi-factorial and consideration should be given to cost, resources, ease of use, data management and accuracy of the tool.

Accurate measurement of physical activity

Establishing a valid and reliable tool for measuring physical behaviour patterns is important to ensure accurate reporting of habitual behaviour and intervention effects. Physical behaviour is complex with many components and behaviour can be reported in many different ways. For example, studies may describe outcome measures such as the number of steps taken per day (Tudor-Locke et al., 2011); cadence of stepping (Tudor-Locke & Rowe, 2012); or breaks in sedentary behaviour (Alghaeed et al., 2013). Measurement tool selection should be appropriate to the outcome measures to be examined, appropriate to the population, and yield accurate and desirable outcome measures.

Subjective and objective measurement methods

Subjective methods of measurement can be completed by research participants known as self-reporting and may be in the form of a questionnaire and/or an activity diary. Direct observation of physical activity is also regarded as a subjective method (Thomas, Nelson, & Silverman, 2005). Direct observation is a method which can be especially favourable for example when measuring children who may be more unpredictable in their movements (Epstein, McGowan, & Woodall, 1984). Direct observation is usually performed by a researcher or an independent observer, and the observations can be qualitatively or quantitatively analysed. Being able to observe behaviour in a real-time, true environment without hindrance to participants is also an advantage of this measurement method. Subjective measures can be low cost, easy and flexible to administer, personal, yet are subject to participants' memory bias and can be limited by external factors such as the complexity of the questions (Sylvia, Bernstein, Hubbard, Keating, & Anderson, 2014).

Objective methods of measuring physical behaviour include accelerometers, pedometers, heart-rate monitors and multi-sensory armband technology. A review of the evidence was presented on the validity of methods to assess physical activity as applied in health and disease (Westerterp, 2014). The researchers found that accelerometers are an optimal tool for valid assessment of physical activity. Objective methods have also been compared to subjective methods in measuring activity levels in adults with lower limb absence (Stepien, Cavenett, Taylor, & Crotty, 2007). In this study the researchers took data from activity monitors functioning as accelerometers and step counters (StepWatch3™ Activity Monitor, modus health llc, Washington, DC). The monitors were attached to the prosthesis pylons (shin tubes). The data were compared with data from activity diaries completed by $N = 77$ participants who recorded their activity and sedentary behaviour over 8 days. In a 24-hour monitoring period, the frequency of activity measured by the data from the self-report diaries was over-estimated when compared with the activity measured by the monitors at four pre-determined levels of rest: resting (64.6% vs. 58.0%); medium (4.4% vs. 2.0%); and high (0.3% vs. 0.2%) levels of activity. The exception was for low levels of activity where participants underestimated their activity levels when compared with the activity monitor recording (30.7% vs. 39.7%). The researchers concluded that self-reporting of activity by this clinical population is not an accurate method in a true living experimental setting due to the fact that the participants over-estimated the levels of their physical activity compared to the levels recorded by the accelerometers and step counters. Although this was an investigation of subjective methods using an objective method as a criterion, the study is one of the few to present measurement of physical activity in adults with lower limb absence. Studies have been carried out using a number of different measurement tools to assess physical activity in people with lower limb absence. Based on this, there appears to be consensus across the evidence that accelerometers and activity monitors are suitable for recording movement and posture in those with lower limb absence even though the physical state of having limb absence can alter gait patterns (Kishner, 2015; Smith, Michael, & Bowker, 2004).

Reliability and validity of measurement devices

Reliability of a measurement is defined as the consistency of the device or measurement by raters or judges over repeated measurements. Reliability reflects the confidence given to the observed score as being a reflection of what the device or person really knows, believes, or is able to do (Benson & Clark, 1982). Reliability estimates are used to evaluate different observers scoring an event (or events) using the same observation criteria. Repeated observations might be determined within one rater, between a number of raters, between measurement instruments, across a number of trials, and across a number of days (Kimberlin & Winterstein, 2008). A correlation coefficient can be used to assess the degree of reliability. If a test is reliable it should show a high positive correlation. Reliability coefficients are recorded as values from 0.00 to 1.00 with values closer to 1.00 indicating higher levels of reliability. Negative values are also possible but unusual and are usually truncated to 0. There are two types of reliability known as internal reliability and external reliability. Internal reliability assesses the consistency of results across items within a test. External reliability refers to the extent to which a measure varies from one use to another (McLeod, 2007).

Inter-rater reliability is the degree of agreement between or among raters. It gives a score of how much consensus there is in the ratings given by judges (McHugh, 2012). It is useful in refining the measurement tools used by raters, for example, by determining agreement on the number of steps a person took, or how long the participant took to perform an individual activity. If consensus is found in the raters' measurements, the measurement could be deemed to be appropriate for the task. Reliability is a necessary but not sufficient requirement for a criterion reference. Parallel forms reliability is a second type of reliability of relevance to this study. The same measurement tool (two parallel forms) will measure the physical behaviour of a specific sample of people, in this case people with unilateral limb absence wearing two monitors of the same make and model, one on each leg. The correlation between the two parallel forms is the estimate of reliability. The parallel forms (the two measurement instruments) are constructed so that the two forms can be used independent of each other and be considered equivalent measures (Trochim, 2006). Agreement between the recordings from the sound side placed monitor and the limb-absent side monitor is of interest and relevance to the current study.

Validity of measurement indicates the degree to which an instrument measures what it purports to measure. Validity is an important factor in choosing an instrument deemed appropriate to measure physical behaviour in a specific population. Validity research is now focused on the intended use of test scores and how they are interpreted rather than being regarded as a property of the test itself (Rowe & Mahar, 2006). This means that supporting the appropriateness of an intended interpretation of scores is a focus instead of demonstrating that a test is valid. Although reliability and validity of an instrument can be considered independently, it must be noted that an instrument cannot be valid without being reliable. Criterion validity (or criterion-related validity) measures how well one measure establishes an outcome for another measure. A test has this type of validity if it is useful for establishing performance or behaviour in another situation at a point in time. In the case of using an accelerometer to measure physical behaviour, it is important to assess if the chosen accelerometer is a valid method of measuring posture and movement in people with limb absence. Posture and movement of the study participants can be videotaped and the video footage reviewed and assessed. The video footage, or criterion reference, can then be deemed a valid tool for predicting how well the accelerometer will perform. The lack of relevant criterion variables on which to base findings is one of the challenges in physical activity research. This is especially the case in research featuring people with limb absence. It is therefore important to create opportunities wherever possible to collect predictor and criterion variables concurrently.

Reliability and validity of the activPAL™ accelerometer in healthy populations

Reliable and valid measurement of physical behaviour in adults with lower limb absence is crucial in accurately describing physical behaviour patterns and clinical intervention effects. It is important to understand the evidence around the reliability and validity of measurement devices prior to any device being considered for use in a study design. Lack of physical activity has been recognised as a major underlying cause of death, disease, and disability (World Health Organization, 2011). Physical activity guidelines have been developed to reduce the risk of developing specific conditions. Included in these guidelines is a statement directed at sedentary adults that recommends participation in 30 minutes of moderate intensity physical activity on at least fine days of the week (Department of Health, 2011). Accurate measurement of activity is important in helping us understand the relationship between physical activity, sedentary behaviour and health. Several studies have described the activPAL accelerometer and the merits and shortcomings of the device and its use. The activPAL has proven reliability and validity in measurements of walking activity (Ryan, Grant, Tigbe, & Granat, 2006). This study describes device validity and inter-device reliability in measuring step number and cadence in 20 healthy adults. Four activPAL physical activity monitors (two on the thigh of each leg, one monitor positioned distally to the other) were attached to determine interdevice reliability which was deemed excellent for both step number ($ICC \geq .99$), and for cadence ($ICC \geq .99$). Reliability was acceptable across five treadmill walking speeds in one part of the study (0.90, 1.12, 1.33, 1.56, and 1.78 m/s). Three self-selected outdoor walking speeds (slow, normal and fast) were selected by participants in another experimental aspect of the study. The absolute percentage error of the activPAL was < 1.11% for step number and cadence irrespective of walking speed. The activPAL in this study showed consistently good performance across all testing conditions. The researchers did acknowledge that the activPAL may not perform as well with other populations, such as the frail elderly. This is due to the algorithms used may be favoured towards the gait of healthy adults. This study focussed on the performance of the device with healthy adults walking at a wide range of cadences, and showed consistently good performance across all testing conditions. In designing the current study, it would be reasonable to consider that the gait of people with limb absence may also be considered slower than normal gait, or gait which featured purposive (purposeful) stepping. Incidental stepping which could be regarded as a more hesitant gait pattern may prevail in the population of people with limb absence.

The activPAL monitor was also evaluated on 10 healthy participants performing sitting, standing and walking using observational analysis as the criterion reference (Grant, Ryan, Tigbe, & Granat, 2006). In this study, three activPAL monitors were attached to the participants' thigh on one side only. One monitor was placed distally to the first, with the third monitor placed on top of the distal monitor. Interdevice reliability (*ICC*) ranged from .79 to .99, and mean percentage difference between the activPAL and observation was 0.19% for sitting, 1.4% for standing, and -2.0% walking. A similar study examined validity in measuring posture and motion in 21 community-dwelling participants performing everyday activities (Grant, Dall, Mitchell, & Granat, 2008). The researchers concluded acceptable device validity with an absolute percentage error of <1%. Understanding sedentary behaviour is also important and one such study examined the validity of the activPAL device in measuring breaks in sitting time in 13 participants (Lyden, Kozey Keadle, Staudenmayer, & Freedson, 2012). In expressing breaks from sedentary time as a rate per sedentary hour (brks.sed-hr^{-1}), the activPAL produced valid estimates of all sedentary behaviour measures and was sensitive to changes in break-rate between baseline and treatment conditions (baseline - 5.1 (2.8 to 7.1) brks.sed-hr^{-1}, treatment -8.0 (5.8 to 10.2) brks.sed-hr^{-1}).

These studies demonstrate the activPAL accelerometer to be a reliable and valid tool in the measurement of physical behaviour in healthy adult populations. However, researchers must be mindful of the tendency of the device to overestimate or underestimate the number of steps, and periods of standing and walking time. Care should therefore be taken when interpreting data outputs. One study of people with rheumatoid arthritis described how the activPAL underestimated step count by 26% when compared to direct observation (378 vs. 506 steps) and underestimated transition count by 36% (7 vs. 11 transitions) (Larkin, Nordgren, Brand, Fraser, & Kennedy, 2015). The researchers concluded that the activPAL activity monitor was not a valid measure of step counts and transition counts for people with rheumatoid arthritis. However, the activPAL activity monitor was considered a valid measure of time spent in sedentary, standing, and walking behaviours relative to direct observation. In another study, 16 adult men and women wore seven different models of activity monitors one of which was the activPAL monitor (Storm, Heller, & Mazza, 2015). The experimental protocol included walking along an indoor straight walkway, descending and ascending 24 steps, free outdoor walking and free indoor walking. These tasks were repeated at three self-selected walking speeds. An average underestimation of 29 steps was recorded for the activPAL, although the researchers acknowledged that the device had good accuracy overall.

The use of a criterion reference with which to compare the data from an objective measurement device is a method adopted by researchers to assess reliability and validity of accelerometers in healthy populations (Grant et al., 2006; Storm et al., 2015). Similarly, criterion references have been used successfully in the comparison of data in objective measurement using the activPAL in people with limb absence as described in the following section.

Measurement of physical behaviour in people with lower limb absence

One of the first studies of activity monitor validity and reliability in people with limb absence examined the validity and reliability of an unnamed activity monitor for measuring normal daily activities in five males (Bussmann, Reuvekamp, Veltink, Martens, & Stam, 1998). To allow for a comparison to be made with the activity monitor data, video recordings were taken as the criterion reference. Both the video equipment and the activity monitor were synchronised in terms of time. Validity and reliability were reported as being good with the overall percentage agreement between the activity monitor output and the criterion reference being 90%. It was later shown that the rating of the video recordings by two raters had an accuracy of 99.7% demonstrating the reliability of the criterion reference. From this study, it was recommended that an activity monitor could be used in rehabilitation and therapy settings. Another study (Redfield, Cagle, Hafner, & Sanders, 2013), described how a prosthesis mounted accelerometer (ActiLife ActiGraph GT3X+, Florida, www.actigraphcorp.com) could accurately identify general postures and movements of eight participants with transtibial amputation. The identification of these movements and postures were compared to visual observation by study researchers who achieved an accuracy of 96.6% for the criterion. An algorithm was also successfully developed to an accuracy of 92% to classify standing, sitting, or when the prosthesis was not worn. Separate results were not given for each activity mode.

Activity monitors (accelerometers and pedometers) have been shown to be accurate tools for monitoring physical behaviour in people with lower limb absence. Dudek et al (2008) explored the accuracy of the Yamax Digi-Walker SW-700 pedometer (New-Lifestyles, Inc; Lee's Summit, Missouri) and the Össur patient activity monitor (Reykjavík, Iceland) in a study of 20 people with transtibial amputation (Dudek, Khan, Lemaire, Marks, & Saville, 2008). In order to obtain criterion step count data, the subjects were videotaped. The distance covered by the participants was measured by a measurement wheel, and the walking time from video data and the percent accuracy calculated. The mean step count accuracy of the Digi-Walker and the patient activity walker was equivalent for both the household activity (75.3% vs 70.6%) and the walking course (93.8% vs 94.0%). The mean distance measurement accuracy was better with the Digi-Walker than with the patient activity monitor (household activity: 72.8% vs 0%, walking course: 92.5% vs 86.3%; $p < .05$). With acceptable step count accuracy, both devices were considered appropriate for assessing relatively continuous ambulation. The Digi-Walker may be preferred for its more accurate distance measurements yet neither device was found to be accurate in measuring home-based free-living activities. The Össur patient activity monitor, originally designed for amputee population measurement, is no longer commercially available (K. Farr, personal communication, September 27, 2017).

A systematic review was conducted on instruments and aspects related to the assessment of the level of physical activity in people with amputation (Piazza, Ferreira, Minsky, Pires, & Silva, 2017). The review of 12 articles concluded that validated measurement tools are used in the assessment of physical behaviour. Yet these tools were not originally intended for use in a population of people with limb absence. In addition, it was suggested that physiological parameters such as energy expenditure and movement pattern, may be different in people with limb absence and may not be taken into account by these measurement tools. A small number of studies have attempted to explore these possible differences. Salih et al (2016) conducted a laboratory-based study with 21 participants with limb absence ($n = 17$ who had transtibial absence) who wore accelerometers (Salih, Peel, & Burgess, 2016). activPAL™ accelerometers (PAL Technologies Ltd., Glasgow, UK) were placed on participants amputated and non-amputated sides whilst performing lifestyle simulated tasks (walking, and sitting in and propelling a wheelchair). A method of comparing the observed activities with the activPAL output was used to test validity of the device. Sensitivity was calculated as the proportion of the occurrences of a particular observed activity category that was correctly detected by the activPAL and shown in the output data. Using the Bland-Altman method, the mean difference between observed and activPAL monitor measures for total time spent walking for the sound, non-amputated side was < 0.01 seconds (limits of agreement 0.09 to 0.10 seconds) and for amputated side was 0.11 seconds (limits of agreement 0.43 to 0.66 seconds). To consider the difference between observed and measured times it is important to understand the time period over which the activities were carried out. The activity routine included participants walking for 5 minutes wearing the prosthesis, and self-propelling in a wheelchair and being pushed in a wheelchair for 3 minutes, with a rest permitted between the different tasks. An analysis between monitored and observed time found the sensitivity for time spent walking for the non-amputated side was 90.5% and for the amputated side was 86%. The researchers concluded that acceptable levels of accuracy in measuring walking time were demonstrated in this clinical population. However, the researchers in this study did not assess parallel forms reliability and therefore did not make recommendations on the side (limb absent or sound side) to which to attach the monitor to optimise recording of measurements. This was despite the researchers demonstrating that sensitivity was greater when attached to the sound side thigh.

In another study, researchers measured daily standing and stepping of adults with lower limb absence to help in determining optimal prosthetic socket prescription (Buis et al., 2014).The inter-device reliability of the activPAL monitor was established in one participant who wore two monitors attached just above the ankle for 20 trials. The intraclass correlation coefficient was considered excellent with a value of $ICC = .99$. Of final note is a study that examined the validity of a method to quantify free-living prosthetic wearing times, physical activity levels and strides taken (Tang, Spence, Maxwell, & Stansfield, 2012). Analysis algorithms were used to automatically characterize physical activity based on the pressure at the socket relief valve. The algorithms were validated in a laboratory-based protocol that included walking, stair climbing, standing, sitting, and putting on and taking off of the prosthesis. Intraclass correlation coefficient values of >.98 were achieved with mean differences of -2.0%, 0.3%, 1.3%, and 0.7% for agreement between off, static, dynamic times, and stride count respectively as determined by analysis algorithms and concurrent video analysis. However, the study methodology differed from other studies of people with limb absence in that an adapted version of a standard activPAL accelerometer and using a pressure sensor was utilised to measure valve pressure rather than accelerations in the measurement and determination of wear-time and activity levels.

The methodology in the current research study required an objective device which was able to provide information on physical activity patterning. Differentiation of body position (i.e. standing, sitting or lying) and detection of cumulative steps were also considered important. In addition, a measure of time spent performing different physical behaviour of daily living was also required. It was anticipated that the daily physical behaviour of people with limb absence would include a large proportion of time spent sitting. Therefore, as pedometers are unable to record physical behaviour occurring in a horizontal plane such as sitting and lying, an accelerometer was deemed the device of choice. Other factors also influenced the choice of device including activity type and duration, the cost and availability, and the ease of administration.

Based on the sound evidence from reliability and validity studies on healthy and clinical populations, it was appropriate to assess the reliability and validity of measuring physical activity behaviour in adults with lower limb absence with the activPAL accelerometer. Therefore, the three aims of this study were to:

1. determine the inter-rater reliability of a video-rated criterion for directly-observed incidental and purposive stepping, and stepping and reclining time.

2. assess parallel forms reliability of the activPAL accelerometer for measuring physical behaviour in a controlled setting.

3. determine the criterion-related validity of the activPAL accelerometer for measuring incidental and purposive stepping, and stepping and reclining time.

Methodology

Participants were asked to complete three controlled trials in a laboratory setting, consisting of four activities of daily living performed in a pre-determined order. Each trial took less than 2 minutes. Digital video recordings of each trial from two synchronised cameras were classified by three trained researchers. Each participant wore two accelerometers, one attached to the sound, non-amputated side, and the other attached to the prosthetic, limb absent side. To establish validity of the accelerometer output, the data were compared to the observer rated data derived from the digital recordings. Finally, data from the accelerometers were compared to establish the effect of the placement of the monitors on participants' sound and prosthetic side limbs.

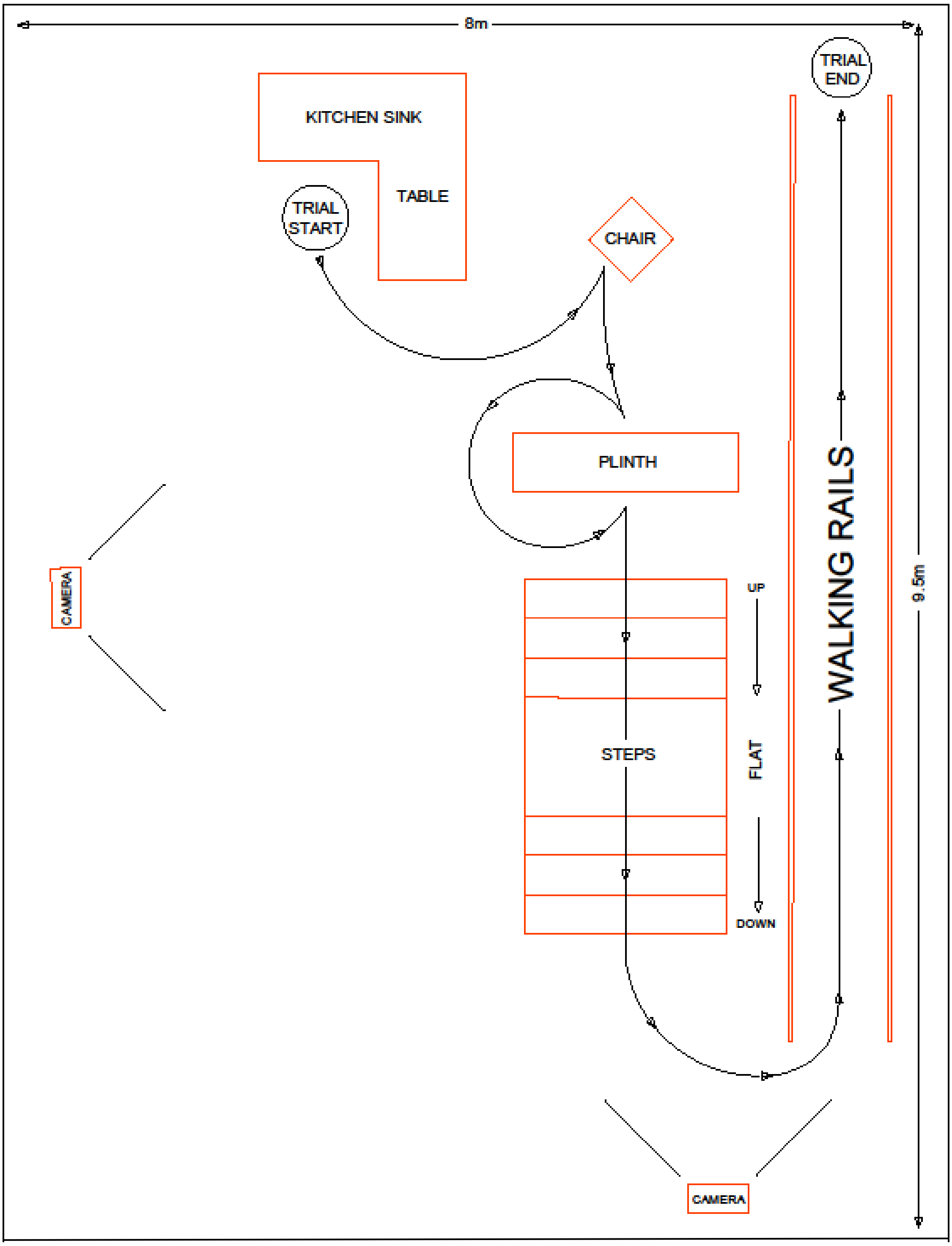
Participants

Potential participants were identified from an attendance list of volunteer patients who had previously been invited to assist with academic training and education at the National Centre for Prosthetics and Orthotics, University of Strathclyde. On arrival at the location, study information was presented to potential participants by a departmental receptionist who was independent of the study. Those who wished to participate indicated their wish to do so and provided signed consent prior to commencement of the laboratory-based study. The majority of testing was carried out on the same day thereby minimising possible inconvenience to the participants. When this was not possible, participants (n = 2) were asked to return to the testing location at their earliest convenience to complete the study procedures. Participants were adults who had unilateral lower limb absence at either transtibial or transfemoral level. Participants had to be routinely wearing and using a prosthesis for free-living activities and be able to understand the requirements of the study.

Equipment

Two digital cameras (HRD-CX115E, Sony Corporation, Tokyo) were used to record the movements of participants during each trial. The cameras were placed at points in the laboratory to record sagittal and coronal views of performance. Figure 2 illustrates the laboratory layout and equipment positioning, and the route taken by participants. Using data analysis software (PnO Data Solutions, The Tarn Group, New Zealand), videos were downloaded and converted to .wmv files for analysis using Windows Media Player (Microsoft Corporation, Redmond, WA). Windows Media Player has an upwards counting timer and displays video time length which would be an important feature when the raters were observing and assessing the video footage.

Figure 2 Illustration of laboratory and equipment layout and participant trial route



The activPAL is a tri-axial accelerometer-based posture and activity device (PAL Technologies Ltd., Glasgow, Scotland. It is a small device (53 x 35 x 7mm) weighing approximately 15 grams and is attached to the anterior mid-thigh using a transparent waterproof film dressing (3M™ Tegaderm™, 3M Healthcare, St Paul, MN). The activPAL monitor measures posture and classifies free-living activity into time periods spent sitting/lying, standing and stepping. The activPAL also records stepping events and produces a step count. The device produces a signal that relates to thigh inclination at rest. For a tri-axial accelerometer a signal between 1g and -1g reflects the inclination of each axis to vertical. The long axis of the thigh is used to discriminate between upright and sedentary postures. A differential threshold exists where the sit-to-stand transition is closer to standing than to sitting. Angles are pragmatically determined to ensure that the changes in inclination of the thigh as seen in cycling for example, do not interfere with posture change detection and that cycling is classed as an upright activity (D. Maxwell, personal communication, 4th November, 2015).

Two activPAL physical activity monitors per participant were connected to a password protected laptop computer and initialised prior to attachment on the participant's thighs. The time of initialisation was noted for later identification of the beginning of each of the three trials in the continuous data output. The activPAL monitors were placed anteriorly to the lateral and longitudinal midpoint of each thigh of the participant using Tegaderm. A trained researcher demonstrated this process then assisted each participant to position and attach two initialised monitors to the prosthetic and sound side thighs. If the participant had transfemoral limb absence, then the prosthetic side activity monitor was positioned on the outer prosthetic socket at the same level as the monitor positioned on the middle of their sound side thigh.

Procedures

Data collection took place in a clinical facility within the National Centre for Prosthetics and Orthotics, University of Strathclyde. Before the trials commenced participants were asked to complete a questionnaire to collect demographic and other relevant information such as any pre-existing medical conditions. The questionnaire also asked about their habitual locomotor modes in their home. Participants were briefed on the equipment including the activPAL monitors, the room layout and the sequential tasks to be performed during each trial.

For consistency, identical equipment set up was ensured over each data collection day by marking the laboratory floor with tape on the first day of testing. Walking speed was self-selected by each participant. Participants were shown where to stand for the start of the trial. The trial route was then demonstrated by a researcher who moved through the stations in the following order: setting a table in a mock kitchen; sitting in a chair; lying down on a plinth; negotiating six stairs (three stairs up, a flat section of one metre, and three stairs down); walking the length of the room between walking rails; and finally standing at ease at the trial end. Each of the three trials lasted for less than 2 minutes. Participants were prompted to move from station to station by a researcher. Clinical judgment by a qualified prosthetist was used to determine each participant's tolerance for standing and incidental stepping, and ambulatory walking.

The study procedure was approved in early November 2014 by the University's School of Psychological Sciences and Health Ethics Committee. Appendix F contains evidence of University Ethics Committee and sponsorship approval. Recruitment communication for participants is contained within Appendix G.

Data processing and data analysis

Data were handled and analysed by three members of the data collection team. The raw and cleaned data were coded so that participants could not be identified. The data were stored on an encrypted and password protected University server. All analyses were conducted using SPSS 22.0 (IBM Corp., Armonk, NY).

Inter-rater reliability of a video-rated criterion

To assess inter-rater reliability, values were derived by three trained raters who examined each video trial. All participants successfully completed three laboratory trials each and so a total of nine sets of video scores were produced per participant (three raters assessing three videos per participant). Two types of scores were recorded: step counts; and time elapsed in seconds. Analysis was carried out of three types of behaviour namely, standing, sitting/lying, and stepping. Using a hand held mechanical tally counter, the following variables were recorded by the three raters for counting steps:

- incidental steps – all steps taken from video start until the participant reached the plinth
- purposive steps – all steps taken from leaving the plinth until the participant stood at the trial end
- end of purposive walk between the parallel bars
- video recording end time as determined by Windows Movie Player

The following total step and time values were derived by each rater, for each trial, for each participant:

- incidental steps
- purposive steps
- total steps (the sum of incidental and purposive steps)
- reclining time
- purposive stepping time

The rater values for each of the above variables across all three trials for each participant were summed, and the median of the three raters' values was used as the criterion measure. In 2012, McHugh's work described a number of ways of determining inter-rater reliability including Cohen's kappa (for two raters), the Fleiss kappa (adaptation of Cohen's kappa for three or more raters), the contingency coefficient, the Pearson *r*, the Spearman Rho, and the intraclass correlation coefficient (McHugh, 2012). In the current study, the raters were the same across all participants therefore inter-rater reliability was calculated using the two-way intraclass correlation coefficients model (Shrout & Fleiss, 1979). All results were adjusted for a single rater. For clarification, the activPAL event file shows a recording output of steps from the side on which the monitor is being worn. This is different from the activPAL summary file output where the value has already been calculated by doubling the value. In rating the videos and counting steps, the raters counted the prosthetic and sound side steps and the values summed to give the total number of incidental and purposive steps. To be clear, the values were not averaged, as this would not have yielded the true number of steps recorded by the monitors and shown in the event file. Therefore, results for criterion-related validity for steps will be presented as raters versus the sum of prosthetic and sound side devices for observed and measured stepping.

Conversely, for time variables, the event file gives the time spent in each activity recorded by one monitor. Therefore, for reclining and purposive stepping time variables, the raters' values derived using the media player file clock were compared to those from the prosthetic side event file, and then repeated for the sound side event file. Therefore, two separate results for criterion-related validity for time will be presented; raters versus sound side device; and raters versus prosthetic side device.

Parallel forms reliability and criterion-related validity of the activPAL accelerometer

Upon completion of the three trials, data from the two monitors were downloaded. The Excel files were reprocessed from 10 second time increments to 0.1 second increments. Cells containing date and time information were reformatted, and each file was saved as an Excel Macro-Enabled Workbook. An example of the accelerometer output for three consecutive participant trials is presented in Figure 3. Notes are also given on this output for how the manual calculations were made for total incidental stepping time, total reclining time and total purposive stepping time in each trial. The researcher highlighted the events in green, yellow and red to indicate the following:

- green - trial start showing standing and incidental stepping events
- yellow - chair sitting and plinth lying reclining events
- red - trial end showing standing event

For all data analyses, ICC values of between .75 and .90 were considered good, and values ≥.90 were deemed to show excellent reliability (Koo & Li, 2016). Nunnally and Bernstein (1994) described an *ICC* =.70 and above as being minimally acceptable (Nunnally, 1994). Paired t-tests were used to compare the mean measures between raters. No significant or meaningful differences would be detected if the values yielded by the raters or the devices were identical.

Figure 3 Sample accelerometer output

NOTES

All '2' activity codes recorded between Trial Start and Plinth Lying Event are regarded as ***Incidental Stepping***
All '2' activity codes recorded between Plinth Lying Event and Trial End are regarded as ***Purposive Stepping***
Chair Sitting Event Time + Plinth Lying Event Time = ***Total Reclining Time***

Time	Interval (seconds)	Activity Code (0=sedentary, 1= standing, 2=stepping)	Cumulative Step Count	Participant ID TT15L10
13/11/2014 14:51:41	1.2	2	10	
13/11/2014 14:51:42	1.1	2	11	
13/11/2014 14:51:43	1.2	2	12	
13/11/2014 14:51:44	1	2	13	
13/11/2014 14:51:45	1.3	2	14	
13/11/2014 14:51:47	72.6	1	14	START TRIAL 1
13/11/2014 14:52:59	1.2	2	15	
13/11/2014 14:53:00	1.1	2	16	
13/11/2014 14:53:02	1.2	2	17	
13/11/2014 14:53:03	2.4	1	17	
13/11/2014 14:53:05	12.5	0	17	CHAIR SITTING EVENT
13/11/2014 14:53:18	1.4	1	17	
13/11/2014 14:53:19	1.1	2	18	
13/11/2014 14:53:20	1.2	2	19	
13/11/2014 14:53:21	0.3	1	19	
13/11/2014 14:53:22	23.2	0	19	PLINTH LYING EVENT
13/11/2014 14:53:45	2.2	1	19	
13/11/2014 14:53:47	2.1	2	20	
13/11/2014 14:53:49	1	2	21	
13/11/2014 14:53:50	1.2	2	22	
13/11/2014 14:53:51	1.6	2	23	
13/11/2014 14:53:53	1.9	2	24	
13/11/2014 14:53:55	1.8	2	25	
13/11/2014 14:53:57	1.6	2	26	
13/11/2014 14:53:58	1.1	2	27	
13/11/2014 14:53:59	1.4	2	28	
13/11/2014 14:54:01	1.6	2	29	
13/11/2014 14:54:02	0.9	2	30	
13/11/2014 14:54:03	1.2	2	31	
13/11/2014 14:54:05	1.3	2	32	
13/11/2014 14:54:06	1.7	2	33	
13/11/2014 14:54:08	0.9	2	34	
13/11/2014 14:54:08	19	1	34	END TRIAL 1
13/11/2014 14:54:27	1.3	2	35	
13/11/2014 14:54:29	1.2	2	36	
13/11/2014 14:54:30	1.4	2	37	
13/11/2014 14:54:31	2.5	2	38	
13/11/2014 14:54:34	5.6	2	39	
13/11/2014 14:54:39	28.8	1	39	START TRIAL 2
13/11/2014 14:55:08	1.5	2	40	
13/11/2014 14:55:10	2.4	2	41	
13/11/2014 14:55:12	2.2	1	41	
13/11/2014 14:55:14	6.3	0	41	CHAIR SITTING EVENT
13/11/2014 14:55:21	2.1	1	41	
13/11/2014 14:55:23	1.4	2	42	
13/11/2014 14:55:24	2	2	43	
13/11/2014 14:55:26	0.3	1	43	
13/11/2014 14:55:26	15.1	0	43	PLINTH LYING EVENT
13/11/2014 14:55:41	1.6	1	43	
13/11/2014 14:55:43	2.4	2	44	
13/11/2014 14:55:45	1.2	2	45	
13/11/2014 14:55:47	1.7	2	46	
13/11/2014 14:55:48	1.3	2	47	
13/11/2014 14:55:50	1.5	2	48	
13/11/2014 14:55:51	1.1	2	49	
13/11/2014 14:55:52	1.3	2	50	
13/11/2014 14:55:54	1.3	2	51	
13/11/2014 14:55:55	1.2	2	52	
13/11/2014 14:55:56	1.1	2	53	
13/11/2014 14:55:57	1.2	2	54	
13/11/2014 14:55:58	1.3	2	55	
13/11/2014 14:56:00	1	2	56	
13/11/2014 14:56:01	1.2	2	57	
13/11/2014 14:56:02	10	1	57	END TRIAL 2
13/11/2014 14:56:12	1.2	2	58	
13/11/2014 14:56:13	1.1	2	59	
13/11/2014 14:56:14	1.2	2	60	
13/11/2014 14:56:15	1.3	2	61	
13/11/2014 14:56:17	29.4	1	61	START TRIAL 3
13/11/2014 14:56:46	1.2	2	62	
13/11/2014 14:56:47	1.4	2	63	
13/11/2014 14:56:49	1	2	64	
13/11/2014 14:56:50	1.4	2	65	
13/11/2014 14:56:51	2.1	1	65	
13/11/2014 14:56:53	7.9	0	65	CHAIR SITTING EVENT
13/11/2014 14:57:01	2	1	65	
13/11/2014 14:57:03	1.9	2	66	
13/11/2014 14:57:05	0.4	1	66	
13/11/2014 14:57:05	11.2	0	66	PLINTH LYING EVENT
13/11/2014 14:57:17	1.5	1	66	
13/11/2014 14:57:18	1.2	2	67	
13/11/2014 14:57:19	1.4	2	68	
13/11/2014 14:57:21	1	2	69	
13/11/2014 14:57:22	1.7	2	70	
13/11/2014 14:57:23	1.6	2	71	
13/11/2014 14:57:25	1.2	2	72	
13/11/2014 14:57:26	1.1	2	73	
13/11/2014 14:57:27	1.2	2	74	
13/11/2014 14:57:29	1.2	2	75	
13/11/2014 14:57:30	1.1	2	76	
13/11/2014 14:57:31	1	2	77	
13/11/2014 14:57:32	1.2	2	78	
13/11/2014 14:57:33	1.2	2	79	
13/11/2014 14:57:34	1.5	2	80	
13/11/2014 14:57:36	10	1	80	END TRIAL 3
13/11/2014 14:57:46	2.8	2	81	
13/11/2014 14:57:49	2.2	2	82	

Effect size

The effect size indicates whether that difference is large enough to be practically meaningful. Cohen suggested that $d = 0.2$ be considered a small effect size, 0.5 represents a medium effect size, and 0.8 a large effect size (Cohen, 1988).

Results

All results are based on $N = 15$ participants

Characteristics of the study population.

A convenience sample of 15 participants (two females and 13 males) was recruited. Of the sample, four participants had transfemoral absence, and 11 participants had transtibial absence. Trauma was the most common reason for limb absence ($n = 8$). Additional descriptive statistics are presented in Table 19.

Inter-rater reliability of directly observed stepping, and reclining and purposive stepping time

One video trial file capture failed due to equipment malfunction, therefore 44 video files from a possible total of 45 video files were analysed. Missing step count and time data values for the failed video trial data capture were substituted using the average of the values from the two successfully recorded video trials for this participant. This was considered an appropriate and accurate approach based on a study on individual information-centred imputation of missing data (Kang, Rowe, Barreira, Robinson, & Mahar, 2009). The total time participants took to complete all three trials ranged from 207.32 to 384.93 seconds ($M = 243.85$, $SD = 46.49$). As shown in Table 20, there was an excellent level of inter-rater reliability for incidental steps, purposive steps and total number of steps, and reclining time and purposive stepping time. *ICCs* ranged from .94 -1.00 (95% CI = .87-1.00).

Table 19 Characteristics of study participants

Measurement		All (N = 15)	Male (n = 13)	Female (n = 2)
Age (years)*		59.20 ± 12.03	62.60 ± 8.56	37.00 ± 2.83
Height (metres)*		1.74 ± 0.11	1.76 ± 0.09	1.58 ± 0.04
Weight (kilograms)*		84.90 ± 18.77	89.50 ± 15.35	54.80 ± 1.77
Body mass index (kg/m^2)*		27.80 ± 3.68	28.70 ± 3.08	22.10 ± 0.38
Level	Transtibial	11	10	1
	Transfemoral	4	3	1
Side	Right	10	9	1
	Left	5	4	1
Cause of limb absence	Trauma	8	8	
	Cancer	3	2	1
	Infection	1	0	1
	Congenital	1	1	
	Peripheral arterial disease	2	2	
	Thrombosis			
Employment status	Retired	9	8	1
	Full-time	3	2	1
	Part-time	2	2	
	Unemployed	1	1	
Wheelchair user	No	14	12	2
	Yes	1	1	

*Note.** values are means ± 1 standard deviation

Table 20 Inter-rater reliability of directly observed stepping, and reclining and purposive stepping time.

Measurement	*ICC*	95% CI	
		LL	***UL***
Incidental steps	0.95	0.88	0.98
Purposive steps	0.94	0.87	0.98
Total steps	1.00	0.99	1.00
Reclining time (s)	0.98	0.96	0.99
Purposive time (s)	1.00	0.97	0.99

Note. ICC=intraclass correlation*; CI*=confidence interval*; LL*=lower limit*; UL*=upper limit; s=seconds

Parallel forms reliability prosthetic side device vs. sound side device for stepping and time

Parallel forms reliability was poor for incidental steps *ICC* = .05 (95% CI = -.46 -.53) indicating almost no consistency in the measurement between devices. For purposive steps and total steps the intraclass correlation coefficients were: *ICC* = .88 (95% CI = .67 - .96) and *ICC* = .77 (95% CI = .44 - .92) indicating close to excellent and good intraclass correlation coefficients respectively. Time-based measurements showed excellent parallel forms reliability for reclining time *ICC* = .99 (95% CI = .96 – 1.00), and for purposive stepping time *ICC* = .99 (95% CI = .97 - 1.00). Table 21 shows the results of paired t-test analyses for prosthetic and sound side placed devices. There were no significant differences for any of the variables.

Table 21 Paired t-test analyses for prosthetic side device vs. sound side device for stepping and time

Measurement	Statistic	Prosthetic	Sound	Paired differences	*t*	*p*	*d*
Incidental steps	*M*	10.07	12.20	2.13	1.36	0.20	0.48
	SD	3.61	5.09	6.08			
Purposive steps	*M*	45.13	45.13	0.00	0.00	1.00	0.00
	SD	9.55	9.06	4.61			
Total steps	*M*	55.20	57.33	2.13	1.00	0.34	0.18
	SD	11.36	12.98	8.29			
Reclining time(s)	*M*	78.67	77.78	0.89	1.40	0.18	0.06
	SD	16.72	15.13	2.48			
Purposive time(s)	*M*	65.39	65.61	0.21	0.24	0.81	0.01
	SD	21.89	23.06	3.42			

Note.M = mean, *SD* = standard deviation, s=seconds

Criterion-related validity of raters vs. sum of prosthetic and sound side devices for observed and measured stepping

The intraclass correlation coefficients between the raters' values and the sum of the counts of the two activPAL monitors for stepping were found to be excellent for two of the measurements. The values were as follows: for purposive steps *ICC* = .94 (95% CI = .82-.98) and for total steps *ICC* = .90 (95% CI = .73-.96). The exception was incidental steps with a correlation of *ICC* = .58 (95% CI = .12-.84) which is below the minimally acceptable value of .70.

Table 22 displays the results of the paired t-tests comparing raters' values to the activPAL recorded values. Notably, there was an exceptionally large difference in means between total incidental steps recorded by the raters and those recorded by the activPAL monitors combined, with the difference being significant ($t_{(14)} = -18.05$, $p = .007$, $d = 4.26$).

Table 22 Paired t-test analyses of raters vs. sum of sound and prosthetic side devices for stepping

Measurement	Statistic	Raters	activPAL total	Paired differences	*t*	*p*	*d*
Incidental steps	*M*	59.80	22.27	37.53	-18.05	0.0070	4.26
	SD	10.69	6.40	4.29			
Purposive steps	*M*	105.53	90.27	15.26	-8.68	< 0.0001	0.80
	SD	20.27	18.03	2.24			
Total steps	*M*	165.07	112.53	52.54	-17.45	< 0.0001	2.00
	SD	29.10	22.94	6.16			

Note. *M* = mean, *SD* = standard deviation

Criterion-related validity of raters vs. sound side device and raters vs. prosthetic side device for observed and measured time

The consistency of raters in assessing reclining time and purposive stepping time from the video recordings was compared with the total reclining and purposive stepping time as recorded by sound and prosthetic side positioned activPAL monitors. The consistency was found to be excellent. For reclining time, the sound side placed device correlation was *ICC* = .99 (95% CI = .98 -1.00) and for the prosthetic side placed device the correlation was *ICC*= .98 (95% CI = .95-1.00). Total purposive stepping time intraclass correlation values were lower than those for reclining time but still regarded as good consistency [sound side *ICC* = .87 (95% CI = .66-.96), prosthetic side *ICC* = .88 (95% CI = .68-.96)].

In the paired t-test analyses, results for reclining and purposive stepping times were reasonably close between the raters' assessment from the video recordings when compared with the recorded values from the monitor placed on the sound side. Means were close and the effect size was small for reclining time despite being significantly different ($t_{(14)}$ = -11.65, p < .0001, d = 0.25). For purposive stepping time, comparisons between the raters assessment from the video recordings and the recorded values from the sound side placed monitor were not found to be significantly different and the effect size was small ($t_{(14)}$=-1.91, p=.077, d = 0.25).

Finally, results were reasonably close between the raters' assessment from the video recordings when compared with the recorded values for the monitor placed on the prosthetic side. Again, means were close and the effect size was small for reclining time despite being significantly different ($t_{(14)}$ = -5.43, p <.0001, d = 0.25). For purposive stepping time, comparisons between the raters assessment from the video recordings and the recorded values from the prosthetic side placed monitor were not found to be significantly different ($t_{(14)}$ = -2.13, p = 0.051, d = 0.27). The results for the intraclass correlations and paired t-tests analyses performed are shown in Table 23.

Discussion

This laboratory study had three aims which will be described in the following sections.

Inter-rater reliability of directly observed stepping, and reclining and purposive stepping time

The results indicate that trained raters are consistent in counting all measures of directly observed incidental and purposive stepping in people who have either unilateral transtibial or unilateral transfemoral limb absence. In addition, sedentary behaviours such as sitting and lying can also be measured consistently. The inter-rater results of *ICC* = .98 - 1.00 from this study align with another study of inter-rater reliability in measuring sitting, standing and walking in 12 participants (Lugade, Fortune, Morrow, & Kaufman, 2014). In this laboratory study, tri-axial custom built accelerometers recorded static orientations of standing, sitting and lying. Dynamic

Table 23 Criterion-related validity of raters vs. sound side device and raters vs. prosthetic side device for time

Measurement	Rater	*ICC*	95% CI		*M*	*SD*	Paired differences between rater and device		*t*	*p*	*d*
			LL	UL			*M*	SD			
Reclining time (s)	Raters				82.61	14.57					
	Sound	0.99	0.98	1.00	77.78	23.06	-4.83	8.49	-11.65	<.0001	0.25
	Prosthetic	0.98	0.95	1.00	78.71	16.73	-3.90	2.16	-5.43	<.0001	0.25
Purposive stepping time (s)	Raters				70.63	16.57					
	Sound	0.87	0.66	0.96	65.61	23.06	-5.02	6.49	-1.91	0.077	0.25
	Prosthetic	0.88	0.68	0.96	65.39	21.89	-5.24	5.32	-2.13	0.051	0.27

Note. M = mean, *SD* = standard deviation, CI=confidence interval*; LL*=lower limit*; UL*=upper limit; s=seconds movements of walking, jogging and transitions between postures were identified. Additionally, subjects walked and jogged at self-selected slow, comfortable, and fast speeds. Two investigators identified tasks during each second of video observation. The intraclass correlation coefficients for inter-rater reliability were *ICC* >.95 for all activities except for transitions. Here, video identification of transitions had *ICC* values of 0.47, indicating differences between the two raters in identifying lying to lying, upright to lying, lying to upright, sit-to-stand, and stand-to-sit transitions. However, in another study, researchers examined the reliability of observers (n = 10) performing manual steps counting of a healthy individuals who had been video recorded (Busse, van Deursen, & Wiles, 2009). Relationships between data from the StepWatch monitor and manual step counts (n = 18); the activPAL monitor; and self-reported activity levels (n = 22) were assessed using correlations. A count of the same video recording was repeated three times by each observer. The researchers determined that inter-rater reliability of measuring stepping was very poor *ICC* = .26 when compared to the values determined for incidental and purposive stepping in the current study (*ICC* = .94 and *ICC* = .95). The design of this particular reliability aspect of the study differed in that the same video footage taken of one participant was rated (analysed) three times by 10 raters. In the current study, the rating of three video-captured trials per participant by three raters meant that for 15 participants a total number of 135 videos were rated.

To date, there are no known studies in which the inter-rater reliability has been analysed when rating the physical behaviour of those with limb absence. In the current study the data show excellent reliability across three raters. Based on the high reliability when adjusted for a single rater, it can be concluded that more than three raters are not required to obtain reliable data. Therefore, a reliable record of physical behaviour for criterion-related validation of the activPAL monitor in those with limb absence has been established.

Parallel forms reliability of the activPAL accelerometer for measuring stepping and time

Reliability between the measurements recorded by the sound and prosthetic side placed monitors was found to be poor in measuring incidental steps which in turn had an effect on the overall measurement of total steps. Because the monitors undercounted and miscounted incidental steps, the total step count value was also underestimated. However, the reliability in measuring total steps can still be described as good due to the reliability of the device in measuring purposive steps. A possible explanation for poor reliability in measuring incidental steps could be the nature of the participants' clinical condition. Due to the fact that participants walked with prostheses, some did walk with a more hesitant gait particularly when ascending and descending the stairs. This was seen in the video evidence where participants were less confident in incidental stepping during the initial activities of each trial. On review of the video footage, participants' confidence was seen to increase with each trial performed which could be attributed to their increased mastery of the activities and their familiarity of the laboratory route. There was a general reduction in the length of time taken to complete the trials from the first to the third attempts for most of the participants. Completion of the trials may have been quicker had the participants not had to negotiate the stairs. Staircase negotiation has been described in a laboratory-based experiment with people who have transtibial absence (Ramstrand & Nilsson, 2009). In this study, sound and prosthetic foot placement and foot clearance during stair ascent and decent were examined. When compared to an able-bodied population, results showed reduced walking velocity, reduced step length, wider walking base, and a prolonged period of double support (both feet in contact with the ground). The phenomenon may be further compounded for people with transfemoral absence due to the loss of the natural knee and ankle joints though this has not been investigated. Further, reduced participant cadence and velocity may not be detected by the activPAL due to the algorithms being designed to be more suitable for healthy adults rather than those with clinical conditions affecting posture and movement (Ryan, Grant, Tigbe, & Granat, 2006). Indeed, one of the participants used elbow crutches in all three trials meaning this person would not have been bearing full body weight through sound and limb-absent sides. Partial weight bearing indeed affected the way the activPAL monitors detected and recorded steps with an underestimation by 75 steps compared to the median criterion reference value over three trials. Further, the activPAL monitors were reliable in measuring time despite a short trial length and irrespective of whether the monitor was placed on the sound or the limb-absent side.

The optimal side of placement of an accelerometer in a population of people with unilateral absence was considered. Generally across participants, the monitor placed on the prosthetic side underestimated measured stepping to a greater degree than the monitor placed on the sound side, especially in measuring incidental stepping. In the case of one of the participants with transfemoral absence and in counting incidental steps in one trial, the median rater count was 80 steps. However, in the same trial, the combined number of steps recorded by the prosthetic and sound side activPAL monitors was only 28 steps (11 steps prosthetic side monitor and 17 steps sound side monitor). In the cases where the prosthetic-side placed monitor recorded more steps than the sound side-placed monitor (n = 8), the differences in the measurements were much less than the differences recorded when the prosthetic side monitor underestimated steps. Similarly, in the same participant example for time the recorded median rater value was 66.30 s for total reclining time yet the activPAL monitors recorded values of 58.30 s and 59.60 s for prosthetic and sound side placed monitors respectively. This corresponds to the findings from a similar study featuring adults with lower limb absence (Salih, Peel, & Burgess, 2016). Researchers tested the accuracy of the activPAL accelerometer in 21 participants with limb absence who wore one device on the limb absent side, and one device on the sound side. Here, measurements compared more favourably between the observed raters measurements and sound side placed monitor ratings (90.5% agreement), than between the observed and the prosthetic side monitor (86% agreement). In considering the parallel forms reliability, the higher agreement for the purposive steps is understandable as the monitors, irrespective of placement side, were able to detect the continuous bout of purposive stepping due to adequate acceleration of the limb segment (in this case the thigh). To confirm or refute this, it was helpful to re-examine the captured video footage of the participants. The incidental steps were also observed to be more irregular in pattern, were not ambulatory, and may have been influenced by distinct and individualistic features of gait patterns.

The laboratory conditions may also have contributed to the restriction of normal gait patterns which influenced the results. For example, the participants took fewer incidental steps relative to purposeful steps on both the prosthetic and sound sides (as presented in Table 21). This can also be described in terms of the number of purposeful steps dominating over incidental steps taken and therefore influencing the number of total steps taken as described in Table 22. The impact of this methodological design means that there would have been a larger percentage error over the course of each trial. This may not be representative of a free-living situation where a relatively higher proportion of purposeful steps might be taken by people with lower limb absence. That said, the evidence does suggest that the use of a single monitor placed on the sound side is more accurate in recording step counts and lapsed time in a population of people with limb absence.

In the current study, the raters' measures and the activPAL monitor measures were generally consistent across the three trials for each participant albeit the measures were different in magnitude. The activPAL monitors did underestimate time measurements over the length of each trial. However, the underestimation could be attributed to the monitoring of a particular activity (sitting/lying, standing, or stepping). It could be feasible to calculate in percentage terms an adjustment to the monitor output in order to calibrate the stepping and time values correctly. Returning the monitors to the manufacturer as part of an ongoing programme of calibration (as yet not known to be implemented) could also be carried out at pre-determined after-sales time points or number of device uses.

Criterion-related validity of the activPAL accelerometer for measuring incidental and purposive stepping, and stepping and reclining time

Based on the findings, criterion-related validity of the activPAL in a population of people with limb absence is excellent for detecting purposive stepping, excellent for recording reclining time, and good for recording stepping time. This study has shown that the activPAL monitor may be valid in the measurement of incidental stepping in those with limb absence who use prostheses. A limitation is that to derive the criterion reference, the raters counted the total number of steps (prosthetic plus sound side steps) rather than counting and recording individually only the prosthetic steps, and then counting and recording individually only the sound side steps. Because there was an accelerometer attached to each thigh, each monitor was only recording the gravitational accelerations resulting from segmental movement on the prosthetic side or on the sound side. There was a greater sensitivity in the recording of actual steps recorded by the activPAL and therefore a more accurate value derived for total steps than for the criterion reference. Improvement in device validity may be seen in replication research with longer sampling periods and a true real time environment for performing activities.

Strengths, limitations and future work

One of the strengths of this study is confirmation that trained raters are able to reliably judge incidental and purposive stepping, and to judge sitting and lying activity from a video recording of people with limb absence performing simulated daily tasks. Indeed, one rater may be sufficient to confirm inter-reliability and criterion-related validity. A second strength of the study is the endorsement of the activPAL monitor as a reliable and valid objective measurement device when used in the testing of participants with lower limb absence. A third strength of the study is that the optimal placement of one activPAL monitor has been shown to be the sound side thigh, rather than the prosthetic side thigh.

The current study participants had either transtibial or transfemoral limb absence. Those with transfemoral level of absence had the prosthetic side activPAL monitor positioned on the external prosthetic socket rather than the usual protocol of attaching the monitor directly onto the skin of the thigh. Attaching the monitor to a laminated prosthetic socket material rather than directly with the skin may have affected the sensitivity of the monitor. This study did not explore between transtibial group and transfemoral group differences and future work could yield information on optimal positioning of activity monitors in those with different levels of limb absence. In addition, the participant numbers may be considered small (N = 15). The cohort was non-representative in terms of cause of amputation due to only two participants of the 15 stating the reason for amputation being peripheral arterial disease; in the United Kingdom this is most common aetiology in people with limb absence. This could be addressed by recruiting randomly from a prosthetic-centred clinical facility rather than from a convenience sample.

The controlled laboratory environment in which the study took place may have been limiting for the participants in being able to realistically perform the simulated free-living movements. Gait patterns may have also been affected by the limited space in the laboratory. Short distances between the chair and the plinth for example may have led to participants taking proportionally more incidental steps than purposive steps at walking cadences slower than usual. Replication of the study using longer trial lengths and walking routes which encourage more purposeful gait at greater cadence might be conducive to the activPAL being more sensitive in recording incidental and purposive steps. Future work could focus on a larger number of true free-living activities in a larger environment. Drawing on the validity and reliability study where posture and stepping were measured (Sellers, Dall, Grant, & Stansfield, 2016), participants could be assessed for longer periods of time, for example up to 30 minutes and performing a greater variety of activities. Allowing participants to walk over a longer duration assessed period could mean the activPAL monitor is more sensitive to the greater number of purposive steps the participant would take. The number of transitions would also be reduced over longer monitoring periods in comparison with the current study where participants moved between many stations and transitioned from sitting to lying to standing often.

Finally, in this study the activPAL appeared to be valid in detecting short duration activity. However, the data were reprocessed for 0.1 second increments in order that incidental steps were not rejected, nor those events occurring at faster speeds such as purposive walking. In the current study, the simulated free-living activities could be regarded as being abnormal in daily living. Although direct observation of free-living activity is not feasible, other observational monitoring methods could be considered. For example, wearable cameras such as the SenseCam (Microsoft Corporation, Redmond, WA, USA) which includes an on-board triaxial accelerometer for recording and contextualising physical behaviours could be used. Researchers conducted a study with the SenseCam to objectively categorise the behaviour type and context of participants' accelerometer-identified episodes of activity (Doherty et al., 2013). They concluded that the SenseCam was the best objective method available to categorise the social and environmental context of accelerometer-defined episodes of activity in free-living conditions. Objective measurement of free-living activities for time periods up to the maximum recording period for the activPAL monitor of 14 days can be explored. In this way, a better understanding of realistic posture and movement, and patterns of movement could be gained. Monitoring week day and weekend time periods when it is known that physical behaviour patterns can be altered could be studied (Drenowatz et al., 2016). Further, the activPAL monitor is an appropriate instrument for measuring physical behaviour in those with limb absence. However, conducting studies which test other accelerometers, such as the ActiGraph GT3X should be prioritised (ActiGraph, LLC; Ft. Walton Beach, FL). This would aid researchers in determining the optimal movement, sedentary behaviour and posture measurement device for use in this clinical population.

Summary of Chapter 5

This study has shown that multiple raters are not needed to obtain reliable data, and that these data can be used to obtain a reliable record of physical behaviours for criterion-related validation of other measures such as the activPAL accelerometer. Further, the activPAL accelerometer is a reliable instrument for measuring purposive stepping and reclining events over a short period in a laboratory setting. It can be considered a useful tool by clinicians and researchers in measuring simulated activities of daily living in people with lower limb absence. It has been shown that placement of the accelerometer on the sound leg of people with limb absence is more sensitive in recording than a monitor placed on the prosthetic side. The activPAL monitor is a valid device for detecting purposive stepping, and recording reclining and stepping time. The activPAL monitor may be valid in the measurement of incidental stepping in those with limb absence who use prostheses. It is also proposed that the activPAL monitor would be useful in monitoring stepping and reclining over longer time periods of days and weeks. Therefore, it is proposed that by conducting real-time, free-living studies, the findings could contribute to the knowledge and understanding of physical behaviour patterns in those with lower limb absence.

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Appendix F Study 3: University ethics and sponsorship approval

Sarah Deans

From:	James Baxter
Sent:	06 November 2014 15:11
To:	HaSS Research and Knowledge Exchange; David Rowe
Cc:	Sarah Deans
Subject:	Objectively measured physical activity and sedentary habits in people with lower limb absence.
Attachments:	Rowe-Deans ethics revisions - responses to reviewers.pdf; All Components Ethics Application ROWE DEANS RESUBMITTED 051114.pdf

Dear Dave,

'Objectively measured physical activity and sedentary habits in people with lower limb absence.'

Thank you for amending your application which the SEC now approves. I'm passing it to HASS R & KE for sponsorship approval. Please wait to hear from them before beginning the work.

Best wishes

Jim Baxter

The University of Strathclyde is a charitable body, registered in Scotland, number SC015263

From: David Rowe
Sent: 06 November 2014 14:16
To: James Baxter
Subject: Rowe-Deans ethocs - revision

Dear Jim:

Thank you from Sarah Deans and myself for your rapid turnaround time of our initial review, and for the helpful comments.

I provide attached a revised version of the application, and responses to each point made in the initial review, stating where changes were made in the application. In addition, changes are highlighted in yellow in both documents, for convenience.

If there are any immediate problems, or you have any questions, please do not hesitate to contact me.

Regards,

1

Appendix G Participant covering letter, participant information sheet and consent

Participant covering letter

Dear Prospective Participant,

Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

I am writing to you about a project which aims to support people living with limb absence to continue to be active or increase the amount of daily and weekly activity they participate in. The work is supported by the School of Psychological Sciences and Health, and Biomedical Engineering incorporating the National Centre for Prosthetics and Orthotics. These are both departments of the University of Strathclyde in Glasgow.

This on-going doctoral work in the area of physical activity for health has been given full ethical approval by the School of Psychological Sciences and Health Ethics Committee at the University of Strathclyde. I do hope you will consider being involved.

About this project

We are keen to find out about physical activity levels and sedentary behaviour in those who use prostheses (artificial limbs). To do this, participants will be asked to wear an activity monitor which is worn on the thigh and records free-living posture and movement. The monitor will be attached using waterproof sticking tape which is non-allergenic. As part of the same study, we would like to ascertain how valid and reliable the activity monitor is in measuring your sitting, lying, standing, stepping and walking in a laboratory setting.

On completion of the study, the results will be disseminated at national and international prosthetic/orthotic conferences and in a relevant rehabilitation medicine journal.

Your involvement

If you are a person who has either unilateral (on one-side), transtibial (below the knee) or transfemoral (above the knee) limb absence, routinely wear a prosthesis (artificial limb), and are over 18 years of age, you are warmly invited to read the detailed participant information sheet to find out more about the study. If you have been invited to help with one of the National Centre's undergraduate teaching modules, you will also have the opportunity to participate in some basic lying, sitting, standing, stepping and walking activities lasting no more than 15 minutes. Whilst this is happening you will be wearing a small activity monitor on each thigh (or on the prosthetic socket if you wear a transfemoral prosthesis), and you will be observed and video recorded. On completion of this clinical activity, you will then continue to wear the monitors for a further seven days. At the end of the seven day period, you will remove the monitor and either return it by post in a pre-paid envelope, or deliver it in person when next visiting the department.

It is your decision whether or not to take part in the investigation or not. You do not have to participate. Data downloaded from the activity monitor will be stored and analysed only after the monitor has been returned to the researcher by the participant.

Because the data will always be anonymous, your data cannot be used to identify you. You will however be able to withdraw your data should you choose to withdraw personally from the study.

Background and the issue

Regular physical activity is well established as an important part of maintaining good health and a good way to reduce the risk of many diseases. Yet low levels of physical activity are prevalent; only 40% of men and 28% of women in the UK meet the minimum recommended physical activity levels. We believe the limb absent population could also be more physically active and hope this study is able to inform us about the ways in which this could be achieved.

I hope you will consider supporting this work and please contact me if you would like any further information. Thank-you.

With my kindest regards,

Sarah A. Deans

Prosthetist/Orthotist & Teaching Fellow
Department of Biomedical Engineering incorporating the
National Centre for Prosthetics and Orthotics
Curran Building
131 St James Road
Glasgow, G4 0LS, UK
E: sarah.deans@strath.ac.uk
T: 0141 548 3929

Project Supervisor:
Dr David Rowe
Reader
School of Psychological Sciences and Health
GH533 Graham Hills Building
50 George Street
Glasgow, UK
E: david.rowe@strath.ac.uk T: 0141 548 4069

Participant information sheet and consent

Name of department: School of Psychological Sciences and Health, Faculty of Humanities and Social Sciences

Title of the study: Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

Introduction

You are invited to take part in a study which is being conducted at the University of Strathclyde by two members of staff from the School of Psychological Sciences and Health, and Mrs Sarah Deans who is a Teaching Fellow at the Department of Biomedical Engineering incorporating the National Centre for Prosthetics and Orthotics. Dr Rowe is a Reader in Exercise Science and Mrs Deans is a State Registered Prosthetist and Orthotist. Two undergraduate students from the School of Psychological Sciences and Health will also be helping with the research and they will be fully trained and supervised throughout the research testing procedures.

This information sheet will tell you about the study so that you can decide if you would like to be involved or not.

What is the purpose of this investigation?

In this study, we are keen to find out about physical activity levels and sedentary behaviour in those who have lower limb absence and who use a prosthesis (artificial limb). As part of the same study, we would also like to ascertain how reliable an activity monitor is in measuring sitting, lying, standing, stepping and walking in a clinical laboratory setting.

Do you have to take part?

No, you do not have to take part in this study. If you do decide to take part, you are free to withdraw your participation at any time, without having to give a reason and without any consequences. In addition, you are free to withdraw any information about you that has been collected as part of the study, without having to give a reason and without any consequences. If you wish to withdraw your information, you will be able to do this up to one month following completion of the week-long activity monitoring. You can do this by contacting Mrs Deans.

Why have you been invited to take part?

You have been invited to take part in this study because you are a person who has either unilateral (one-sided) transtibial (below the knee) or transfemoral (above the knee) limb absence.

What will you do in the project?

You will be asked to make a maximum of two visits for all study procedures. These will be conducted in a room within the National Centre for Prosthetics and Orthotics unit in the Curran Building at the University of Strathclyde.

During visit one the researcher will make sure that you understand what will be required during the study and answer any questions that you may have prior to any data collection. Firstly, you will be asked to complete a short questionnaire on some background information such as your age and amputation level. In addition, during the first visit, two activity monitors similar in size to a two pound coin, will be attached to the middle of each of your thighs (or the outside of your prosthesis) using waterproof, non-allergenic sticky tape. One of the researchers (Deans, Sloan or Walker) will demonstrate the attachment of the monitor to their own thigh, and then assist you in attaching the monitors to your own thighs.

You will then be asked to lie down, sit, stand, step and walk for short timed periods of approximately one or two minutes. You will be timed and observed when performing these five types of movement patterns, and with your consent we will also video record these activities for future analysis by us.If you move around the home in other ways (such as with crutches) we may also ask you to do this in the laboratory. This first stage of testing should take no longer than 30 minutes. For the second stage of testing, you will return home with both activity monitors still attached. The monitors will be worn continuously by you for a period of seven days, although you will be able to remove the device if required. You will also be able to shower or bath while wearing the monitors.

Following the seventh day of recording, you will be asked to remove the monitors and return to the researcher either by post in a prepaid envelope, or during a subsequent visit to the University department. The researcher will give you an instruction sheet about the activPAL monitor and how to fit it (in case you need to take it off) and a diary sheet to write down any time the monitor or your prosthesis is taken off. You will also be asked to record the time you get up and the time you went to bed during the monitoring period.

Please note:
If an activity monitor fails, which can sometimes happen, then you may be asked to wear the monitor again while the study procedures are repeated. However, this is completely up to and you do not have to wear it again if you do not want to.

What are the potential risks to you in taking part?

There are no known risks associated with any of the procedures being used to collect information about you. However, if you feel uncomfortable with any of the procedures, you can stop the procedure(s) or ‘opt out’ from any of the procedures at any time, and you will be reminded of this at the start of each visit.

The activity monitor (activPAL) is attached using a medical adhesive. This adhesive is low allergy therefore the risk of you experiencing any irritation or sensitivity is minimal. However, if you do experience any irritation or sensitivity then you will be advised to remove the activPAL immediately.

The researcher who previously demonstrated the attaching of the monitor to your thigh, will also demonstrate how to remove the medical adhesive and monitor should you wish to do so during Stage 2 or when they have come to the end of the study. You may experience slight discomfort when removing the adhesive (similar to removing a sticking plaster). However, following the researchers monitor removal demonstration, you will come to understand the removal technique designed to minimise or avoid any discomfort.

For the home-based monitoring stage, you will be asked to carry out your normal daily activities.

What happens to the information in the project?

Only the consent form and the demographic questionnaire will include your name and other identifying information (e.g. contact details), these documents will be stored in a locked filing cabinet in a locked room at the University and will be stored separately from the rest of your information. A study code will be assigned to you and all other information will use this study code. Paper copies of information (e.g. questionnaires) will be stored in a separate locked filing cabinet and electronic information will be stored on a password protected computer based at the University.

With your permission, the activities conducted during visit one to the National Centre for Prosthetics and Orthotics will be video recorded. Immediately after the activity has finished, the video files will be transferred to a password protected university based computer. The video files will be deleted from the recording device as soon as the files have been transferred. Only the lead researcher (Sarah Deans) and the students undertaking this study for their fourth year dissertation project and the supervisors (Dr Rowe, Dr Kirk, Dr McGarry) will have access to your information. Students will have access to your information only until the end of their dissertation project, whereas the supervisors will retain your information for publication and will securely store your information (as described above) for up to five years following the project end. After this time your information will be destroyed. Your identity will remain confidential in any presentations, publications or reports arising from this study.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?

If you are happy to be involved in the study, please sign a consent form to confirm this. If you do not want to be involved in the study, thank you for your attention and for reading this information sheet.

Researcher contact details:
If you have any questions about this study please contact

Chief Investigator Dr David Rowe Reader in Exercise Science School of Psychological Sciences and Health GH533 Graham Hill Building 50 George Street Glasgow, UK E: david.rowe@strath.ac.uk T: 0141 548 4069	Lead Researcher Mrs Sarah Deans Teaching Fellow National Centre for Prosthetics and Orthotics Department of Biomedical Engineering Curran Building 131 St James Road Glasgow, G4 0LS, UK E: sarah.deans@strath.ac.uk T: 0141 548 3929

This study was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee.

If you have any questions/concerns, during or after the study, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Dr Jim Baxter

(Convener of the Ethics Committee)
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow
G1 1QE

Telephone: 0141 548 2242 Email: j.baxter@strath.ac.uk

Consent

You are required to give your consent if you wish to participate in this investigation.

Name of School: School of Psychological Sciences and Health, Physical Activity for Health

Title of the study: Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction if I have required them to do so.

- I understand that my participation is voluntary and that I am free choose not to participate, without having to give a reason and without any consequences.
- I understand that any information recorded in the investigation will remain confidential and no information provided can be identifiable with me
- I understand that the study data is pseudo-anonymous and therefore data cannot be identifiable with me.
- I understand that I can withdraw my activity monitor data from the study
- I consent to being a participant in the project
- I consent to one of the researchers assisting me to attach the monitors to my thighs (or prosthetic socket)
- I consent to being video recorded as part of the project (please circle)
  Yes/ No

(PRINT NAME)	I hereby agree to take part in the above project
Signature of Participant:	Date:

Chapter 6 Study 4: Objectively measured free-living physical behaviour in adults with lower limb absence

Chapter overview

This cross-sectional study investigates objectively measured free-living physical behaviour in a sample of adults with lower limb absence using 8 days of continuous accelerometer data. The daily activity is expressed in time spent in physical behaviour, the average daily step count, and step count in pre-determined cadence bands. In addition, the data is compared with those from matched control data of people who do not have limb absence.

Introduction

Participating in physical activity is important to maintaining health (Haskell et al., 2007). Several methods have been employed to monitor the physical behaviour of people with limb absence, including direct observation, self-report questionnaires, physiological testing using the doubly labelled water technique, and monitoring using activity monitors (Kaufman et al., 2008). Direct observation is impractical over long periods, and self-report questionnaires often yield inaccurate physical activity assessments in older populations and people with limb absence (Schrack et al., 2016; Stepien, Cavenett, Taylor, & Crotty, 2007). In addition, the doubly labelled water technique can be costly to administer (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005).

Redfield et al. (2013) examined physical activity in people with transtibial limb absence and classified prosthetic use and body posture using accelerometry and visual observation known as the criterion reference (Redfield, Cagle, Hafner, & Sanders, 2013). In this study, six male and two female participants wore a triaxial accelerometer (ActiLife ActiGraph GT3X+, Florida, www.actigraphcorp.com). All subjects had a unilateral transtibial amputation. Subjects' mean age was 53.0 years (*SD* = 11.6 years), mean weight was 90.4 kg (*SD* = 11.6 kg), mean height was 178.0 cm (*SD* = 7.2 cm). The data from the accelerometers was analysed using a Binary Decision Tree to identify when the prosthesis was being worn and to classify periods of use as movement such as walking, standing or sitting. Results showed that a mean accuracy of 96.6% could be achieved (*SD* = 3.0%) based on sensitivity of classifications compared to visual observation by study researchers. Classification accuracy reached a maximum when the lower threshold was 0.01g and the upper threshold was 0.1g. Accuracy decreases significantly if lower thresholds are chosen, but higher thresholds result in smaller losses in accuracy. However, the actual variables of time that participants spent in daily physical behaviours such as sitting/lying, standing or stepping, and daily step count were not reported.

Research has also been conducted to present empirical data on the daily and weekly physical behaviour of people with limb absence. Buis et al. (2014) used the activPAL™ accelerometer to measure physical activity of people with limb absence and establish if prosthetic socket design influenced daily step count in people with transtibial limb absence (Buis et al., 2014). A sample of $N = 48$ participants recruited from an out-patient rehabilitation centre was split into two experimental subject groups, each group wearing a different design of prosthetic socket (a pressure cast design and a conventional total surface bearing design). Each subject wore the activPAL monitor continuously for 6 days and the number of steps taken per day and time spent walking (stepping) was determined for each group. Cadence of daily activity and time of daily activity over a 24-hour period was also reported. The interdevice reliability of the activPAL monitors was assessed using Intraclass Correlation (2,1) analysis and it was found to exhibit a high level of consistency between devices ($ICC = .997$). The findings indicated that both subject groups were active throughout the day, with a mean number of 8000 steps taken daily (9130 steps/days for those wearing the pressure cast design, and 7383 steps/day for those wearing the conventional total surface bearing design). The researchers did acknowledge that a high proportion of participants who had sustained amputation due to traumatic cause were recruited to the study. This may have positively influenced upwards the values recorded for daily step count and time spent walking. Time spent in different physical behaviours such as sitting/lying and standing and variables of daily expenditure and daily sit-to-stand transitions, was not examined in the Buis et al. (2014) study.

Cadence is an important activity variable and allows researchers to determine intensity of physical behaviour. Cadence was examined during music-prompted and self-regulated walking in adults with lower limb absence (Rowe et al., 2014). In this study of people with unilateral transtibial amputation, n = 15 men and n = 2 women walked at self-selected brisk walking intensity on a treadmill and over ground in two trials each lasting 5 minutes. Results showed that walking cadence significantly and accurately predicted energy expenditure ($p < .001$, $R^2 = .55$, $SEE = 0.50$ METs), and a cadence of 86 steps/minute was equivalent to a 3-MET intensity. Although most participants were able to match cadence to prescribed music tempo, gait symmetry was not improved during the music-guided condition, compared with the self-regulated condition.

In summary, only a small number of studies have explored objective measurement of physical behaviour in people with lower limb absence. Most studies have focused on exploring the validity or reliability of activity monitors for use in this clinical group and have been conducted within a laboratory setting. There has been little research exploring patterns of physical behaviour (including sedentary behaviour and intensity of physical activity) within a free-living context. In addition, there are no known studies which have explored the free-living physical behaviour of people with limb absence and compared the findings with the same data derived from a healthy, matched control sample. Therefore, the primary aim of the current study was to determine the free-living physical behaviours of adults with lower limb absence. The second aim was to compare the free-living physical behaviour of people with limb absence with that of healthy people using gender, age and employment status as the matching variables.

Methodology

Participants

Participants were adults with unilateral lower limb absence with either transtibial or transfemoral level of absence. Participants had to be routinely wearing and using a prosthesis for free-living activities and be able to understand the requirements of the study. People who used a wheelchair for periods of the day were not excluded from the study but were asked to describe their daily/weekly wheelchair use in a self-report diary.

Equipment

The activPAL3™ is a small, triaxial device (53 x 35 x 7mm) weighing approximately 15 grams and is normally attached to the wearer's thigh. The default sampling frequency in the software is 20 Hz for the activPAL3. A memory capacity of 32MB and a sampling frequency of 20 Hz allows up to 14 day of recording. In this study, 14 days of recording were necessary in order to allow for postal distribution, monitor wear time of a minimum of 7 days, and return posting of the monitor. The activPAL provides three types of information; information on stepping and time which can be used to quantify physical behaviour; and inclinometer information which can be used to determine posture and postural changes (standing is when the thigh is vertical, and sitting/lying when the thigh is horizontal). The minimum valid bout length to define a new posture was set at 10 seconds. This time period was deemed appropriate for the sample population of people with limb absence where it was anticipated that transitioning between postures may take longer than in a non-clinical population.

Pre-data collection considerations

Number of days of monitoring

It has been shown that in order to achieve intra-class correlations (*ICC*) of 0.8 and 0.9 respectively, 5 days and 11 days of monitoring are needed for sitting, 5 days and 10 days of monitoring for standing, and 7 days and 15 days of monitoring for stepping in a population of older adults (Reid et al., 2013). Further, most previous studies have used a monitoring period of around 7 days (Edwardson et al., 2016). Therefore, in this study participants were asked to wear their activPAL monitor for 8 consecutive days over a continuous 24-hour period to secure at least 7 days of data and allow comparison with other published work. Participants were also asked to note the start day of recording to aid in the identification of the start day in the activPAL output.

Recruitment

Ethical approval was granted for the study by the University of Strathclyde's Ethics Committee (first approved November 16, 2014, amendment approved September 07, 2015). All participants gave written informed consent prior to participation (please refer to Appendix H). Recruitment for this study was carried out as follows. Email contact was made with 14 UK amputee support groups, and more than 40 individuals with whom the researcher has professional connections. UK private prosthetic practices were also contacted. A recruitment poster, a covering letter; a participant information sheet and a consent form were included in the communication (please refer to Appendix I). It should be noted that n = 15 participants of the overall study sample N = 57 were previously recruited for and participated in the earlier accelerometer validation and reliability study. These participants also received the same documentation as detailed in Appendix I. The contacted support group representative/s circulated these documents to potential participants known to have lower limb absence. In addition, the support group used social media or web dissemination of the recruitment poster if this was available to the organisation. Potential recruits made contact with the researcher by email or telephone. If the interested party had not yet received a Participant Information Sheet and Consent Form, this was mailed to them electronically or by post for review and completion.

Incentives were not offered, but all participants were given the option of receiving feedback on their activity patterns and sedentary behaviour via a summary sheet with a brief description of how to interpret the information after the monitoring period had been completed.

Data were handled only by the principal investigator and one member of the research team, and the data were coded. Neither the raw nor cleaned data contained identifying information. The data were stored on an encrypted and password protected University server.

Procedures

A number of tasks in relation to the postal distribution around the United Kingdom of the activity monitors were completed chronologically and repeated. Please refer to

Appendix J for a detailed description of these tasks. Appendix K shows the information that was contained within the activity monitor information sheet, personal recording diary, and demographic questionnaire.

Data collection and downloading, data analysis rationale, data processing and data screening and cleaning

Data were collected between December 2015 and June 2016. Data collected and stored on the activPAL monitors were accessed via a USB interface through the activPAL proprietary software (activPAL3™ Version 7.2.32). The data for the entire duration of recording was exported to a Microsoft Excel comma separated values file format (Microsoft Corporation, Redmond, WA, USA). Activity summaries from the activPAL accelerometer were presented by week, by day and by hour. The following variables were produced:

- start time and stop time (date and hours and minutes)
- total number of steps
- duration of time spent sitting/lying (decimal proportion of one hour increments)
- time standing (decimal proportion of one hour increments)
- time stepping (decimal proportion of one hour increments)
- sit-to-stand transitions
- energy expenditure (METs/hour)
- step number within 24 cadence bands in increments of 10 (e.g. 1-10, 10-20, 20-30, 30-40, and so on to > 240). Cadence is measured in steps/minute.

Following data download and upon examination of each participant's summary file, any lost, unusable, or non-compliant data were removed from the dataset. Of the eligible consenting recruits to the study (N = 62), the following participants were not included in the final analytic sample:

- *n* = 1 participant chose not to participate, monitor returned, no data.
- *n* = 1 participant was unable to follow research guidance, monitor returned, no data.
- *n* = 1 participant had issues with monitor attachment, monitor lost, no data.
- *n* = 2 participant non-compliance, monitor returned, insufficient number of monitored days.

The number of datasets with 7 or 8 days of useable data available for data reduction and analysis was *N* = 57.

From the PAL (*.pal) file downloaded for each participant, the summary results by week were saved to ascertain participants' daily and weekly physical behaviour. The Comma Separated Values (*.csv) file format for the weekly summary results was converted to a Macro-enabled Excel Workbook (*.xlsm) file format to allow for the identification and highlighting of key periods of interest. To determine waking time and going-to-bed time, self-report participant diary data was used to identify the timings in the Excel summary file. A fixed waking period of 16 hours of waking time from 07:00 until 23:00 was also applied to each day of data in order to allow for future comparisons to be made with matched participant data (more detail is provided later in the section). Figure 4 shows an extract from a participant's data file showing part of one day of a 14-day recording period. The figure provides two examples of the process of identification of sleep and waking time wear. One example is the individualised daily waking activity corroborated with the participant's self-report diary data; the other example is the fixed, 16-hour waking duration applied to the data.

Figure 4 Example of sleep and waking time identification: An individualised approach and a fixed waking period approach

The pink shading indicates the person was awake from sometime between 07:00 and 08:00 until sometime between 20:00 and 21:00 on 14-12-15.The waking time is between 07:00 and 08:00 on 14-12-15 (confirmed by diary data) since 0.69h of this hour has been spent sitting/lying, following sleep, and 0.87h is spent sitting/lying before going to bed.

The blue shading shows the values used for calculating precise waking standing time. Firstly the column is summed for the core hours identified in pink shading (in this case 08:00 until 20:00). Then, the part hour immediately before (0.27h) and immediately after (0.11h) are summed.

Activity summary for LS29-AP470772 12Dec15 12-00am for 14d 0m
Monitor serial number: aP430772 Stop Time: 12:00:07 AM 26-Dec-15
Start Time: 12:00:00 AM 12-Dec-15 Elapsed Time: 14day(s) 00h 00m 07s

Summary by week:

StartTime	StopTime	Time Sitting/lying (h)	Time Standing (h)
#2015-12-12#	#2015-12-19#	137.99	18.28
#2015-12-19#	#2015-12-26#	158.41	7.55
#2015-12-26#	#2015-12-26 00:00:07#	0	0

Summary by day:

StartTime	StopTime	Time Sitting/lying (h)	Time Standing (h)
#2015-12-12#	#2015-12-13#	22.83	1.14
#2015-12-13#	#2015-12-14#	21	2.1

Summary by hour:

StartTime	StopTime	Time Sitting/lying (h)	Time Standing (h)
#2015-12-13 19:00:00#	#2015-12-13 20:00:00#	0.94	0.03
#2015-12-13 20:00:00#	#2015-12-13 21:00:00#	0.95	0.03
#2015-12-13 21:00:00#	#2015-12-13 22:00:00#	0.87	0.1
#2015-12-13 22:00:00#	#2015-12-13 23:00:00#	0.95	0.05
#2015-12-13 23:00:00#	#2015-12-14#	1	0
#2015-12-14#	#2015-12-14 01:00:00#	1	0
#2015-12-14 01:00:00#	#2015-12-14 02:00:00#	1	0
#2015-12-14 02:00:00#	#2015-12-14 03:00:00#	1	0
#2015-12-14 03:00:00#	#2015-12-14 04:00:00#	1	0
#2015-12-14 04:00:00#	#2015-12-14 05:00:00#	0.98	0.01
#2015-12-14 05:00:00#	#2015-12-14 06:00:00#	1	0
#2015-12-14 06:00:00#	#2015-12-14 07:00:00#	1	0
#2015-12-14 07:00:00#	#2015-12-14 08:00:00#	0.69	0.27
#2015-12-14 08:00:00#	#2015-12-14 09:00:00#	0.77	0.14
#2015-12-14 09:00:00#	#2015-12-14 10:00:00#	0.3	0.18
#2015-12-14 10:00:00#	#2015-12-14 11:00:00#	0.24	0.12
#2015-12-14 11:00:00#	#2015-12-14 12:00:00#	0.21	0.2
#2015-12-14 12:00:00#	#2015-12-14 13:00:00#	0.76	0.15
#2015-12-14 13:00:00#	#2015-12-14 14:00:00#	0.91	0.05
#2015-12-14 14:00:00#	#2015-12-14 15:00:00#	0.98	0.01
#2015-12-14 15:00:00#	#2015-12-14 16:00:00#	1	0
#2015-12-14 16:00:00#	#2015-12-14 17:00:00#	0.74	0.18
#2015-12-14 17:00:00#	#2015-12-14 18:00:00#	1	0
#2015-12-14 18:00:00#	#2015-12-14 19:00:00#	1	0
#2015-12-14 19:00:00#	#2015-12-14 20:00:00#	0.93	0.04
#2015-12-14 20:00:00#	#2015-12-14 21:00:00#	0.87	0.11
#2015-12-14 21:00:00#	#2015-12-14 22:00:00#	1	0
#2015-12-14 22:00:00#	#2015-12-14 23:00:00#	0.98	0.02
#2015-12-14 23:00:00#	#2015-12-15#	1	0
#2015-12-15#	#2015-12-15 01:00:00#	1	0
#2015-12-15 01:00:00#	#2015-12-15 02:00:00#	0.94	0.05
#2015-12-15 02:00:00#	#2015-12-15 03:00:00#	1	0

The olive shading shows a fixed period of 16 hours of waking time applied from 07:00 until 23:00 on 14-12-15. All shading would be applied across all rows in the spreadsheet to encompass all variables in the timeframe.

The yellow shading indicates the person went to sleep between 21:00 and 22:00 on 13-12-15, and between 20:00 and 21:00 on 14-12-15. The sleep time is between 20:00 and 21:00 on 14-12-15 (confirmed by diary data). The data tell us that 0.87 of this hour has been spent sitting/lying. To precisely calculate the point the person went to bed is 0.87 x 60 minutes = 52. This means for 52 minutes of this hour the person was sitting/lying and so they went to bed at 20:08 (since the remaining 8 minutes (60-52) of the hour they were standing or stepping).

Matched participants

To compare the physical behaviour of people with limb absence to that of people without limb absence, it was necessary to secure data from people who had participated in similar free-living physical behaviour research. Researchers from Glasgow Caledonian University (GCU), Glasgow, Scotland, UK are experienced in performing large population studies in physical behaviour. Their research has resulted in the compilation of numerous datasets of activPAL data recorded from clinical and non-clinical populations. An agreement of terms of access to data from the GCU physical activity database was negotiated. Age, gender and employment were the variables utilised in the matching process. Matching tolerance on the variable of age was set at +/- 5 years. Matched participant data were selected from three GCU databases provided by the custodian. Only activPAL data and demographic data were supplied; self-report diary was not available for control group participants. Appendix L shows the matching achieved between study participants with lower limb absence (who will be referred to as PLLA) and GCU database participants who formed the control group (who will be referred to as CG).

For consistency, matched participant data were handled in the same way as for participants with lower limb absence. The duration of the waking period applied to the control group datasets had to match that of the PLLA datasets, but the actual waking and sleeping hours necessarily did not. A fixed 16-hour waking time period was derived from all PLLA datasets (N = 57) and from a random sample of control group datasets (n = 10). This fixed waking time was calculated by taking the mean waking time in the CG randomly sampled summary files from the controls, all summary files of the PLLA, and through inspection of the PLLA diary data. The olive-coloured block in Figure 3 also shows periods of sitting/lying (consecutive '1' values) interceded by standing and/or stepping activity (decimal time points). Identical fixed hours from 07:00 until 23:00 were applied for both the PLLA and CG datasets.

Following the identification of individualised and fixed period wake and sleep time, daily totals for all variables were calculated within the Macro-enabled Workbook (*.xlsm) file. Further, an average daily total was calculated for all variables by dividing the weekly totals by the number of valid full days of activity identified. Appendix M contains the PLLA individualised datasets, and the PLLA and CG fixed waking time period datasets. These datasets were used in the final data analysis.

Data analysis

Reduced and cleaned Excel file data were imported for analysis to IBM SPSS Version 24 (IBM Corp., Armonk, NY).

Descriptive statistical analysis was performed on PLLA demographic data: age at testing; gender; employment status; height and weight (from which body mass index was calculated); level, side and cause of limb absence; wheelchair use per week; and home country of residence. Descriptive statistical analysis was performed on the supplied demographic data for the CG sample (gender, age at testing, and employment status). Physical behaviour outcomes were also derived in the analysis. These were: time spent awake and sleeping; time spent sitting/lying; time spent standing and stepping; daily step count; sit-to-stand transitions; and energy expenditure. Comparisons were also made between gender, level of limb absence, and cause of limb absence.

Normal distribution was checked with the Kolmogorov-Smirnov test using a significance level $p > .05$. All variables were distributed normally. A comparison of time spent in different activities between the PLLA and the CG participants was performed with paired samples t-tests.

Results

The number of PLLA included in the final analytic sample was *N* = 57. Scotland (*n* = 32), England (*n* = 23) and Wales (*n* = 2) were the home countries of residence of the participants with lower limb absence (please see Table 24).

Table 24 Characteristics of participants with lower limb absence

Measurement		All (*N* = 57)	Male (*n* = 40)	Female (*n* = 17)
Age (years)*		57.39 ± 12.09	59.40 ± 10.85	52.65 ± 13.82
Height (m)*		1.73 ± 0.10	1.77 ± 0.07	1.63 ± 0.07
Weight (kg)*		81.48 ± 16.99	87.58 ± 14.67	67.14 ± 13.17
Body mass index (kg/m^2)*		27.14 ± 4.54	27.94 ± 4.26	25.27 ± 4.76
Level	Transtibial	40	27	13
	Transfemoral	17	13	4
Side	Right	29	22	7
	Left	28	18	10
Cause of limb absence	Trauma	28	22	6
	Cancer	8	3	5
	Infection	8	6	2
	Congenital	5	3	2
	Peripheral arterial disease	7	5	2
	Thrombosis	1	1	0
Employment status	Retired	28	22	6
	Full-time	18	13	5
	Part-time	9	4	5
	Unemployed	2	1	1
Wheelchair user	No	40	31	9
	Yes	17	9	8

*Note.** values are means ± 1 standard deviation

Matching tolerance

All PLLA were matched to CG participants on gender (*N* = 57). The mean age matching tolerance was 0.58 years which was calculated by taking the mean of the differences between the ages of the PLLA and CG participants. The number of participants matched on employment was *n* = 44 (77%). Those not matched on employment were as follows: Full-time-Retired, *n* = 7; Part-time-Retired, *n* = 3; Full-time-Part-time, *n* = 2; Full-time-Unemployed, *n* = 1. Exact matching on all variables could not be achieved due to the priority being given to matching on gender, then on age, then employment status. It was therefore improbable that matching would occur exactly on all three variables. Height, weight and body mass index values were supplied with the control group participants' data (please refer to Table 25). All CG participants were resident in Scotland at the time of testing. With the exception of weight ($t_{(56)} = -2.05$, $p = 0.045$, $d = 0.4$), there were no significant differences in the other sample characteristics of age, height, and body mass index.

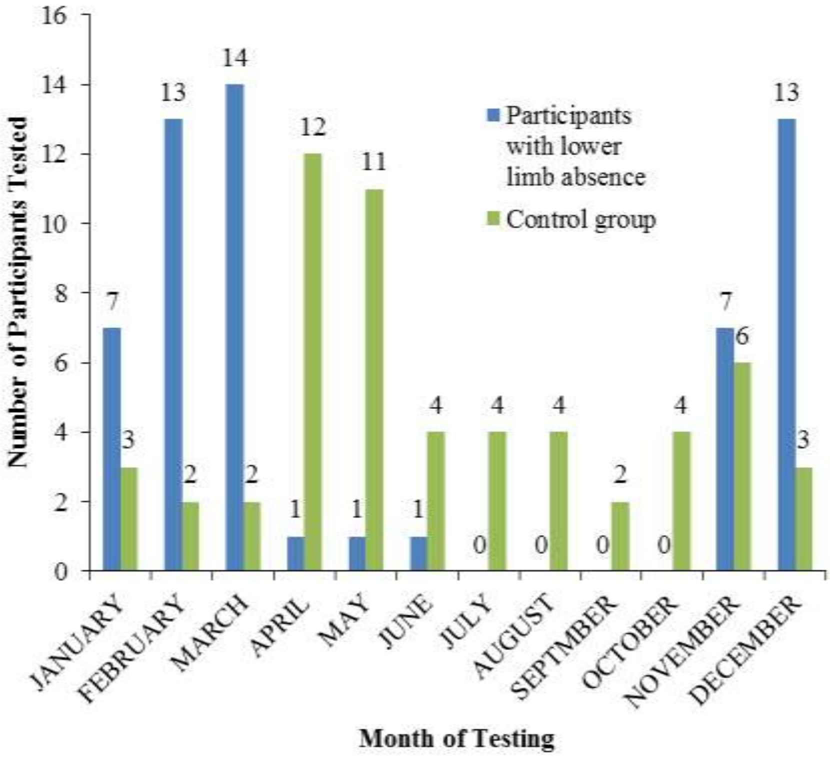
Table 25 Characteristics of control group participants

Measurement	All (*N* = 57)	Male (*n* = 40)	Female (*n* = 17)
Age (years)*	57.86 ± 14.10	59.92 ± 13.48	53.00 ± 14.73
Height (metres)*	1.72 ± 0.10	1.77 ± 0.07	1.61 ± 0.06
Weight (kilograms)*	75.94 ± 10.99	79.61 ± 10.14	67.30 ± 7.69
Body mass index (kg/m^2)*	25.74 ± 3.22	25.80 ± 3.42	25.58 ± 2.79

*Note.** values are means ± 1 standard deviation

Testing with PLLA took place mostly during winter and spring months, whereas testing of the CG participants took place over every month of the calendar year. The timing of the testing is illustrated in Figure 5.

Figure 5 Testing schedule by month for PLLA and CG participants



Physical behaviour of participants with lower limb absence

Table 26 presents the average daily physical behaviour for participants with limb absence (N = 57) by gender during waking time including: time spent awake, asleep, sitting/lying, standing and stepping; average daily step count; sit-to-stand transitions; and energy expenditure. Actual values expressed in terms of the percentage of the waking day are also presented. Independent t-tests identified no significant differences in physical behaviour across gender. Table 27 presents the average daily values by level for all physical behaviour variables. Independent t-tests identified no significant differences in physical behaviour by level of limb absence.

In considering cause of limb absence, only one participant had limb absence due to thrombosis. Therefore, causes peripheral arterial disease and thrombosis were combined to create the group known as Circulatory for meaningful differences to be tested using an independent t-test analysis.

Table 26 Average individualised daily physical behaviour of PLLA by gender

Activity variable	All (N = 57)	Male (n = 40)	Female (n = 17)
Time awake (h)	14.88 ± 0.98	14.98 ± 0.98	14.66 ± 0.95
Time awake (%)	62.02 ± 4.07	62.42 ± 4.08	61.07 ± 3.98
Time asleep (h)	9.12 ± 0.98	9.02 ± 0.98	9.34 ± 0.95
Time asleep (%)	37.98 ± 4.07	37.57 ± 4.09	38.93 ± 3.98
Time sitting/lying (h)	10.44 ± 10.99	10.61 ± 1.91	10.03 ± 1.58
Time sitting/lying (%)	70.45 ± 12.92	71.35 ± 14.28	68.35 ± 8.98
Time standing (h)	3.19 ± 1.43	3.10 ± 1.58	3.42 ± 1.01
Time standing (%)	21.24 ± 8.91	20.37 ± 9.66	23.30 ± 6.65
Time stepping (h)	1.25 ± 0.82	1.27 ± 0.91	1.21 ± 0.59
Time stepping (%)	8.31 ± 5.13	8.29 ± 5.56	8.35 ± 4.11
Daily step count	5569 ± 4083	5677 ± 4535	5316 ± 2852
Number of daily sit-to-stand transitions	57 ± 20.00	54 ± 20.00	65 ± 20.00
Daily energy expenditure (METs/h)*	7.32 ± 2.39	7.46 ± 2.70	6.97 ± 1.45

Note. *Adjusted to remove base waking hours energy expenditure. Values are means ± 1 standard deviation

Table 27 Average individualised daily physical behaviour of PLLA by level of limb absence

Activity variable	Transtibial (*n* = 40)	Transfemoral (*n* = 17)
Time awake (h)	14.91 ± 0.98	14.82 ± 0.99
Time awake (%)	62.12 ± 4.10	61.77 ± 4.12
Time asleep (h)	9.09 ± 0.98	9.17 ± 0.99
Time asleep (%)	37.87 ± 4.09	38.23 ± 4.12
Time sitting/lying (h)	10.25 ± 1.92	10.90 ± 1.55
Time sitting/lying (%)	69.06 ± 13.60	73.72 ± 10.83
Time standing (h)	3.32 ± 1.49	2.89 ± 1.29
Time standing (%)	22.06 ± 9.21	19.32 ± 8.11
Time stepping (h)	1.34 ± 0.90	1.04 ± 0.58
Time stepping (%)	8.88 ± 5.56	6.95 ± 3.74
Daily step count	6085 ± 4449	4356 ± 2809
Number of daily sit-to-stand transitions	60 ± 21	50 ± 15
Daily energy expenditure (METs/h)*	7.56 ± 2.56	6.75 ± 1.89

Note. *Adjusted to remove base waking hours energy expenditure. Values are means ± 1 standard deviation

Table 28 shows there were no statistical differences detected in any of the physical behaviour variables for cause being trauma and the groupings of cancer, infection and congenital absence. However, in comparing trauma and circulatory groupings there were statistically significant differences in all physical behaviours except for sit-to-stand transitions (please see Table 29). People who had sustained amputation due to circulatory causes spent more time sitting/lying throughout the day, and less time standing and stepping than those people who had amputation due to trauma. In addition, those in the trauma grouping took more daily steps, and performed more sit-to-stand transitions than those in the circulatory grouping. Finally, those with circulatory issues had lower daily energy expenditure than those who had experienced traumatic amputation.

The individualised average daily number of steps achieved by PLLA within 25 cadence bands is shown in Figure 6. The activPal software exports cadence in hourly time bands, and is classified as steps taken in certain cadence bands within each one hour time period. The lowest cadence band in which steps were recorded was 20-30 steps/minute (128 steps). The greatest number of steps recorded was within the three cadence bands of 80-90, 90-100, and 100-110 steps/minute (798, 845 and 797 steps respectively). The lowest daily average of 6 steps/minute was recorded within the cadence band of 170-180 steps/minute. In all cadence bands of 100 steps/minute and above, a daily average of 1891 steps were recorded. No steps were recorded in any of the cadence bands 1-10 and 10-20 steps/minute, or 180 steps/minute and above.

Physical behaviour of PLLA vs. CG participants

Data analysis was also performed on PLLA data and compared with data from CG participants. This was performed using a fixed waking period protocol of 16 hours (as previously shown in Figure 4). Table 30 shows the comparison of average daily values for time spent sitting/lying, time spent standing, time spent stepping, the average number of sit-to-stand transitions performed, and the average daily energy expenditure for PLLA (N = 57) and CG participants (N = 57). Paired t-tests were performed to ascertain statistical differences in the physical behaviour of each group of participants. Again these are presented in Table 30. It was hypothesised that the sample of people with limb absence would have lower activity levels and display more sedentary behaviour. It was shown that all physical behaviour variables displayed differences between the groups again with the exception of the number of daily sit-to-stand transitions ($t_{(56)} = 1.80$, $p = 0.107$, $d = 0.39$). It is interesting to note that the number of sit-to-stand transitions were 12% more for PLLA despite the daily activity in terms of standing and stepping being lower. With the exception of the sit-to-stand variable, physical behaviour outcomes are more favourable for CG participants than PLLA. As an example, CG participants took 39% more daily steps than PLLA.

Table 28 Average individualised daily physical behaviour of PLLA by cause of limb absence

Activity variable	Trauma (*n* = 28)	Cancer (*n* = 8)	Infection (*n* = 8)	Congenital (*n* = 5)	Circulatory (*n* = 8)*
Time awake (h)	14.84 ± 0.97	15.47 ± 0.76	14.70 ± 0.84	14.65 ± 1.54	14.78 ± 0.96
Time awake (%)	61.84 ± 4.03	64.47 ± 3.15	61.25 ± 3.48	61.05 ± 6.41	61.57 ± 3.98
Time asleep (h)	9.16 ± 0.97	8.53 ± 0.76	9.30 ± 0.84	9.35 ± 1.54	9.22 ± 0.96
Time asleep (%)	38.16 ± 4.06	35.53 ± 3.15	38.75 ± 3.48	38.95 ± 6.41	38.43 ± 3.98
Time sitting/lying (h)	9.75 ± 1.74	10.59 ± 1.95	10.99 ± 1.46	10.59 ± 1.61	12.07 ± 1.48
Time sitting/lying (%)	66.07 ± 12.87	68.63 ± 13.15	74.64 ± 7.53	72.87 ± 13.13	81.89 ± 10.71
Time standing (h)	3.57 ± 1.37	3.47 ± 1.47	2.65 ± 0.74	2.94 ± 1.96	2.28 ± 1.52
Time standing (%)	23.88 ± 8.39	22.28 ± 9.01	18.17 ± 5.51	19.35 ± 11.32	15.24 ± 9.79
Time stepping (h)	1.52 ± 0.92	1.41 ± 0.73	1.05 ± 0.50	1.12 ± 0.50	0.42 ± 0.21
Time stepping (%)	10.05 ± 5.56	9.09 ± 4.60	7.19 ± 3.44	7.78 ± 3.84	2.87 ± 1.45
Daily step count	6817 ± 4607	6376 ± 3583	4536 ± 2552	5449 ± 2790	1502 ± 778
Number of daily sit-to-stand transitions	61 ± 20	58 ± 20	54 ± 13	61 ± 26	46 ± 22
Daily energy expenditure (METs/h)**	7.72 ± 2.80	8.51 ± 1.87	6.64 ± 1.47	7.02 ± 1.89	5.59 ± 1.26

Note. * Circulatory group comprises conditions peripheral arterial disease and thrombosis combined
** Adjusted to remove base waking hours energy expenditure. Values are means ± 1 standard deviation

Table 29 Comparison of daily physical behaviour between limb absence cause

Activity variable	Statistic	Trauma *n* = 28	Circulatory* *n* = 8	*df*	*t*	*p*
Time sitting/lying (h)	*M*	9.75	12.07	34	-3.42	.002
	SD	1.74	1.48			
Time standing (h)	*M*	3.58	2.28	34	2.29	.028
	SD	1.37	1.52			
Time stepping (h)	*M*	1.52	.42	34	3.31	.002
	SD	.92	.21			
Step count	*M*	6817	1502	34	3.22	.003
	SD	4607	777			
Sit-to-stand transitions	*M*	60	46	34	1.80	.082ǂ
	SD	20	22			
Energy expenditure (MET/h)**	*M*	7.71	5.59	34	2.08	.046
	SD	2.80	1.26			

Note. All variances were tested with Levene tests and found to be equal
* Circulatory group comprises conditions peripheral arterial disease and thrombosis combined
**Adjusted to remove base waking hours energy expenditure. Values are means ±1 standard deviation
ǂ Result not statistically significant

Figure 6 Individualised daily cadence for participants with lower limb absence

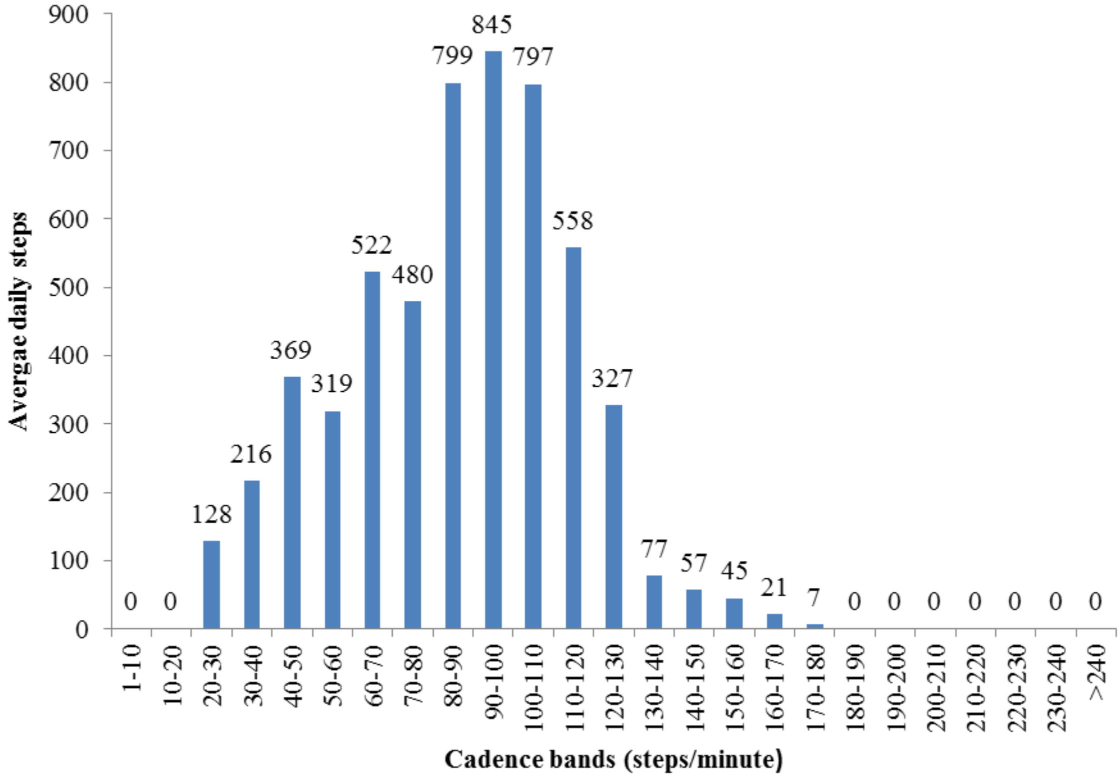


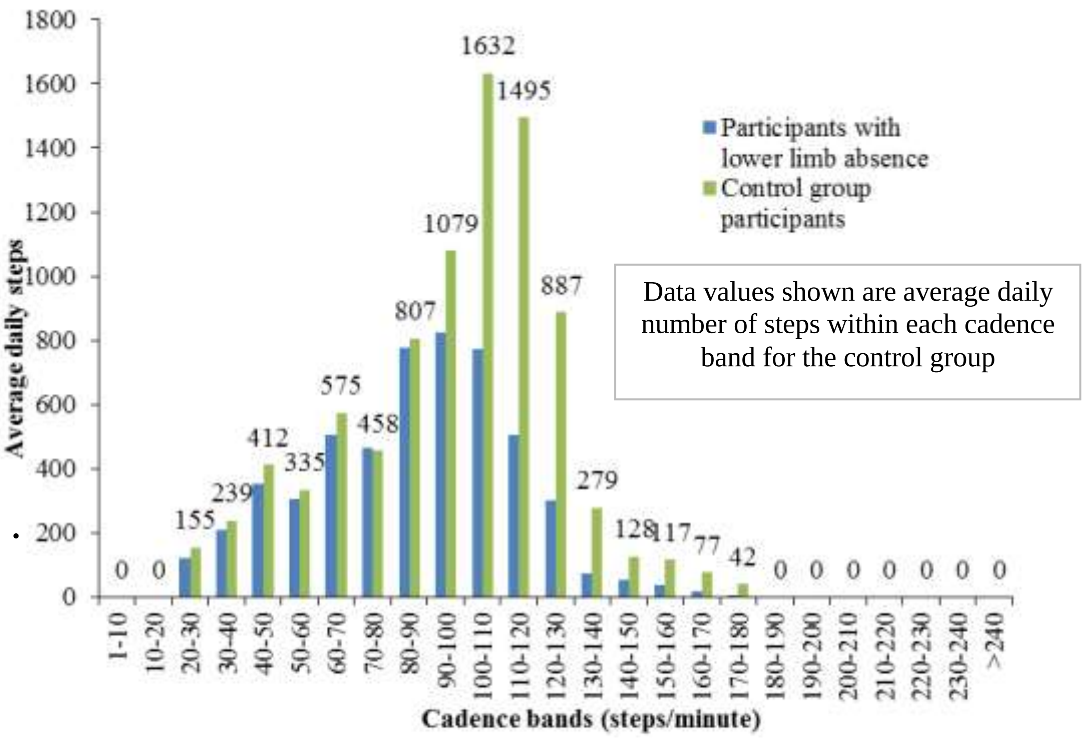
Table 30 Average daily physical behaviour of PLLA vs. CG participants

Activity variable	Statistic	PLLA *N* = 57	CG *N* = 57	Percentage difference % PLLA vs. CG	*df*	*t*	*p*
Time sitting/lying (h)	*M*	11.73	10.41	13	56	-3.42	< .001
	SD	1.99	1.38				
Time standing (h)	*M*	3.07	3.98	23	56	2.29	< .001
	SD	1.38	1.11				
Time stepping (h)	*M*	1.20	1.75	31	56	3.31	< .001
	SD	0.75	0.49				
Step count	*M*	5340	8715	39	56	3.22	< .001
	SD	3613	2639				
Sit-to-stand transitions	*M*	54	48	12	56	1.80	0.107ǂ
	SD	20	11				
Energy expenditure (MET/h)*	*M*	22.53	24.13	20	56	2.08	<.001
	SD	1.66	1.21				

Note. All variances were tested with Levene tests and found to be equal
* Adjusted to remove base waking hours energy expenditure.
ǂ Result not statistically significant

Finally, cadence was compared between the two participant groups. CG participants took more steps across all cadence bands except for the 70-80 steps/minute cadence band where PLLA took 6 more steps (463 vs. 457 steps). None of the participants recorded steps in the lowest two bands of 1-10 and 10-20 steps/minute. Of particular note is the comparison in average daily cadence band values in the three cadence band ranges spanning 100-130 steps/minute where CG participants achieved more daily steps (p = 0.00 for all three cadence bands). For all the cadence bands of 100 steps/minute and above, CG participants took 4656 average daily steps compared to PLLA who took an average of 1775 steps/minute ($t_{(56)} = -7.73$, $p = 0.00$, $d = 1.76$). Figure 7 shows the greatest difference was in the 100-110 steps/minute band where PLLA took 774 steps compared to 1632 steps for CG participants. Paired samples t-tests showed that there were significant differences in all cadence bands 100 steps/minute and above with the exception of two cadence bands of 140-150 steps/minute ($t_{(56)} = -1.94$, $p = 0.058$, $d = 0.76$), and 170-180 steps/minute ($t_{(56)} = -1.84$, $p = 0.071$, $d = 0.92$)

Figure 7 Average daily cadence of PLLA and CG participants



Discussion

This study examined the free-living physical behaviour of adults with lower limb absence. The clinical sample was also compared with a healthy sample of adults who did not have lower limb absence. No adverse effects of activity monitoring were reported by the participants. Indeed, the majority of study participants took the available opportunity to seek feedback on their daily activity behaviour which may have supported positive behaviour change in the short or long term.

The study participant sample with lower limb absence

The sample was representative of the national limb absent population in terms of gender, with the proportion of the total number of male and female recruits being 70.2% and 29.8% respectively. The gender split for the UK national limb absent population during 2011-2012 was 69.9% and 30.2% respectively (United National Institute for Prosthetics Orthotics Development, 2011-2012). The relative proportion of study participants with transtibial limb absence in this study was higher than the national average (69.9% versus 59.3%) and the relative proportion with transfemoral absence was lower than the national average (30.1% versus 40.7%). Almost half of the participants with limb absence (*n* = 28, 49.1%) sustained amputation due to trauma which may have led to recorded activity levels being unrepresentatively greater. To explain, those who had limb absence due to peripheral arterial disease took 1541.45 steps/day (*SD* = 831.23) versus those who had experienced trauma who took 6817.28 steps/day (*SD* = 4607.16). Based on 49.1% of the PLLA sample having experienced traumatic amputation, this could be regarded as being unrepresentative of the general UK amputee population where trauma accounts for only 18.5% of amputations (United National Institute for Prosthetics Orthotics Development, 2011-2012). Waters et al. conducted a relevant study in 1976 which observed men and women who had sustained transtibial or transfemoral amputation due to trauma and vascular compromise (*N* = 70). A group of control participants also allowed for the comparison of data and reporting of differences and similarities (Waters, Perry, Antonelli, & Hislop, 1976). The participants walked around a measured track for 5 minutes at self-selected speed, and then at their fastest possible speed. Data were collected in each test for 2 minutes. The researchers reported that those who sustained amputation due to vascular compromise tended to be less physically active than those who sustained amputation due to trauma. These findings were based on the measurement of velocity, cadence and stride length and not step count. It must be acknowledged that gait parameters were examined under controlled conditions rather than free-living or field conditions. Another study of 25 people with transtibial amputation also concluded that people who have had amputation due to trauma rather than vascular causes are more physically active ($p < .001$), younger in age, and have generally been using a prosthesis for a longer period of time (Mateus & Palmeira, 2013). However, when participant age, and function and duration of use of the prosthesis are considered, the differences became non-significant. Finally, a study examined the daily number of strides taken by 22 people with transtibial amputation due to diabetic neuropathy (Kanade, van Deursen, Harding, & Price, 2006). Participants wore step activity monitors continuously for 24 hours over 7 days. Participants took an average of 1894 strides per day, and as one stride can be defined as two steps taken by left and right, this would be the equivalent of 3788 steps/day. This value is higher than the Circulatory grouping in this study (transtibial and transfemoral levels) who achieved 1502 steps/day, yet considerably lower than the Transtibial grouping in this study (all causes) who achieved 6085 steps/day.

Physical behaviour of participants with lower limb absence

In the following section, physical behaviours of those with limb absence are described for an individualised waking period. Being able to accurately determine the waking hours and sleep time was possible due to the PLLA completing a self-report diary data.

The number of recorded average daily steps taken by the study participants was 5569 steps/day. It is known that healthy, older adults average 2000-9000 steps/day, and clinical populations average 1200-8800 steps/day (Tudor-Locke, Craig, et al., 2011). Based on these normative data, the study participants took more steps than 2500-4999 steps/day, a range of daily steps which represents limited activity for healthy adults (Tudor-Locke, Johnson, & Katzmarzyk, 2009).

The aim of another study of adults with lower limb absence (*N* = 48), was to determine how transtibial prosthetic socket design influenced the average number of daily steps taken by two independent groups of participants with limb absence (Buis et al., 2014). The participants in each group wore a different prosthetic socket design. The mean participant daily step count (*n* = 24 in each group) was 9130 and 7383 steps/day respectively. These reported values are greater than those in this study for the group with limb absence (PLLA individualised daily steps 5569, and PLLA fixed waking period steps 5340). Buis et al. also reported on stepping time of participants with lower limb absence who spent around 1.67 hours/day (6.67%) stepping (Buis et al., 2014). This compares to an average of 1.25 hours/day stepping (8.31%) by the participants in the current study. The number of total steps in the Buis study may have been calculated over a 24 hour period rather than being related to an individualised waking period or within a predetermined waking period of 16 hours as was the case in the current study. In addition, it is likely that analysis was conducted on a fewer number of days of recorded data than the current study (8 days) since it was reported that participants wore the monitor continuously for a maximum period of 6 days. Placement of the activity monitor on the anterior prosthesis at the ankle as opposed to the anterior sound side thigh as per manufacturer's recommendations could have been another possible reason for the differences in daily step counts. However, the monitor placement on the prosthesis rather than the sound side thigh does not account for the larger number of steps recorded. It was reported in Chapter 5 that generally across participants, the monitor placed on the prosthetic side underestimated measured stepping to a greater degree than the monitor placed on the sound side, especially in measuring incidental stepping.

Researchers conducted a study and examined activity levels using a StepWatch 3 Activity Monitor in 77 adults with lower limb amputation (Stepien, Cavenett, Taylor, & Crotty, 2007). Participants were instructed in the use of the activity diary, which consisted of a table for each day of the week, with rows corresponding to time in 15-minute increments and columns corresponding to four defined levels of activity. Those four predetermined levels were defined per leg as follows: resting (no steps taken), low (1–15 steps per minute), medium (16–40 steps per minute), and high (40 steps per minute). The StepWatch3 Activity Monitor, fitted to the participant's prosthesis, was programmed to record 8 days of activity to ensure that 6 days of complete data were collected for each participant. Daily data was used in the comparison with data recorded by the activity monitor. In order for the rate of agreement between self-report and recorded data to be as accurate as possible, only the period between 0900 and 2100 on each day of data collection was analysed when it was proposed that the majority of participants were likely to be active. Stepien et al. reported that participants averaged 6126 steps per day. The authors also reported that those with transtibial absence (n = 54) took on average 6790 steps/day, and those with transfemoral absence (n = 23) took on average 4568 steps per day. These values are not dissimilar from the values derived in this study for those with transtibial absence and transfemoral absence calculated as 6085 and 4356 steps respectively. The StepWatch2 Activity Monitor was utilised in another study (Klute, Berge, Orendurff, Williams, & Czerniecki, 2006). Findings showed those with transtibial absence are more active on weekdays than on weekend days (6158 steps/day versus 4772 steps/day). In the current study, the decision was taken not to analyse the study data when grouped by weekday versus weekend days. This was due to more than 68% of the study participants being retired, unemployed or in part-time employment and therefore it was felt that weekend versus weekday effects were unlikely to be factors in this case.

In considering sedentary behaviour, the average individualised daily waking sitting/lying time of the PLLA was 10.44 hours (70.45% of waking day). An evaluation of the sedentary behaviour of 6329 participants from the 2003–2004 National Health and Nutrition Examination Survey (NHANES) determined that healthy participants spent 7.7 hours/day (54.9% of waking day) of average monitored time being sedentary (Matthews et al., 2008). A more recent study used the activPAL monitor to measure sedentary behaviour calculated the total waking sedentary time as 9.63 hours/day (Dowd, Harrington, Bourke, Nelson, & Donnelly, 2012). The methodology featured a 24-hour wear protocol and only data sets that provided four full days of accelerometer recording including at least one weekend day were processed for the analysis. It is acknowledged the research was carried out with 44 healthy adolescent females who are demographically dissimilar to this study’s participants. However, it does show that the sedentary behaviour demonstrated by the participants with lower limb absence is more than that of an ostensibly younger and healthier sample.

Participants' cadence was also considered. Under laboratory testing conditions in two mixed-gender studies with healthy participants (*n* = 75 and *n* = 50 respectively), cadence at 3 Metabolic Equivalents (METs) has been valued at 103 steps/minute and 102 steps/minute respectively (Rowe et al., 2011; Tudor-Locke, Sisson, Collova, Lee, & Swan, 2005). Moderate-intensity physical activity is defined as 3-6 METs and a systematic review has shown that a proportion of steps taken at the rate of 100 steps/minute can be prescribed for adults in order for them to achieve this activity intensity (Slaght, Sénéchal, Hrubeniuk, Mayo, & Bouchard, 2017; Tudor-Locke & Rowe, 2012). In the current study, PLLA achieved the greatest number of steps (2378 steps in total) within cadence bands 80-90, 90-100, and 100-110 steps/minute, meaning 44.5% of the total number of daily steps were at cadences between 80 and 110 steps/minute. Another study which has been previously described, examined cadence during music-prompted and self-regulated walking in adults with lower limb absence (Rowe et al., 2014). In this study of people with unilateral transtibial amputation (*n* = 15 men, *n* = 2 women), it was reported that walking briskly at 86 steps/minute corresponded to an intensity of 3 METs. This suggests that PLLA are achieving moderate intensity levels of physical activity over the course of the day. The average cadence for the participants was not calculated in this study, although it has been reported previously that cadence differed significantly ($p < .05$) based on level and cause of amputation (Waters et al., 1976). The authors showed that in this historical study values for those with vascular compromise were 87 steps/minute transtibial level and 72 steps/minute transfemoral level; and for those with traumatic amputation 99 steps/minute transtibial level and 87 steps/minute transfemoral level. The greatest number of steps taken by PLLA and CG participants was in the cadence bands of 90-100 steps/minute and 100-110 steps/minute respectively (826 steps PLLA and 1632 steps CG participants).

Physical behaviour of participants with lower limb absence vs. control group participants

In the following section, physical behaviour is described for a fixed waking period of 16 hours to allow standardised comparison between the two population groups. This is due to self-report diary data not being available from the control group participants. The results show that people with limb absence are less active and more sedentary than healthy, age, gender and employment matched controls. The data in Table 30 shows that people with limb absence spend significantly more time sitting/lying during the waking day and less time standing and stepping when compared to healthy controls. The greatest difference was seen in the average daily number of steps taken by PLLA who took 39% fewer steps than CG participants (5340 compared to 8715 steps/day). Control group participants did achieve many more steps in the higher cadence bands, suggesting that people with limb absence do not reach higher intensities of daily physical activity. That said, it is encouraging that almost half the number of daily steps taken by the PLLA is at an intensity regarded as adequate for maintaining health. A historical recommendation proposed that achieving 10000 steps/day was a reasonable attainment goal for healthy adults. More recent evidence suggests that this value may not be achievable for older adults and those living with long-term conditions (Tudor-Locke & Bassett, 2004; Tudor-Locke, Myers, & Rodger, 2001). The original recommendation of 10000 steps was revised downwards to recommend the attainment of between 7000-8000 steps/day when data from more than 3500 individuals were examined (Tudor-Locke, Leonardi, Johnson, Katzmarzyk, & Church, 2011). The healthy adults in the control sample achieved 8715 steps/day which suggests that healthy adults can achieve more than the recommendations. However, those with transtibial and transfemoral limb absence, who take on average 5340 steps/day, are achieving more than 1500 steps less than the baseline recommendation of 7000 steps. Based on a method to determine physical activity in healthy adults, the values are reflected in an original classification index whereby: less than 5000 steps/day is considered a sedentary lifestyle; 5000-7499 steps/day is typical of daily activity excluding sports/exercise; and 7500-9999 steps/day could be considered somewhat active. People achieving more than 10000 steps/day and 12500 steps/day would be considered as active and highly active respectively (Tudor-Locke & Bassett, 2004). This step index was later revised as part of an updated review (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). The lowest index category was further split into basal activity (< 2500 steps/day) and limited activity (2500-4999 steps/day) groupings (Tudor-Locke et al., 2009). The number of daily steps taken by participants with limb absence whose data has been analysed using either individualised or standardised waking periods, suggests they are achieving a typically representative level of daily activity which excludes sport/exercise.

The graph in Figure 6 indicates that the groups differ in the number of steps attained within specific cadence bands. The most common cadence band for PLLA was 90-100 steps/minute in which an average of 825 steps were taken compared to an average of 1079 steps/minute for the control group participants (p = .009). Above the threshold of 100 steps/minute, the total number of steps taken by PLLA equalled 1775 steps which is considerably lower than the 4656 steps achieved by the control group. Again, this suggests that PLLA are accumulating most of their steps at lower stepping cadences and could be encouraged to be physically active at a higher stepping cadence in order to maintain or improve health.

This section has principally discussed daily time spent sitting/lying, standing and stepping as well as daily step counts. However, it is important to acknowledge the usefulness of sit-to-stand transitions data in understanding physical behaviour in general and clinical populations. The concept of interrupting sedentary behaviour with standing and stepping behaviours has emerged as a way of modifying the detrimental effects on health caused by sedentary behaviour (Chastin, Egerton, Leask, & Stamatakis, 2015; Owen, Healy, Matthews, & Dunstan, 2010). Chastin et al. 2015 conducted a meta-analysis by using the inverse variance method for experimental trials. For observational studies, a Bayesian posterior probability of existence of an association between breaks with adiposity and cardio metabolic markers was used. The results from nine experimental studies showed that breaks in sedentary periods of at least light intensity may have a positive effect on glycaemia but not on lipoedema for adults. It is unclear whether this effect is independent of total sitting time. However, the 10 identified observational studies showed an association with breaks, which was independent of total sedentary time, but only for obesity metrics. This experimental evidence suggests that interrupting sitting time may be associated with better health outcomes.

Another literature review summarised 10 articles on the topic of sit-to-stand manoeuvre as a component of everyday mobility in both healthy people and those with diagnosed conditions such as stroke, cancer and osteoarthritis (Bohannon, 2015). The mean number of daily transitions was at least 45 for all groups with the exception of a group of community-dwelling older adults where 39 transitions were recorded. In comparing the daily transitions recorded for the participants in this study with those of other clinical populations, the data compares favourably with participants with lower limb absence who achieved between 54 and 57 transitions daily (individualised and fixed waking period values respectively).

Strengths, limitations and future work

At the time of writing, there are no known studies which have explored the free-living physical behaviour of people with limb absence and compared the findings with the same data derived from a healthy, matched control sample. This work is therefore a new contribution to the field of physical behaviour. There were several strengths of the study which were underpinned by recruitment methodology and participation. Only five datasets were unsuitable for inclusion in the data analysis meaning PLLA compliance rate was high at 92%. Similar free-living physical behaviour studies in healthy populations have achieved comparable compliance of 86% (Dowd et al., 2012). The average number of full days of recorded data achieved was 7.7 days which is higher than the number of full days achieved in other comparable studies which have used the activPAL accelerometer (Buis et al., 2014). It is believed that these positive aspects were due to active study promotion utilising professionally produced marketing material which was distributed throughout the researcher’s own professional networks, through UK amputee support groups, and by the use of social media to recruit participants. It is also thought that personal contact made by the researcher at key stages of recruitment increased participation and retention numbers. Email or telephone support was offered to participants on receipt of their activity monitor pack, throughout the monitoring period and following return of the accelerometer to the researcher. This may have contributed to retention of participants until completion of the monitoring period. The use of a detailed information sheet containing verbal, visual and written guidance, and a link to an online demonstration video may also have enhanced compliance. Feedback by participants on these aspects was constructive with many reporting that they felt sufficiently well supported prior to, during and following the study. Many also welcomed research on what they regarded as an unexplored patient community and topic area. The implementation of a 24-hour, continuous-wear protocol was also important in that it allowed for the identification of the waking time and movements of each participant before retiring to bed. This enabled precise examination and calculation of waking time and sleep time as detailed in Figure 4. The continuous wear protocol also facilitated the presentation of results as an accurate percentage of total waking time. Finally, the possibility of behaviour modification simply as a result of the novelty of participating in a research study and being observed must be considered and taken into account in the interpretation of the results. Being recruited to participate in the study may have elicited subtle research participation effects such as increased awareness of unhealthy behaviour (MacNeill, Foley, Quirk, & McCambridge, 2016).

In future work, the generalisability of the study could be extended and replicated with larger sample sizes which could allow further comparison within the group. For instance, physical behaviour linked to levels of amputation and cause of amputation could be further explored. A more representative sample in terms of cause of amputation could be achieved by recruiting from and conducting the research in a healthcare setting, for example national disablement service centres. Concentrated study promotion and recruitment of participants from disablement service centres in Wales and Northern Ireland could yield a more representative UK geographical sample. Time spent in sedentary behaviour has emerged as a new public health risk, independent of the amount of daily time someone spends being active (Chastin, Mandrichenko, Helbostadt, & Skelton, 2014). Further examination of activity and sedentary bout durations is therefore recommended. Analysis of physical behaviour data when grouped by weekday versus weekend day could also answer the question of differences and similarities in daily physical behaviour in a younger population of people with limb absence where weekday and weekend effects and differences in behaviour may be more evident. These aspects could all be considered in future work.

Summary of Chapter 6

People with limb absence participate in less physical activity and display more sedentary behaviour than healthy people to whom they have been matched on age, gender and employment. Findings support the need for future research to explore further patterns of physical behaviour in addition to patient motivations and barriers towards leading an active lifestyle. Furthermore, future research should also explore the development and implementation of clinical and community based interventions to support an active lifestyle based on the Medical Research Council's evaluation framework for developing complex interventions.

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Appendix H Study 4: University ethics and sponsorship approval

Sarah Deans

From:	James Baxter
Sent:	01 September 2015 10:10
To:	Sarah Deans; David Rowe; HaSS Research and Knowledge Exchange
Cc:	Anthony McGarry; Alison Kirk
Subject:	FW: Type 1 Ethics Application -SEC Approval of Amendments
Attachments:	Ethics 280815 ROWE DEANS.zip

Dear Sarah,

I confirm that those amendments to a previously approved procedure raise no new ethical issues. I am copying this to RaKET for their records. Please wait confirmation from them that you may proceed before beginning the new work.

Best wishes

Jim Baxter

The University of Strathclyde is a charitable body, registered in Scotland, number SC015263

From: Sarah Deans
Sent: 28 August 2015 13:09
To: James Baxter
Cc: David Rowe; Alison Kirk; Anthony McGarry
Subject: FW: Type 1 Ethics Application - Approval

Dear Dr Baxter,

Study title: Objectively measured physical activity and sedentary habits in people with lower limb absence.

I provide attached amended documents and would be grateful if the Committee would consider these as a notice of an amendment to the previous study. I include the Type 1 Ethics Application approval communication for the original study below.

Amendments are highlighted in yellow in all documents, which we hope is convenient for you.

If there are any immediate issues, or you have any questions, please do contact me, and my thanks in advance to you and the Committee for your consideration.

I look forward to hearing from you. Thank-you.

Kind regards, Sarah

From: Laura Clark
Sent: 06 November 2014 16:25
To: David Rowe; Sarah Deans; Alison Kirk
Subject: Type 1 Ethics Application - Approval

1

Sarah Deans

From:	HaSS Research and Knowledge Exchange
Sent:	07 September 2015 10:20
To:	David Rowe; Sarah Deans
Cc:	Anthony McGarry; Alison Kirk
Subject:	FW: Type 1 Ethics Application -SEC Approval of Amendments
Attachments:	David Rowe Ethics Application form Type 1 04.09.15.docx

Type 1 Ethics Application - Approval

Our ref: 481 (1st approved 06-Nov-14 - Amendment approved 07-09-15)

Dear All

Objectively measured physical activity and sedentary habits in people with lower limb absence.

CI David Rowe Other Investigator Sarah Deans

I can now confirm full ethical and sponsorship approval for the above study.

Best wishes

Margaret

Margaret Keoghan
Assistant Manager
Research and Knowledge Exchange Team (RaKET) Level 3, Lord Hope Building Faculty of Humanities and Social Sciences University of Strathclyde
141 St James Road
Glasgow
G4 0LT

Tel: 0141 444 8416

-----Original Message-----
From: Rachel Bell
Sent: 04 September 2015 11:25
To: HaSS Research and Knowledge Exchange
Cc: Madeleine Grealy
Subject: RE: Type 1 Ethics Application -SEC Approval of Amendments

Appendix I Recruitment poster, covering letter, participant information sheet and consent

Covering letter

Dear…………………

Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

I am writing to you about a project which aims to find out about physical activity levels and sedentary behaviour in those who use prostheses (artificial limbs). The work is supported by the School of Psychological Sciences and Health, and Biomedical Engineering incorporating the National Centre for Prosthetics and Orthotics. These are both departments of the University of Strathclyde in Glasgow.

This project has been given full ethical approval by the School of Psychological Sciences and Health Ethics Committee at the University of Strathclyde. I do hope you will consider being involved.

About this project

We are keen to find out about physical activity levels and sedentary behaviour in those who use prostheses (artificial limbs). To do this, participants will be asked to wear an activity monitor which is worn on the thigh and records free-living posture and movement. The monitor will be attached using waterproof sticking tape which is non-allergenic. There will also be a short demographic questionnaire to complete which asks about your age, gender etc.

On completion of the study, the results will be disseminated at national and international prosthetic/orthotic conferences and in a relevant rehabilitation medicine journal.

Your involvement

If you are a person who has either unilateral (on one-side only), transtibial (below the knee) or transfemoral (above the knee) limb absence, routinely wear a prosthesis (artificial limb), and are over 18 years of age, you are warmly invited to read the detailed participant information sheet to find out more about the study. You will be sent a package containing a small activity monitor which you will wear on the thigh of your *non-amputated* side for eight days. Your usual weekly activities should not be curtailed or changed by wearing the monitor. At the end of the eight-day period, you will remove the monitor and return it by a secure post service in a pre-paid envelope.

It is your decision whether or not to take part in the investigation. You do not have to participate. Data downloaded from the activity monitor will be stored and analysed only after the monitor has been returned to the researcher by the participant.

Because the data will always be anonymous, your data cannot be used to identify you. If you wish to withdraw your information, you will be able to do this up to one month following completion of the eight-day activity monitoring.

Background and the issue

Regular physical activity is well established as an important part of maintaining good health and a good way to reduce the risk of many diseases. Yet low levels of physical activity are prevalent; only 40% of men and 28% of women in the UK meet the minimum recommended physical activity levels. We believe the limb absent population could also be more physically active than they currently are and hope this study is able to inform us about the ways in which this could be achieved.

I hope you will consider supporting this work and please contact me if you would like any further information. Thank-you.

With my kindest regards,

Sarah A. Deans

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T: 0141 548 4069

Participant information sheet – lifestyle study

Name of department: School of Psychological Sciences and Health, Faculty of Humanities and Social Sciences

Title of the study: Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

Introduction

You are invited to take part in a study which is being conducted at the University of Strathclyde by two members of staff from the School of Psychological Sciences and Health, and Mrs Sarah Deans who is a Teaching Fellow at the Department of Biomedical Engineering incorporating the National Centre for Prosthetics and Orthotics. Dr Rowe is a Reader in Exercise Science and Mrs Deans is a State Registered Prosthetist and Orthotist.

This information sheet will tell you about the study so that you can decide if you would like to be involved or not.

What is the purpose of this investigation?

In this study, we are keen to find out about physical activity levels and sedentary behaviour in those who have lower limb absence and who use a prosthesis (artificial limb).

Do you have to take part?

No, you do not have to take part in this study. If you do decide to take part, you are free to withdraw your participation at any time, without having to give a reason and without any consequences. In addition, you are free to withdraw any information about you that has been collected as part of the study, without having to give a reason and without any consequences. If you wish to withdraw your information, you will be able to do this up to one month following completion of the week-long activity monitoring. You can do this by contacting Mrs Deans.

Why have you been invited to take part?

You have been invited to take part in this study because you are a person who has either unilateral (one-sided) transtibial (below the knee) or transfemoral (above the knee) limb absence.

What will you do in the project?

The researcher will make sure that you understand what will be required during the study and answer any questions that you may have prior to any data collection. You can do this either by email or by telephone to Sarah Deans. If you would like to participate, you are kindly asked to either complete the consent form enclosed and return by post to Sarah Deans, or you can telephone or email Sarah to consent to participation. Sarah's details are below. Once this important consent stage has been satisfied, you will receive a parcel containing a number of items related to the testing and data collection. Firstly, you will complete a short questionnaire on some background information such as your age and amputation level.

One activity monitor similar in size to a two pound coin, will be attached to the middle of the thigh of your non-amputated side using waterproof, non-allergenic sticky tape. If you have access to the internet, a link to a short instructional video on how to attach and remove the monitor will be provided for you to review in your own time.

The monitor will be worn on your thigh continuously for a period of eight days, although you will be able to remove the device if necessary. You will also be able to shower, swim or bath while wearing the monitors.

Following the eighth day of recording, you will be asked to remove the monitors and return to the researcher by post in a prepaid envelope. The researcher will give you an instruction sheet about the activPAL™ monitor and how to fit it (in case you need to take it off) and a diary sheet to write down any time the monitor or your prosthesis is taken off. You will also be asked to record the time you get up and the time you went to bed during the monitoring period as well as describe when you might have used a wheelchair during the day and week of testing.

Please note:

If an activity monitor fails, which can sometimes happen, then you may be asked to wear the monitor again while the study procedures are repeated. However, this is completely up to and you do not have to wear it again if you do not want to.

What are the potential risks to you in taking part?

There are no known risks associated with any of the procedures being used to collect information about you. However, if you feel uncomfortable with any of the procedures, you can stop the procedure(s) or opt in or opt out from any of the procedures at any time.

The activity monitor (activPAL™) is attached using a medical adhesive. This adhesive has low allergy properties, therefore the risk of you experiencing any irritation or sensitivity is minimal. However, if you do experience any irritation or sensitivity then you will be advised to remove the activPAL™ immediately. In order to avoid skin irritation, we recommend you do not shave the non-amputated side thigh prior to attaching the activity monitor, nor should you shave during the eight-day monitoring period.

You may experience slight discomfort when removing the adhesive (similar to removing a sticking plaster). However, following the monitor removal demonstration in the online video, you will come to understand the removal technique designed to minimise or avoid any discomfort.

You should carry out your normal daily activities whilst wearing the monitor.

What happens to the information in the project?

Only the consent form and the demographic questionnaire will include your name and other identifying information (e.g. contact details). When you have returned these documents to the researcher, they will be stored in a locked filing cabinet in a locked room at the University and will be stored separately from the rest of your information. A study code will be assigned to you and all other information will use this study code. Paper copies of information (e.g. questionnaires) will be stored in a separate locked filing cabinet and electronic information will be stored on a password protected computer based at the University.

Only the lead researcher (Sarah Deans) and supervisors (Dr Rowe, Dr Kirk, Dr McGarry) will have access to your information. The supervisors will retain your information for publication and will securely store your information (as described above) for up to five years following the project end. After this time your information will be destroyed. Your identity will remain confidential in any presentations, publications or reports arising from this study.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?

If you are happy to be involved in the study, please sign a consent form to confirm this. If you do not want to be involved in the study, thank you for your attention and for reading this information sheet.

Researcher contact details:

If you have any questions about this study please contact

Chief Investigator
Dr David Rowe
Reader in Exercise Science
School of Psychological Sciences and Health
GH533 Graham Hill Building
50 George Street
Glasgow, UK
E: david.rowe@strath.ac.uk
T: 0141 548 4069

Lead Researcher
Mrs Sarah Deans
Teaching Fellow
National Centre for Prosthetics and Orthotics
Department of Biomedical Engineering
Curran Building
131 St James Road
Glasgow, G4 0LS, UK
E: sarah.deans@strath.ac.uk
T: 0141 548 3929

This study was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee.

If you have any questions/concerns, during or after the study, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Dr Jim Baxter
(Convener of the Ethics Committee)
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
40 George Street
Glasgow
G1 1QE
Telephone: 0141 548 2242
Email: j.baxter@strath.ac.uk

Consent

You are required to give your consent if you wish to participate in this investigation.

Name of School: School of Psychological Sciences and Health, Physical Activity for Health

Title of the study: Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction if I have required them to do so.

- I understand that my participation is voluntary and that I am free to choose not to participate, without having to give a reason and without any consequences.
- I understand that any information recorded in the investigation will remain confidential and no information provided can be identifiable with me
- I understand that the study data is pseudo-anonymised and therefore data cannot be identifiable with me.
- I understand that I can withdraw my activity monitor data only until the pseudo-anonymised data is deleted at the end of the study
- I consent to wearing an activity monitor on my non-amputated side for eight days
- I consent to being a participant in the project

(PRINT NAME)	I hereby agree to take part in the above project
Signature of Participant:	Date:

Appendix J Procedural tasks in the preparation, distribution and return of study participant packs

Step	Task	Notes
1	Compile a record of those who have given consent and provided postal address	Create participant checklist file called *Participant name and ID*
2	Compile testing schedule order	Testing schedule is compiled as consenting participants make contact with researcher
3	Assign unique identification ID number to each participant and record	Record IDs in *Participant name and ID* checklist file.
4	Print, collate and cross-check study documentation to be included in participant packs	Documentation included: • activity monitor use information sheet containing verbal, visual and written guidance including a link to an online researcher-led demonstration video http://www.bit.ly/1MJufFo • participant activities of daily living diary • participant demographic questionnaire • return address, postage paid, padded envelope identifiable by unique participant ID marked on outer Appendix K contains Activity Monitor Information Sheet, Personal Recording Diary, and Demographic Questionnaire
5	Code activPAL monitors and cross reference to participant ID.	Record codes/IDs in *activPAL log* and *demographic questionnaire* file for easy reference on receipt of returned monitors.

Table continued overleaf

6	Initialise activPAL monitors and wrap in nitrile sleeves	Time and date of initialisation recorded in participant file. Correct placement direction of monitor marked on outer sleeve in pen
7	Compile contents, cross-check and seal envelopes	Items included in envelope: • initialised activPAL™ monitor in nitrile sleeve • patches of Tegaderm™ medical adhesive (n = 4) • nitrile sleeves (n = 4) • study documentation (detailed in Step 4)
8	Send completed packs and record date	Packs sent by Royal Mail Signed For® 1st Class for security, insurance and tracking Date recorded on participant file
9	Follow-up email or telephone call to participant	Confirm receipt of participant pack, application of monitor, and start of monitoring. Confirm monitoring end day and postal return date. Answer any questions participant may have about study or procedures. All information recorded on participant file
10	Receipt of returned activPAL monitor and documentation	Receipt date recorded on participant checklist file
11	Begin data download process on receipt of returned monitor	Download date and time recorded on participant checklist file
12	Repeat steps 4-11 if retesting is required	Distribution of second monitor and re-recording required if monitor malfunctioned, or incomplete data collection occurred due to human error (activity monitor, self-report diary, or demographic questionnaire)

Appendix K Activity monitor information sheet, personal recording diary, and demographic questionnaire

Research study: Objectively measured physical activity and sedentary behaviour in people with lower limb absence.

Thank-you again for agreeing to participate in this study. Your pack should contain the following:

- activity monitor information sheet including a link to online self-help instructional video **http://www.bit.ly/1MJufFo**
- an activPAL activity monitor
- waterproof sticky tape
- waterproof sleeves
- an activities of daily living diary
- a participant demographic questionnaire
- a return address, pre-paid, padded envelope

Please contact the researcher Sarah Deans on 0141 548 3929 or sarah.deans@strath.ac.uk if there are any of these items missing from your pack or if you have any questions.

Study participants guidelines for the use of the activPAL™ activity monitor

The activPAL™ activity monitor consists of an orange unit with a picture of a person on the front. The monitor should already be contained within a rubber sleeve. The monitor should be worn on the thigh of your non-amputated side. Attachment instructions for the monitors are on page 2. There is also an online video which demonstrates how to apply and remove the monitors which can be accessed at http://www.bit.ly/1MJufFoYou would also follow the procedures demonstrated in the video when attaching and removing the monitor.

Please wear the activPAL™ monitor continuously (including when in bed, showering, swimming, playing sport). Your activPAL™ has been fitted with a waterproof sleeve which allows you to keep it on while taking a shower or bath, or during swimming.

To enable us to identify your working, leisure and sleep time we also ask if you could record times when you got up, or started work, finished work and when you went to bed. Please do this in **Table 1** - **My waking, dining and sleeping times** on the next page. Please start from the first full day you use the monitor and please note that Day 1 can be any day of the week.

It is unlikely that you would need to take the monitor off during the eight day period. However if this is the case, please record the time you take it off and the time you put it back on in **Table 2 - Activity monitor removal and reattachment diary below.**

Finally, it is important for us to understand when you put your prosthesis on and take it off. Some prosthesis users (amputees) may not do this at all during the day, but there are others who may put on and take off their prosthesis several times throughout the day. We also understand that there are some people who use prostheses and also use a wheelchair. We would be grateful if you could record this information in **Table 3** - **Putting on and removing**

prosthesis events, and wheelchair use. Again Day 1 can be any day of the week and would generally be the day that you first apply the monitor.

We would be very grateful if you could complete this information as fully as possible. As soon as is possible after the final day of recording, please return this information with the activPAL™ monitor and your demographic questionnaire in the pre-paid padded envelope provided, along with any unused medical adhesive.

activPAL™ attachment and reattachment instructions:

The online instructional video available at http://www.bit.ly/1MJufFo demonstrates the attachment and removal of the monitor. You might find this helpful.

If you have shaved the front of your thigh in the week prior to receiving the activity monitor, please wait four days before attaching the monitors and completing your documentation. We advise you not to shave the thigh area before or during the study.

The activPAL™ monitor will be placed on the front of your thigh, close to the middle. An arrow has been drawn onto the outer sleeve covering the monitor and you should ensure that this is pointing upwards towards the sky. The monitor should be worn on your non-amputated thigh continuously for the eight-day duration.

The activity monitor should already be contained within the waterproof sleeve when you receive it. If you need to fold over the waterproof sleeve, then please do so with the fold away from your skin and on the outer side of the monitor. The activPAL™ should always remain in an individual rubber sleeve and attached using the medical adhesive. In dimmer lighting conditions, you may notice a small flashing light on the monitor which is normal.

If you need to re-attach your monitor, please take the medical adhesive patch off your thigh. If it is at all possible then keep the activPAL™ monitor in its waterproof sleeve, and position on the thigh in a slightly higher or lower position using a new piece of medical adhesive. The arrow on the sleeve should always be pointing up. If there is any irritation, please avoid the area and move the monitor slightly up or down your thigh from this original site. You will need to use a new piece of medical adhesive to stick the activity monitor onto the thigh ensuring you put the monitor in the sleeve with the arrow pointing up.

If extreme irritation occurs, please remove the monitor immediately and contact the research team by telephone or email using their details below.

activPAL™ Activity Monitor Personal Record **Unique study code:___________**

Please kindly return the following in the pre-paid envelope which should be taken to the Post Office as soon as you can following the last day of recording. Thank-you.

- This activity monitor personal record
- The demographic questionnaire
- The activity monitor
- Any unused rubber sleeves and medical adhesive patches

For further information or if you require more medical adhesive or sleeves please contact:

Mrs Sarah Deans T: 0141 548 3929/3298 E: sarah.deans@strath.ac.uk
Dr David Rowe T: 0141 548 4069 E: david.rowe@strath.ac.uk

Please note your recording start day here: ______________________________

Table 1- My waking, dining and sleeping times

Day	Time you got out of bed	Time you had lunch	Time you had supper	Time you went to bed
Example	*7:25 am*	*12:10pm*	*6:55pm*	*10:55pm*
Start day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				
End day 8				

Table 2 – Activity monitor removal and reattachment diary

Please only complete this table in the unlikely event that you have to remove and reattach the monitor

Day	Reason for removal of monitor	Time monitor removed	Time monitor reattached
Example Day 4	*Itchy skin at site of monitor.*	*11am*	*1115am*

Table 3 – Putting on and removing of prosthesis events, and wheelchair use

Please record on this sheet any time you remove your prosthesis. Each time, please record the day, time of removal, and time of replacement of your prosthesis. Some initial example entries have been provided.

Day	Time prosthesis removed	Time prosthesis put on again	Time wheelchair use began	Time wheelchair use ceased	Reason
Examples					
Monday	1020am	1055am			Sat to watch TV
Monday	115pm	230pm			Took a nap
Tuesday	6pm	7pm			Had a bath
Friday			1100am	2pm	Went to shops

Correct positioning of the activPAL™ monitor

Monitor should already be placed in nitrile sleeve when you receive it. Sleeve should be folded over to outside (not skin side) before attaching with the medical adhesive patches.

Monitor contained in sleeve showing sleeve fold to outside. The monitor is positioned on middle of non-amputated side thigh using medical adhesive.

Study Participant Demographic Questionnaire

Unique study code: ___________________________ (supplied by the researcher)

<table>
<tr><td colspan="2">Date of birth (day/month/year)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Gender (male or female)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Height (metres or feet/inches)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Weight (kg or stones/pounds)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Limb absence level
(transtibial or transfemoral)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Amputation/absence side
(right or left)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Cause of amputation/absence(for example, trauma, cancer, peripheral arterial disease)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Prosthetic prescription (e.g. ischial containment socket, free knee joint, SACH foot)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Any other health conditions (please list)</td><td colspan="2"></td></tr>
<tr><td>Wheelchair – please indicate by circling whether you use a wheelchair and the frequency and time of</td><td>YES/NO</td><td>Daily/Weekly/Monthly?</td><td>Hours per use?</td></tr>
<tr><td colspan="2" rowspan="2">Geographical location of home and home type bungalow, two-storey)</td><td>Postcode</td><td>Home type</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Number of people living with you at home</td><td>Number of adults</td><td colspan="2"></td></tr>
<tr><td>Number of children</td><td colspan="2"></td></tr>
</table>

Caring responsibilities	Do you care for someone at home or elsewhere or do you have a home carer/visitor	
	Nature of caring/carers responsibilities, please detail in the box on the right	
Employment status		
Full name and postal address (please complete only if you wish us to disseminate feedback on the results)		

Please use this space to note anything you wish us to know about yourself, your physical activity, or your participation in this study. Thank-you for your participation.

Appendix L Matching of participants with limb absence and control group participants

This file is available here as an electronic supplement to the thesis, and is also available on request from the author.

Individual Level
Matching THESIS

Appendix M Example dataset of average daily values of physical behaviour variables produced by the activPAL accelerometer

This file is available here as an electronic supplement to the thesis, and is also available on request from the author.

Example datasets
from activPAL output

Chapter 7: Research findings and recommendations for future practice

Chapter overview

This chapter restates the thesis aims and provides a summary of main points from each of the chapters. This chapter collates the findings of the four studies conducted as part of this thesis research. The strengths and limitations of the research will also be discussed. Finally, the chapter will conclude with recommendations for future research. A presentation will be made on how the findings from each of the studies might influence the development and evaluation of clinical interventions.

Restatement of thesis aims

The aims of this research were to: examine the motivations and barriers to participation in physical activity; explore the knowledge and understanding of prosthetic rehabilitation healthcare professionals in relation to physical activity guidelines; understand the current and desired practices of prosthetic rehabilitation healthcare professionals in relation to promotion of physical activity for health; research the suitability of the activPAL activity monitor in the objective measurement of physical behaviour in adults with lower limb absence; and to examine the free-living physical behaviour of adults with lower limb absence.

Summary of main chapter points

The following section describes the main points from each of the chapters including the literature review. Table 31 provides a summary of the four study aims and the key findings.

Table 31 Summary of key findings from the four studies

Chapter, study	Study aims	Key findings
Chapter 3 Study 1	To systematically review the evidence on motivations and barriers to participation in physical activity, exercise and sport for adults with lower limb absence	Adults with lower limb absence were not participating in physical activity at a level conducive to health benefits, and post-amputation levels were lower than pre-amputation levels More barriers than motivators existed to the adoption of a physically active lifestyle A social experience was important when participating in physical activity Much of the literature focussed on sports and exercise rather than physical activity
Chapter 4 Study 2	To build a demographic profile of UK prosthetic healthcare professionals who responded to the survey To explore their awareness and knowledge of the content of physical activity guidelines To seek their views on current and desirable clinical practice with regards physical activity promotion	A representative sample of prosthetic healthcare professionals completed the survey Physiotherapists have most awareness and knowledge of guidelines, and are the professional group most likely to promote a physically active lifestyle to patients Prosthetists have some awareness and knowledge of physical activity guidelines. With the correct support (education, workplace support), they could include physical activity promotion in routine clinical practice

Chapter 5 Study 3	To research the suitability of the activPAL accelerometer for use in objective measurement of people with lower limb absence	One trained rater is sufficient to consistently judge incidental and purposive stepping, and sitting and lying in adults with lower limb absence activPAL monitor placement on the sound side (rather than the prosthetic side) yields more accurate results The activPAL is a valid device for measuring purposive stepping, and for measuring time spent in different activities such as sitting/lying The activPAL was poor in measuring incidental stepping in adults with lower limb absence
Chapter 6 Study 4	To examine the free-living physical behaviours of adults with lower limb absence	Adults with lower limb absence are not sufficiently active for maintenance or improvement in health When compared with individuals from a healthy, non-limb absent control group, adults with lower limb absence are less active, engage in more sedentary behaviour, and take more daily steps at lower cadences

Key findings from Chapter 2 Literature Review

Chapter 2 presented the following topics: motivations and barriers to participation in physical activity; physical activity guidelines for general, clinical and limb absent populations; physical activity promotion; objective measurement of physical behaviour; the use of accelerometers in free-living studies; and the limitations of the evidence in relation to physical behaviour and adults with lower limb absence. The research findings of this chapter identified several important areas where the literature was both comprehensive and lacking. Identifying where the literature was scarce allowed for informed research design in the subsequent four studies.

Motivations and barriers to participation in physical activity

Research methodologies on this topic tend to be qualitative in nature which is helpful in providing rich, detailed data on why people behave in certain ways, and their feelings about these actions. However, quantitative research methodologies should also be encouraged to capture data on larger samples of the population. That said, existing high quality articles serve to inform that there are universal barriers to participation across many clinical conditions. There was a lack of evidence in relation to the exploration of motivations and barriers to physical activity in those with lower limb absence which therefore offered an opportunity for a systematic review to be conducted as detailed in Study 1.

Physical activity guidelines for general, clinical and limb absent populations

Guidelines exist for many westernised general and clinical populations and there is a wealth of evidence upon which researchers can be informed and guided. However, inconsistencies are evident in the content of these guidelines. Differences in the timings of guideline update versions can also lead to inconsistencies in content. Physical activity guidelines do not exist for those with lower limb absence and this is an area for future work. Studies have been conducted into general practitioners' knowledge of physical activity guidelines. Current and desirable practice with regards to physical activity promotion has also been conducted. The evidence around these topics influenced the design of Study 2.

Physical activity promotion

This area is a public health priority and optimising physical activity promotional strategies for the general population continues to be an important research area. Physical activity promotion also takes place in clinical populations where adherence can often be optimised due to the safe and supportive environment in which the promotion, the participation or both takes place. There is no evidence to inform researchers on the subject of physical activity promotion in those with limb absence, although this has been researched in other healthcare professional groups such as general practitioners. Again this presented an opportunity to conduct research in physical activity promotion, in particular around prosthetic rehabilitation healthcare professionals as also seen in Study 2.

Objective measurement of physical behaviour

The consensus from the literature is that objective and subjective methods of measuring physical behaviour yield different information. Although objective methods tend to yield robust and irrefutable data, subjective methods can be helpful in providing contextual data. Using a reliable and valid measurement device is an important consideration and is necessary for robust data collection, analysis and interpretation of the research findings. In addition, the activPAL accelerometer has been widely used in measurement studies of general and clinical populations and the reliability and validity of this device tested. The activPAL has also been tested for reliability and validity in some studies of people with lower limb absence although the evidence-base is more limited than it is for other clinical populations such as those with chronic obstructive pulmonary disorder.

The use of accelerometers in free-living studies of physical behaviour

The evidence from experimental studies that examine free-living physical behaviour is sizeable. General and clinical populations with conditions such as intermittent claudication have been extensively studied. Focus has shifted more recently to encompass the measurement of sedentary behaviour with the aim of reducing or breaking up bouts of sedentary behaviour. This section of the literature review highlighted an under-researched area in terms of the population with limb absence where there have been very few studies which describe free-living physical behaviours. There was also a lack of evidence on aspects of free-living physical behaviour of people with lower limb absence. For instance, the existing evidence reports on daily stepping and cadence, yet few report on other variables of physical behaviour such as standing and sitting and lying time. Similarly, and at the time of writing, no studies reported on the comparisons of physical behaviour of people with limb absence with individuals from a non-clinical, healthy matched control group. Measurement of free-living behaviour was explored in Study 4.

Key findings from Chapter 3 Study 1

The evidence on motivations and barriers to prosthesis users' participation in physical activity, exercise and sport was systematically reviewed. In total, 12 articles were included in this review and critically appraised. The review concluded that people with limb absence who participated in formalised exercise and sports were in the minority. Further, this population was not participating in levels of physical activity recommended for health improvement and maintenance. Findings showed that participation in physical activity following amputation was reduced compared to pre-amputation participation levels. More barriers than motivations existed to adopting or maintaining a physically active lifestyle. Barriers to participation included a lack of time to participate, anxiety about causing further harm to their health or to their residual limb, a perception that specialist prosthetic components were required to participate in activities, and a lack of confidence in being able to participate linked to mastery of use of a prosthesis and body image. The motivations which someone may have to participate in physical activity, sports and exercise include a desire to have a social experience. This suggested that a clinical intervention designed to increase participation based on social support could be explored. In conducting this review, the findings showed that much of the literature focussed on formalised exercise and sports rather than participation in physical activity for health benefits which was an under-researched area. This influenced the focus of the three other PhD studies to be on physical activity and physical behaviours.

Key findings from Chapter 4 Study 2

In this study, 106 prosthetic rehabilitation healthcare professionals from the four home countries of the United Kingdom completed an online survey. The findings from this chapter demonstrated that UK prosthetists have some awareness and some knowledge of physical activity guidelines in order to discuss physical activity with their patients. Physical activity promotion is not a formalised aspect of routine prosthetic care. There are barriers to routine promotion such as a lack of time within clinical appointments, a sense that physical activity promotion is the responsibility of other healthcare professionals, and that promotion of physical activity is out with prosthetists' professional scope. In order to address the possible lack of knowledge, educational materials could be compiled and tested along with possible modes of delivery of the educational content. A clinical intervention could be developed with the aim of exploring, with prior education and ongoing support, which members of the prosthetic rehabilitation are best placed to promote physical activity for health benefits and maintenance. The Medical Research Council framework (Craig et al., 2008) could be used to guide this work in supporting the development and evaluation of complex interventions and this will be presented later in the chapter.

Key findings from Chapter 5 Study 3

Objective measurement of 15 adults with lower limb absence was conducted using the activPAL™ accelerometer during simulated lifestyle activities to assess device reliability and validity. In addition, the inter-rater reliability of directly-observed physical behaviour showed consistency in judging incidental and purposive stepping, and sitting and lying events, and that the data can be used to obtain a reliable record of physical behaviour for criterion validation of accelerometers. There are no known studies that have examined inter-rater reliability of directly-observed stepping in people with limb absence. The activPAL was found to be poor in measuring incidental steps. This meant the total number of steps was underestimated although this did not have a meaningfully detrimental effect on the reliability. The activPAL is valid for measuring purposive steps and time spent in various physical behaviours. In addition, the findings from this study were also used to inform researchers during the design of the subsequent free-living behaviour detailed in Study 4. The sound side thigh was the recommended placement side of an activPAL monitor when measuring physical behaviour in people who have lower limb absence. Validity of the activPAL was considered excellent in detecting purposive stepping, excellent for recording reclining (sitting/lying) time and good for recording stepping time. This study has shown that the activPAL monitor may also be valid in the measurement of incidental stepping in those who use prostheses.

Key findings from Chapter 6 Study 4

Objective measurement of free-living physical behaviour of 57 adults with lower limb absence revealed that this population is physically active, but not at a level currently recommended for the general population for health maintenance or improvement. People with lower limb absence in this study participated in less physical activity and more sedentary behaviour than healthy people to whom they had been matched on age, gender and employment status. These findings explored the variables of cadence and sit-to-stand transitions in addition to the physical behaviours of sitting/lying, standing, and stepping. In future work, a more representative sample could be recruited from regional prosthetic rehabilitation centres where a greater proportion of people who have limb absence due to vascular compromise are accessible. Further, a longitudinal study or randomised control trial that explores change in physical behaviour could be designed and implemented to examine how a physical activity intervention might improve levels of physical activity participation.

Developing and evaluating clinical interventions

The findings from the studies conducted as part of this thesis research could inform the future development and evaluation of one or a number of clinical interventions. Prior to this, it is important to understand the content of a key article which describes the processes involved (Craig et al., 2008). The authors describe the revision and updating of the original Medical Research Council’s (MRC) framework for developing and evaluating complex interventions (Medical Research Council, 2000). Complex interventions are built up from a number of components, which may act both independently and inter-dependently. The components usually include behaviours, parameters of behaviours (for example frequency and timing), and methods of organising and delivering those behaviours (for example the setting and location).

Clinical interventions may be delivered at a number of different levels which are: an individual patient care level; an organisational level; the healthcare professional level; and the population level. Experimental designs are preferred to observational designs, and interventions should be tailored to local operational conditions. For example, it may be practical to design an intervention to evaluate the effectiveness of physical activity promotion by a number of prosthetists in a large prosthetic clinic. However, it may not be as practical to deliver the same intervention by one prosthetist in a remote satellite clinic when consultation time may be limited. The research included in this thesis has strength in exploring physical behaviours in patients with lower limb absence including the motivations and barriers to participation, and patterns of physical behaviours. In addition, this research captures the views, and current and desirable practices of key stakeholders involved in the care of these patients.

The development of an intervention or interventions to further the work of this PhD research will have the aim of ultimately improving patient care, and need not be complex. There are several key elements in the process of development and evaluation which may or may not follow a linear pattern. The following are key elements of the Medical Research Council’s framework:

- Development

- Identifying existing evidence or perform a systematic review to inform researchers

- Identifying and developing theory to assess the likely processes of change

- Modelling processes and outcomes to identify weaknesses and the refinements required (or even show that a full scale evaluation is unwarranted)

- Feasibility and piloting

- Testing the procedures is required to predict acceptability, compliance, delivery of the intervention, recruitment and retention, and smaller than expected effect sizes

- Estimating recruitment and retention of study participants is important

- Determining the sample size required to obtain robust results

- Evaluation

- Assessing effectiveness with regards to randomisation as a robust method of preventing selection bias is required. Although experimental designs are preferred, quasi-experimental or observational designs may be necessary

- Understanding change process by developing a theoretical understanding is important in the early stages of evaluation

- Assessing cost effectiveness should always be weighed against the value of having better information

- Implementation

- Dissemination of research findings to enable replication and synthesis of evidence

- Surveillance is the continuous, systematic collection, analysis and interpretation of health related data. Monitoring is the observation of intervention activities in order that any discrepancies can be anticipated and corrected

- Long term follow-up may be needed to determine whether outcomes predicted by interim or surrogate measures do occur or whether short term changes persist

The studies included in this PhD are focused towards the development stage of the MRC framework. Study 1 is a systematic review which identifies the evidence base and provides important information to inform the identification or development of appropriate theory to support an intervention. Study 2 provides further support for a physical activity intervention including information on potential methods and settings for delivery of an intervention in addition to likelihood of implementing an intervention into routine care. Studies 3 and 4 provide some important information to inform the pilot and feasibility stage of the MRC framework including information on effective methods of recruitment, appropriate methods and procedures for measurement of physical activity, data on retention rates and daily living patterns of physical activity in this group of the population. This information will inform calculations for sample sizes and appropriate methodologies and procedures to use in future research exploring the effectiveness of interventions. Having reported on several of the essential elements to justify and support physical activity promotion within the care of people with lower limb absence, then next steps for this research would be to develop an evidence-based and user-informed intervention and conduct further pilot and feasibility work of intervention delivery. In following the Medical Research Council's framework, subsequent phases should then explore evaluation, assessing effectiveness including cost effectiveness, and understanding the process of change. Implementation of the intervention would be the final phase including dissemination, surveillance and long term follow-up of participants.

Strengths and limitations of the PhD research

The four studies comprising this research were conducted with study methodologies based on good research planning and organisation throughout. Study design and implementation were strengths of the research yet limitations may have compromised certain aspects of the findings. A summary of these strengths and limitations is now presented.

Study 1 highlighted the need to conduct research to inform the evidence base on the topic of physical behaviour in this clinical group. There is confidence in the fact that the review was conducted using a thorough, systematic approach and that all publications available at the time were scrutinised in addition to being independently reviewed by co-authors. Importantly, by conducting this review, a refocussing of the research occurred to examine only physical activity as a component of physical behaviour rather than examining sports and exercise also. In doing this, the findings from this particular chapter were considered a new contribution to the evidence.

All 12 publications reviewed were of survey design. With this, there may have been a response bias from either researchers or study participants, and none of the research was able to present evidence of changes in clinical presentation over time. Whilst this is not a limitation of Study 1 but rather a limitation of the included reviewed studies, there is the suggestion that empirical research should be encouraged that yields objective data rather than observational data on people with lower limb absence. Further, the 12 publications featured research which was conducted in developed countries. This may be a reflection on the possible challenges encountered in conducting research in developing countries possibly due to research funding, research design and implementation, and participant recruitment.

In Study 2 the online survey design allowed for ease and speed of distribution of the survey, minimal design and implementation costs, and allowed a specific rehabilitation population to be reached. Informal participant feedback also suggests the professional quality marketing material was important in attracting potential recruits to the survey. Survey participants also remarked on the ease of navigation through the Qualtrics survey. It is acknowledged however, that all relevant distribution networks may not have been identified thereby alienating some of the specialised sample (Wright, 2005). Although the number of respondents who completed the survey was considered good (N = 106), this should be tempered by the fact that those who responded may have been motivated by personal or altruistic interests in participation in physical activity for health benefits. This may have created sampling bias. Finally, other international countries also have physical activity guidelines and different professional practices with regards prosthetic rehabilitation. Although the findings could be useful and informative and used to draw parallels in other countries, the generalisability of this study research may be limited.

The strength of Study 3 described in chapter 5 was demonstrated in the experimental processes that were carefully controlled to ensure repeatability and consistency across the participant trials. This included the completion of a pre-determined trial route and the subsequent video capture of these participant trials. In addition to determining reliability and validity of the activPAL monitor, it was also demonstrated that a monitor placed on the sound side thigh of a person with unilateral lower limb absence was the preferred side for device attachment. Previous research has not shown this. Future replication research could recruit people with lower limb bilateral absence to assess the reliability of use of the activPAL in this population. In this study a convenience sample of people with transtibial or transfemoral lower limb absence was recruited from a group of volunteer patients attending the University of Strathclyde in Glasgow. For this cohort, a higher number than the national average of study participants had sustained traumatic amputation and as such the sample could not be regarded as representative; the most prevalent cause of lower limb amputation is vascular disease (United National Institute for Prosthetics Orthotics Development, 2011-2012). Recruiting from a regional disablement service centre could control for this confounding factor. In addition, the sample of 15 people comprised n = 4 participants with transfemoral absence, the other n = 11 participants having transtibial absence. This is an important consideration, as the two groups differ physiologically, and in aetiology. For example, people with transfemoral absence expend more energy in ambulation due to the more proximal amputation level and loss of the anatomical knee joint. Data from these two groups within the entire sample was interpreted in combination; more detailed findings might be produced by performing data analysis on homogenised samples. Further, the control of a laboratory experiment creates an artificial environment and potential confounders that raise questions about the generalisability of results (Visser, Krosnick, & Lavrakas, 2000). In addition, the researcher was known to most of the 15 participants which could have led to experimenter bias. To clarify, participants may have altered their behaviour in completing the trials meaning there could have been a threat to the internal validity of the research.

In Study 4 Chapter 6, data were collected from 57 adults from around the United Kingdom who wore a proven valid and reliable activity monitor for 8 days. This sample size was considered positive when compared to other participant numbers in prosthetic-related research which tends to be lower. The recruitment strategy for this study was underpinned by marketing using social media and electronic methods through relevant prosthetic agencies and patient support groups. Participant retention and compliance for the duration of monitor wear was also enhanced by the production of an online video demonstrating the experimental processes that were to be followed by participants. The researcher provided a daily email support service to participants throughout the data collection phase of the research. As acknowledged as a possible shortcoming in Study 2, some distribution networks during the marketing and recruitment phase may not have been reached. Having a comprehensive recruitment strategy is important in maximising participant numbers. This study makes a further unique contribution to the field in that the physical behaviour of people with limb absence was compared to the behaviour of individuals in a control group who were matched on the variables of age, gender and employment status. As described by Rose and van der Laan (2009), matching can increase study efficiency especially if matching variable selection is conducted systematically (Rose & van der Laan, 2009). Another methodological strength of this particular study was that all participants were matched on gender, and the majority was matched on age and employment status.

Final conclusions

Each study in this thesis contributed new knowledge and this will continue to be disseminated through presentation and publication. This work provides a platform for future work to focus on developing and evaluating interventions to support active lifestyles in people with lower limb absence. The four research studies have detailed successful exploration of two groups of people: those with lower limb absence; and those healthcare professionals who care for them. This research began with the idea that the prosthetist's relationship with their patient is a uniquely lifelong one. In this, there is a strong opportunity for prosthetists and possibly other healthcare professionals, to influence the health and well-being of people with limb absence for the better. Future research should focus on developing and evaluating clinically-based interventions which can progress the work described in this thesis. The overall aims are to improve prosthetic care and rehabilitation, and the health and well-being of those with limb absence.

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