The Measurement and Improvement of Fitness Post Stroke

Ashlee Kate Dunn

B ExSporSci (Hons)

The University of Newcastle, Australia

This thesis is submitted in fulfilment of the requirements for the award of

the degree of:

Doctorate of Philosophy (Human Physiology)

The University of Newcastle, Australia

October 2016
Statement of Originality

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

**Unless an Embargo has been approved for a determined period.

__________________________

Name: Ashlee Kate Dunn

Date:
Copyright permission

I warrant that I have obtained, where necessary, permission from the copyright owners to use any third party copyright material reproduced in the thesis (e.g. questionnaires, artwork, unpublished letters), or to use any of my own published work (e.g. journal articles) in which the copyright is held by another party (e.g. publisher, co-author).

_________________________

Name: Ashlee Kate Dunn

Date:
Statement of Collaboration

I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.
Statement of Authorship

I hereby certify that the work embodied in this thesis contains a published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

_________________________
Name: Ashlee Kate Dunn
Date:

_________________________
Name: Prof Robin Callister
Date:
Supervisors

Primary Supervisor
Professor Robin Callister (35%)
Priority Research Centre for Physical Activity and Nutrition
School of Biomedical Sciences and Pharmacy
Faculty of Health and Medicine
University of Newcastle, Australia

Co-supervisors
Associate Professor Neil Spratt (30%)
Priority Research Centre for Translational Neuroscience and Mental Health
School of Medicine and Public Health
Faculty of Health and Medicine
University of Newcastle, Australia

Professor Paulette Van Vliet (35%)
Priority Research Centre for Translational Neuroscience and Mental Health
School of Health Sciences
Faculty of Health and Medicine
University of Newcastle, Australia
Publications, presentations and awards arising from this thesis

This thesis includes a number of chapters that have been published or submitted for publication. To date, four have been accepted or published (Chapters 3, 4, 6, 7) and two have been submitted and are currently under review (Chapters 5, 8). I have also presented research arising from this thesis at numerous conferences, as well as University and Hunter New England Health events. Throughout my candidature, I have received a number of awards and scholarships. The details of the aforementioned publications, presentations and awards are listed below.

*Peer-reviewed Journal Articles:*


2. **A Dunn**, DL Marsden, P Van Vliet, NJ Sprat and R Callister. Independently ambulant, community dwelling stroke survivors have reduced cardiorespiratory fitness, mobility and knee strength compared to an age- and gender-matched cohort. *Topics in Stroke Rehabilitation (epub ahead of print)*


4. **A Dunn**, DL Marsden, P Van Vliet, NJ Sprat and R Callister. Maintenance of cardiorespiratory fitness and walking endurance improvements at 12 months follow-up of an individually tailored home and community-based exercise program for stroke survivors. *Stroke Research and Treatment (under review)*


**Conference Presentations:**


4. DL Marsden, R Callister, **A Dunn**, CR Levi, NJ Spratt. How Fit is the Stroke


9. **A Dunn**, DL Marsden, P Van Vliet, NJ Spratt, R Callister. How do the shuttle walk test and the upright cycle test compare as measures of cardiorespiratory


Improvements in fitness at 12-months follow up of an individualized home and community based exercise program after stroke. Sports Medicine Australia. Melbourne, Australia, 2016. Oral presentation

Awards and Scholarships Arising from Thesis:

1. 2014: Finalist for Best Abstract at Be Active 2014 conference

2. 2013: Smart Strokes Most Controversial Abstract Award


4. Australian Postgraduate Award (APA) Scholarship

5. Emlyn and Jennie Thomas HMRI Postgraduate Medical Research Scholarship (top up)

Research Grants:

1. Hunter New England Allied Health Research Committee Research Grant: $3,000

2. John Hunter Hospital Charitable Trust: $18,000

3. National Stroke Foundation: $19,436

4. Hunter Medical Research Institute Grant: $25,000
**Contributions to this Thesis**

The central component of this thesis is the “How Fit is the Stroke Survivor? (HowFITSS? trial). The HowFITSS? pilot trial forms the basis of my thesis and PhD candidate Ms Di Marsden’s thesis. I have been significantly involved in all aspects of the project from conceptualisation of the trial to implementation and long term follow up of the intervention.

This included involvement and contributions towards:

- Writing and submitting grant applications for personnel and equipment
- Collaborating with Di Marsden to determine data sharing
- Writing and submitting of ethics applications and variations through both the University of Newcastle and Hunter New England Health District
- Selection of equipment and protocols
- Training of research assistants and internship students
- Participant recruitment, including both stroke and non-stroke individuals
- Management of participants throughout the trial including weekly contact support
- Developing training manuals for equipment used in the trial
- Data collection in the Human Performance Laboratory including setting up, calibrating and using equipment
- Management of equipment used in the trial including troubleshooting, maintenance and regular contact with company representatives
- Data management including extracting, organising, checking and data storage
• Statistical analysis
• Writing and editing manuscripts arising from this trial
• Presentation of findings from the HowFITSS? trial at conferences and community events

Further, I have indicated at the beginning of each chapter my contribution.
Acknowledgements

This thesis was written in loving memory of my grandma, Shirley Noonan, who passed away from a stroke. She was an amazing woman who showed unconditional love to us all, and is missed every single day. You will always be in my heart Gran.

This thesis would not have been possible without the support from some amazing people. Firstly, to my supervisors Prof Robin Callister, A/Prof Neil Spratt and Prof Paulette Van Vliet. I am privileged to have worked with such a brilliant team. Thank you for your mentorship, insight and guidance throughout my PhD journey.

To Robin, thank you for the hours spent in your office, for the many drafts you read and re-read and for your unwavering support. I could not have asked for a more dedicated supervisor. Your encouragement and guidance were very much appreciated and I cannot thank you enough for helping me through the past few years.

To the amazing and selfless Jennie Thomas. Thank you doesn’t seem enough. My PhD journey would not have been financially possible without your generous support. Thank you for the reassuring and encouraging emails, for showing me that life is amazing and much bigger than a PhD, and for the warm hugs. You are such an incredible person and I am very blessed to be part of the inspiring Jennie Thomas Family.

To my family; Mum, Dad, Jo and Max. Thank you for always being there for me and always encouraging me to do my best. To my Mum and Dad, thank you for your unconditional love you have always shown myself and Jo, no matter what we do in life we have always had your support and encouragement. Mum, your insight and
motivation, provided on most days throughout my PhD, will never be forgotten. Jo, thank you for always helping me to keep a work-life balance and for all the fun and laughter we shared. I couldn’t ask for a better and more understanding sister. To Kobe and Chloe, thank you for spending days at home helping me get through the months spent writing while everyone else was at work. I love you all.

To my amazing husband Matt. Thank you for living the PhD journey every day with me, for your patience and understanding, and for picking up the slack when I could not. You have been my rock, and have helped me make it through with a smile. Your love and support is forever appreciated, and I can’t see how I would have made it without you. I am looking forward to our lives together thesis free!

To my desk buddy Elroy Aguiar, thank you for your emotional and technical support. From your offers to get me lollies at Pinkies to showing me how to change my reference style in Endnote for the hundredth time, I have appreciated it all. To Carolyn Clark and Jovanka Stojanovski, thank you for being my at-work support network. Your kind and caring approach, alongside your listening ears and supportive words has made a tremendous difference. I am lucky to have such amazing colleagues.

To Di Marsden, thank you for the hours spent in the lab – we finally made it through! To the fantastic team of interns and research assistants who contributed to data collection and data extraction – namely Erin Nugent, Adriana Giles, Erika Brown, Brent Hull, Kate Beatty, Allison Baldwin and Jaeger Olden – I am forever grateful!
To the amazing statistician, Daniel Barker. Thank you for the countless meetings, for your patience and time spent explaining how I should handle data, why I should use certain syntax, and how to create a do file. You allowed me to complete my own statistics and learn skills that I’m sure I will use throughout my career.

Lastly, to our awesome volunteers who spent countless hours in the lab with us, I cannot thank you enough. Your selflessness and willingness to help others is a true testament to the amazing people you are. Thank you for your time, effort and generosity over the years of data collection. You are an inspiring group of people and I am forever grateful.
List of Common Abbreviations

Listed below are the common abbreviations used throughout this thesis. Additional abbreviations used in the main text are defined within chapters at first use.

10MWT – Ten Metre Walk Test
6MWT – Six Minute Walk Test
ACSM – American College of Sports Medicine
ATS – American Thoracic Society
BIA – Bioelectrical Impedance Analysis
BMI – Body Mass Index
cGXT – Cycle Graded Exercise Test
CRF – Cardiorespiratory Fitness
FAS – Fatigue Assessment Scale
HowFITSS? – How Fit is the Stroke Survivor? Program
HR – Heart Rate
HRR – Heart Rate Reserve
ICC – Intra-class Correlation
QoL – Quality of Life
RER – Respiratory Exchange Ratio
SD – Standard Deviation
SWT – Shuttle Walk Test
VE – Ventilation
VO₂ – Oxygen Consumption
Thesis Abstract

The increasing number of people surviving stroke and living in the community with fitness levels below that required to perform activities of daily living is a rising global concern. Previous research has identified the major benefits exercise can provide following stroke, including improvements in quality of life, community participation, addressing additional co-morbidities, as well as assisting in preventing secondary stroke. Previous exercise interventions have demonstrated a lack of i) individualised, tailored programs, ii) exercises that can be conducted at home or in the community, and iii) programs that focus on the improvement and maintenance of fitness over the long term.

Therefore, the central component and primary aim of this thesis was the development and long term evaluation of the How Fit is the Stroke Survivor? (HowFITSS?), an individually tailored, home and community based exercise program for stroke survivors.

However, secondary aims 1, 2 and 3 have been presented first. These aims investigate exercise testing in stroke and provide context for the HowFITSS? trial.

Prior to the development of the program, we investigated the feasibility of various tests of cardiorespiratory fitness (CRF) in stroke. Oxygen consumption (VO\textsubscript{2peak}) and performance measures were compared between the traditional graded cycle ergometer test (cGXT), the commonly used six-minute walk test (6MWT) and a new walking test of CRF, the Shuttle Walk Test (SWT). Results demonstrated that all three tests are indicators of CRF in stroke, with similar VO\textsubscript{2peak} (range: 17.08 - 18.09mL.kg\textsuperscript{-1}.min\textsuperscript{-1}). All three tests were determined feasible, with all stroke survivors completing the
6MWT. One was unable to perform the SWT due to instability identified during the 6MWT and three could not perform the cGXT due to pre-existing lower limb arthritic conditions. Results from this sub-study informed the inclusion of all three tests as outcome measures for the long term evaluation of the HowFITSS? program.

Following baseline assessments, it was identified that there is a lack of reported data for independently ambulant, community dwelling stroke survivors. An age and gender matched comparison group were recruited and assessed using the same fitness tests as stroke survivors, including measures of fatigue, depression and quality of life. Despite the mild deficits evident in this stroke group, they significantly under performed on all fitness tests, including:

- **6MWT VO$_{2peak}$** (stroke group: 16.46±3.66mL·kg$^{-1}$·min$^{-1}$; comparison group: 21.03±8.32mL·kg$^{-1}$·min$^{-1}$)
- **6MWT distance** (stroke group: 464±121m, comparison group: 606±129m)
- **SWT VO$_{2peak}$** (stroke group: 17.44±4.94mL·kg$^{-1}$·min$^{-1}$, comparison group: 23.11±9.48mL·kg$^{-1}$·min$^{-1}$)
- **SWT distance** (stroke group: 415±174m, comparison group: 651±236m)
- **cGXT VO$_{2peak}$** (stroke: 17.0±6.3mL·kg$^{-1}$·min$^{-1}$, comparison: 22.4±6.5mL·kg$^{-1}$·min$^{-1}$)
- **and cGXT final workload** (stroke: 118±32W, comparison: 157±42W)

Stroke survivors also walked slower compared to the non-stroke group. These results further reinforced the need for an exercise intervention in stroke survivors even those with only mild to no motor deficits.
The primary aim of this thesis was to assess the long term effects of the 12-week How Fit is the Stroke Survivor? (HowFITSS?) exercise program on stroke survivors from pre-intervention to 12 month follow up. The HowFITSS? trial was therefore designed as a home and community based program with minimal therapist support. Results found improvements in CRF for the intervention group compared to the control group at 12 weeks. The control group were then provided with the intervention, and both groups followed up at 6 and 12 months. Therapist support was tapered to no communication from the 6 to 12 month time points. Stroke survivors significantly improved VO$_{2\text{peak}}$ and performance measures during the 6MWT (ES=0.75  $p=0.002$) and cGXT (ES=1.09 $p=<0.001$) from baseline to 12-months follow up, with non-significant but promising improvements on the SWT (ES=0.23 $p=0.251$). Similarly, quality of life, balance and walking speed significantly improved, with all measures of fitness maintained during the follow up period alone.

The HowFITSS? model shows promising results as a cost effective, feasible method for improving fitness in stroke survivors over the long term. Both research and clinical practice may benefit from employing the HowFITSS? model, in improving fitness, quality of life, fatigue and depressive symptoms in people after stroke. Further translational studies are required to investigate the HowFITSS? model in a health care setting, with wide dissemination to community dwelling stroke survivors.
Table of Contents

The Measurement and Improvement of Fitness Post Stroke ............................................ i

Statement of Originality ........................................................................................................... ii
Copyright permission ................................................................................................................ iii
Statement of Collaboration ........................................................................................................ iv
Statement of Authorship .......................................................................................................... v
Supervisors ............................................................................................................................... vi
Publications, presentations and awards arising from this thesis ........................................... vii
Contributions to this Thesis ....................................................................................................... xii
Acknowledgements .................................................................................................................. xiv
List of Common Abbreviations ................................................................................................. xvii
Thesis Abstract ........................................................................................................................ xviii
List of Figures ............................................................................................................................ xxix
List of Tables ............................................................................................................................. xxx

Chapter 1 – Thesis Introduction .............................................................................................. 1

1.1 Chapter overview ................................................................................................................ 1
1.2 Background and context ..................................................................................................... 1
  1.2.1 Stroke .......................................................................................................................... 1
  1.2.2 Physical consequences of stroke ............................................................................. 3
1.3 Risk factors for stroke ....................................................................................................... 3
  1.3.1 Primary prevention: non-modifiable risk factors .................................................... 4
  1.3.2 Primary prevention: modifiable risk factors ............................................................ 6
1.4 Recurrent stroke and secondary prevention ..................................................................... 8
1.5 Physical activity and fitness in stroke .............................................................................. 8
1.6 Summary ............................................................................................................................ 9
1.7 Primary and secondary aims ............................................................................................. 10
1.7.1 Primary aim (Chapter 8) .................................................................................. 10
1.7.2 Secondary aim 1 (Chapter 3) ......................................................................... 10
1.7.3 Secondary aim 2 (Chapter 5) .......................................................................... 11
1.7.4 Secondary aim 3 (Chapter 6) .......................................................................... 11
1.8 Study design ........................................................................................................ 12
1.9 Context of this thesis .......................................................................................... 12
1.10 Thesis structure ................................................................................................. 14
1.10.1 Chapter 2 – Literature review ....................................................................... 14
1.10.2 Chapter 3 – Systematic review of the 6MWT in the stroke literature and the impact of walkway length on distance achieved ........................................... 14
1.10.3 Chapter 4 – Systematic review of exercise interventions for stroke survivors and the consequential impact on aerobic fitness ........................................... 15
1.10.4 Chapter 5 – Comparison of three measures of CRF in stroke ..................... 15
1.10.5 Chapter 6 – Comparison of the fitness levels of independently ambulant, community dwelling stroke survivors to healthy age and gender matched comparisons... 16
1.10.6 Chapter 7 – Evaluation of the HowFITSS? controlled trial paper ............... 16
1.10.7 Chapter 8 – Long term follow up paper ...................................................... 17
1.10.8 Chapter 9 – Thesis discussion ..................................................................... 17

Chapter 2 – Literature Review ................................................................................. 18

2.1 Cardiorespiratory fitness .................................................................................... 18
2.1.1 Assessing cardiorespiratory fitness ............................................................... 18
2.1.2 Cardiorespiratory fitness in stroke ............................................................... 20
2.2 Walking ability .................................................................................................. 21
2.2.1 Assessing walking ability ............................................................................. 22
2.2.2 Walking ability in stroke ............................................................................. 22
2.3 Leg strength ....................................................................................................... 23
2.3.1 Assessing leg strength ................................................................................ 24
2.3.2 Leg strength in stroke ................................................................. 24
2.4 Balance .......................................................................................... 25
  2.4.1 Assessing balance ................................................................. 25
  2.4.2 Balance in stroke ................................................................. 26
2.5 Body composition and muscle mass ........................................... 26
  2.5.1 Assessing body composition and muscle mass ................ 26
  2.5.2 Body composition and muscle mass in stroke ...... 27
2.6 Other measures ............................................................................. 28
  2.6.1 Blood pressure ................................................................. 28
  2.6.2 Electrocardiograph (ECG) ...................................................... 28
  2.6.3 Quality of life, fatigue and depression ........................ 28
2.7 Exercise prescription for improving cardiorespiratory fitness in stroke survivors ...... 29
1.8 Summary of Gaps in Knowledge .............................................. 33

Chapter 3 - Protocol variations and six-minute walk test performance in stroke survivors: a systematic review with meta-analysis ........................................... 36

3.1 Preface .......................................................................................... 36
3.2 Citation .......................................................................................... 36
3.3 My contributions .......................................................................... 36
3.4 Abstract ......................................................................................... 37
3.5 Introduction ................................................................................... 38
3.6 Methods ......................................................................................... 39
  3.6.1 Search strategy and selection criteria .............................. 39
  3.6.2 Selection of studies ............................................................... 40
  3.6.3 Data extraction and synthesis .......................................... 41
  3.6.4 Quantitative analysis of adherence to ATS protocol guidelines .................................................. 41
  3.6.5 Meta-analysis ........................................................................ 41
3.7 Results .......................................................................................... 42
3.7.1 Participant characteristics ................................................................. 44
3.7.2 Context of the 6MWT ................................................................. 62
3.7.3 Assistance and instructions provided ................................................ 62
3.7.4 Quantitative analysis of adherence to ATS protocol guidelines ............... 63
3.7.5 Modifications to the 6MWT protocol walkway length .......................... 63
3.7.6 Distances achieved using the 6MWT in stroke survivors ....................... 64
3.8 Discussion ....................................................................................... 65

Chapter 4 – Characteristics of exercise training interventions to improve
cardiorespiratory fitness after stroke: a systematic review with meta-analysis ..... 73

4.1 Preface ............................................................................................ 73
4.2 Citation ............................................................................................ 73
4.3 Background ...................................................................................... 74
4.4 Objective .......................................................................................... 74
4.5 Methods ........................................................................................... 75
4.6 Results .............................................................................................. 75
4.7 Conclusions ..................................................................................... 76

Chapter 5 – Evaluation of three measures of cardiorespiratory fitness in
independently ambulant stroke survivors ......................................................... 77

5.1 Preface ............................................................................................ 77
5.2 Citation ............................................................................................ 77
5.3 My Contribution ................................................................................ 77
5.4 Abstract ............................................................................................ 78
5.5 Introduction ....................................................................................... 78
5.6 Methods ........................................................................................... 81
5.6.1 Participants ................................................................................... 81
5.6.2 Data Collection ............................................................................ 81
5.6.3 Outcome Measures ....................................................................... 84
Chapter 6 - Independently ambulant, community dwelling stroke survivors have reduced cardiorespiratory fitness, mobility and knee strength compared to an age- and gender-matched cohort

6.1 Preface................................................................. 99
6.2 Citation.................................................................. 99
6.3 My Contribution......................................................... 100
6.4 Abstract .................................................................. 100
6.5 Introduction............................................................... 101
6.6 Methods...................................................................... 102
  6.6.1 Participants................................................................. 102
  6.6.2 Cardiorespiratory Fitness............................................... 104
  6.6.3 Six-Minute Walk Test.................................................. 104
  6.6.4 Incremental Shuttle Walk Test........................................ 105
  6.6.5 Upright Cycle Graded Exercise Test.............................. 105
  6.6.6 Walking Speed......................................................... 105
  6.6.7 Isometric and Isokinetic Leg Strength............................ 106
  6.6.8 Body Composition..................................................... 107
  6.6.9 Statistical Analysis..................................................... 107
6.7 Results...................................................................... 107
6.8 Discussion................................................................. 112
6.9 Conclusion............................................................... 115
Chapter 7 – A program of home and community based physical activity can improve the cardiorespiratory fitness and walking endurance of stroke survivors .......................................................... 117

7.1 Preface ........................................................................................................................................... 117
7.2 Citation ........................................................................................................................................ 117
7.3 My Contribution ........................................................................................................................... 117
7.4 An introduction to the HowFITSS? pilot exercise program ...................................................... 118

Chapter 8 – Cardiorespiratory fitness and walking endurance improvements at 12 months follow-up of an individually tailored home and community-based exercise program for stroke survivors ................................................................................. 122

8.1 Preface ........................................................................................................................................... 122
8.2 Citation ........................................................................................................................................ 122
8.3 My Contribution ........................................................................................................................... 122
8.4 Abstract ....................................................................................................................................... 123
8.5 Introduction ................................................................................................................................ 123
8.6 Methods ...................................................................................................................................... 125
  8.6.1 Study Design ............................................................................................................................ 125
  8.6.2 Participants ............................................................................................................................... 125
  8.6.3 Intervention ............................................................................................................................. 126
  8.6.4 Participant characteristics ....................................................................................................... 126
  8.6.5. Assessments .......................................................................................................................... 127
  8.6.6 Outcome Measures .................................................................................................................. 127
  8.6.7 Cardiorespiratory fitness assessments ..................................................................................... 127
  8.6.8 Secondary assessments ........................................................................................................... 129
  8.6.9 Statistical Analysis .................................................................................................................. 129
8.7 Results ........................................................................................................................................... 130
8.8 Discussion .................................................................................................................................... 139
8.8.1 Strengths and Limitations ................................................................. 142
8.9 Conclusion .............................................................................................. 144

Chapter 9 – Thesis Discussion ..................................................................... 145

9.1 Overview ............................................................................................... 145
9.2 Secondary aim 1 ..................................................................................... 146
  9.2.1 Additional studies ................................................................................ 146
  9.2.2 Implications and future considerations in research and practice .......... 147
  9.2.3 Systematic review of exercise interventions after stroke ..................... 148
9.3 Secondary aim 2 ..................................................................................... 149
  9.3.1 Implications and Future Considerations in Research and Practice .......... 150
9.4 Secondary aim 3 ..................................................................................... 151
  Compare cardiorespiratory fitness, walking ability, knee strength and body composition in independently ambulant, community dwelling stroke survivors to healthy age- and gender-matched comparison participants .................................................. 151
  9.4.1 Implications and Future Considerations in Research and Practice .......... 152
9.5 Primary aim ............................................................................................. 153
  9.5.1 Implications and future considerations in research and practice .......... 155
  9.5.2 Future directions for HowFITSS? ......................................................... 157
9.6 Concluding Remarks ............................................................................... 158

Chapter 10. References ................................................................................. 159

Chapter 11. Appendices ................................................................................ 203
  Appendix 1. Published manuscript of Chapter 3 ............................................ 203
  Appendix 2: Published manuscript of Chapter 4 .......................................... 204
  Appendix 3: Published manuscript of Chapter 6 ............................................ 205
  Appendix 4: Published manuscript of Chapter 7 .......................................... 206
  Appendix 5. Hunter New England Ethics Approval ...................................... 207
  Appendix 6: University of Newcastle Ethics Approval .................................. 208

xxvii
Appendix 7: ANZCTR Approval ........................................................................................................ 209
Appendix 8: Information Statement for Stroke Group ............................................................. 210
Appendix 9: Information Statement for Non-stroke Group ...................................................... 211
Appendix 10: Medical Clearance Form for Stroke Group ......................................................... 212
Appendix 11: ESSA Pre-exercise Screening Questionnaire for Non-stroke Group ........... 213
Appendix 12: Medical Clearance Form for Non-stroke Group ................................................ 214
Appendix 13: Participant Consent Form for Stroke Group ....................................................... 215
Appendix 14: Participant Consent Form for Non-stroke Group ............................................... 216
Appendix 16: HowFITSS? Demographics Recording Sheet for Stroke Group .................. 218
Appendix 17: Assessment Recording Sheet for Stroke Group ................................................ 219
Appendix 18: Follow-up HowFITSS? Assessment Recording Sheet for Stroke Group ....... 220
Appendix 19: HowFITSS? Assessment Recording Sheet for Non-stroke Group ................. 221
Appendix 20: Fatigue Assessment Scale (FAS) Questionnaire for Stroke and Non-stroke Group ........................................................................................................................................... 222
Appendix 21: Patient Health Questionnaire (PHQ-9) for Stroke and Non-stroke Group .... 223
Appendix 22: Stroke and Aphasia Quality of Life (SAQoL) Questionnaire for Stroke Group ........................................................................................................................................... 224
Appendix 23: The Short Form 12 Health Survey Questionnaire (SF-12) .............................. 225
Appendix 24: Statement of Contribution Chapter 3 ................................................................. 226
Appendix 25: Statement of Contribution Chapter 4 ................................................................. 227
Appendix 26: Statement of Contribution Chapter 5 ................................................................. 228
Appendix 27: Statement of Contribution Chapter 6 ................................................................. 229
Appendix 28: Statement of Contribution Chapter 7 ................................................................. 230
Appendix 29: Statement of Contribution Chapter 8 ................................................................. 231
List of Figures

Figure 1.2 Study design for the HowFITSS? pilot trial………………………………12
Figure 1.3 Breakdown of papers resulting from the HowFITSS? Trial………………..13
Figure 2.1 Forest plot of aerobic versus mixed interventions in their improvement of VO$_2$peak levels………………………………………………………………………………………..30
Figure 2.2 Diagrammatic overview of the World Health Organisation's International Classification of Functioning, Disability and Health……………………………………31
Figure 3.1 PRISMA flow diagram………………………………………………………..43
Figure 3.2 Distances achieved (point estimate, 95%CI) during the 6MWT based on walkway protocol used…………………………………………………………………………..65
Figure 5.1 Mean VO$_2$ (A), HR (B), VE (C) in each 20% increment of test time for the Shuttle Walk Test (SWT), Six-Minute Walk Test (6MWT) and Cycle Graded Exercise Test ………………………………………………………………………………..88
Figure 5.2 The differences in peak oxygen consumption (VO$_2$peak) achieved on the Cycle Graded Exercise Test – Six-Minute Walk Test (6MWT) and Cycle Graded Exercise Test – Shuttle Walk Test (SWT), plotted against the mean VO$_2$peak for the Cycle Graded Exercise Test……………………………………………………………………92
Figure 6.1 Stroke group results as a percentage of comparison group results (designated as 100%) for A) VO$_2$peak, HR$_{peak}$ and performance on cardiorespiratory fitness tests, and B) peak torque achieved for more affected and less affected limbs…………………..109
List of Tables

Table 3.1 Search strategy used for MEDLINE ................................................40
Table 3.2 Meta-regression coefficients for all studies ........................................44
Table 3.3 Description of included studies ..........................................................46
Table 3.4 Meta-regression coefficients for 30m protocol sub-group .......................64
Table 3.5 Checklist for reporting of the 6MWT ....................................................71
Table 5.1 Participant characteristics .................................................................87
Table 5.2 Peak cardiorespiratory and performance responses to the SWT, 6MWT and cycle GXT ..............................................................90
Table 6.1 Participant characteristics .................................................................108
Table 6.2 Outcome measures for stroke and comparison groups, including between group differences .................................................................111
Table 8.1 Participant characteristics at baseline (n=20). Data are mean ± SD or number (percentage) .................................................................132
Table 8.2 Mean and SD of outcomes measures at four time points over 12 months for those who attended each time point .............................................135
Table 8.3 Changes in outcome measures over the 12 months. P-values based on intention to treat mixed model analysis, effect sizes and percent changes based on those who attended each time point .............................................137