Influencing Sedentary Behavior Through Participation After Stroke

by

Emily A. Kringle

Master of Occupational Therapy, University of North Dakota, 2010

Submitted to the Graduate Faculty of

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2019

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

This dissertation was presented

by

Emily A. Kringle

It was defended on

March 27, 2019

and approved by

Bethany Barone Gibbs, Associate Professor, Department of Health and Physical Activity

Grace Campbell, Assistant Professor, Department of Acute and Tertiary Care

Michael McCue, Professor, Department of Rehabilitation Science and Technology

Lauren Terhorst, Associate Professor, Department of Occupational Therapy

Elizabeth Skidmore, Professor, Department of Occupational Therapy

Influencing Sedentary Behavior Through Participation After Stroke

Emily A. Kringle, PhD, OTR/L

University of Pittsburgh, 2019

People with stroke have persistent high levels of sedentary behavior. Sedentary behavior, or prolonged sitting, has been associated with the exacerbation of chronic health conditions that elevate the risk for recurrent stroke (e.g., diabetes, obesity, depression). Studies examining sedentary behavior and inactivity physiology suggest that reductions in sedentary behavior are associated with improvements in chronic health conditions. Participation in daily activities requires movement out of a seated position to an upright position, thereby reducing sedentary behavior. This may lead to improvements in chronic health conditions and reduced risk for recurrent stroke.

The overarching goal of this dissertation is to identify intervention elements that hold promise for reducing sedentary behavior among people with chronic stroke. A scoping review revealed that current stroke rehabilitation interventions are associated with small reductions in sedentary behavior over time. Few interventions were clearly specified, and few outcomes were clearly defined. This led to the development of the Activating Behavior for Lasting Engagement (ABLE) intervention. The ABLE intervention uses behavioral activation to promote frequent participation in daily activities to reduce post-stroke sedentary behavior. A descriptive case series (n=5) was conducted to specify the intervention protocol. A single group pre-post-test study (n=21) was conducted to assess the feasibility (safety, participant satisfaction, participant tolerability, reliable intervention delivery) and estimate change in sedentary behavior over time. The intervention was deemed safe, tolerable, and reliably delivered. Participant satisfaction scores did

not meet the benchmark for feasibility. Moderate to large effect sizes were detected at post-intervention using an objective measure of sedentary behavior (ActivPAL micro3); small effect sizes were detected at 8-week follow-up.

Future intervention refinement is required to enhance the feasibility and bolster effects of the ABLE intervention. These efforts should incorporate the context of participation and sedentary behavior. In addition, consideration of the role of active and inactive participation, patterns of participation, patterns of sedentary behavior, and aspects of the environment will be critical to develop interventions that reduce sedentary behavior and promote optimal health outcomes.

Table of Contents

Preface .... **xiii**

1.0 Introduction **1**

1.1 Sedentary Behavior **2**

1.2 Full-Day Engagement in Meaningful Activities **3**

1.2.1 Full-day view of sedentary behavior patterns **3**

1.2.2 Activity engagement and participation in meaningful activities after stroke 4

1.2.3 *Activity engagement* to break up sedentary behavior **6**

1.3 Objective and Aims **6**

2.0 Do Interventions Influence Sedentary Behavior and Daily Physical Activity After Stroke? A Scoping Review **8**

2.1 Methods **9**

2.2 Results **11**

2.2.1 Study Characteristics **11**

2.2.2 Participant Characteristics **14**

2.2.3 Outcome Measures **14**

2.2.3.1 Questionnaire-Based Measures **14**

2.2.3.2 Device-Based Measures **17**

2.2.3.3 Risk of Bias **18**

2.2.4 Interventions **18**

2.2.4.1 Studies of Single Component Interventions **21**

2.2.4.2 Studies of Multi-Component Interventions **22**

2.3 Discussion 28
2.3.1 Complex Interventions 28
2.3.1.1 Exercise 29
2.3.1.2 Behavior Change Techniques 29
2.3.1.3 Education 30
2.3.2 Intervention Outcomes 30
2.3.3 Limitations 31
2.3.4 Future Directions 31
3.0 Activating Behavior for Lasting Engagement (ABLE) to Reduce Sedentary Behavior After Stroke: A Descriptive Case Series 33
3.1 Case Description 35
3.1.1 Study Design 35
3.1.2 Participants 35
3.1.3 Intervention 36
3.1.3.1 Structural Elements 37
3.1.3.2 Essential Elements 37
3.1.4 Measures 38
3.1.4.1 Tolerability 38
3.1.4.2 Acceptability 38
3.1.4.3 Reliability 39
3.1.4.4 Safety 39
3.1.4.5 Sedentary Behavior 39
3.1.4.6 Sample Characteristics 40

3.1.5 Analyses 41
3.2 Results 41
3.2.1 Participants 41
3.2.2 Intervention Refinement 43
3.2.3 Feasibility 43
3.2.3.1 Tolerability 43
3.2.3.2 Acceptability 44
3.2.3.3 Safety 44
3.2.3.4 Reliability 44
3.2.4 Sedentary Behavior Outcomes 45
3.3 Discussion 46
3.3.1 Change in Sedentary Behavior 47
3.3.2 Social Environment 47
3.3.3 Assessing Need for Sedentary Behavior Intervention 48
3.3.4 Limitations 49
3.3.5 Future Directions 49
4.0 ABLE After Stroke: Feasibility and Preliminary Effects of a Behavioral Activation-Based Intervention on Sedentary Behavior 51
4.1 Methods 52
4.1.1 Participants 53
4.1.2 Intervention 55
4.1.2.1 ABLE Intervention Protocol 55
4.1.2.2 Feasibility Measures 55

4.1.3 Clinical Measures 57
4.1.3.1 Descriptive Characteristics 58
4.1.3.2 Primary Outcomes 58
4.1.3.3 Exploratory Outcomes 59
4.1.4 Analyses 60
4.1.4.1 Descriptive Characteristics 60
4.1.4.2 Change on primary and exploratory outcomes over time 60
4.2 Results 64
4.2.1 Recruitment and Retention 64
4.2.2 Participants 64
4.2.3 Intervention Feasibility 66
4.2.4 Change over time on primary and exploratory outcomes 67
4.2.4.1 Primary Outcomes 68
4.2.4.2 Exploratory Outcomes 71
4.3 Discussion 72
4.3.1 Limitations 75
4.3.2 Future Directions 76
4.3.3 Conclusions 76
5.0 Discussion 80
5.1 Participation: Daily activities in context 81
5.1.1 Sedentary and non-sedentary participation 82
5.1.2 Participation and activity patterns 83
5.2 Full-day physical activity: Sedentary behavior in context 84

5.2.1 Contextualizing sedentary behavior ... 84

5.2.2 Modifying post-stroke sedentary behavior ... 86

5.2.3 Assessing post-stroke sedentary behavior ... 87

5.3 Future Directions: Contextualizing Post-Stroke Health Behaviors ... 89

5.4 Conclusion ... 91

Appendix A Activating Behavior for Lasting Engagement (ABLE) Intervention Development ... 92

A.1 Theoretical Framework of the ABLE Intervention ... 92

A.2 ABLE Intervention: Iterations ... 94

A.3 Participant Workbook ... 96

A.4 Fidelity Assessment ... 96

Appendix B ActivPAL Procedures ... 102

B.1 ActivPAL Data Reduction ... 102

B.2 ActivPAL Variables ... 104

Appendix C ABLE Study: Change Over Time on Exploratory Outcomes ... 107

Appendix D Publications, Presentations, and Awards ... 115

D.1 Publications ... 115

D.2 Presentations ... 115

Bibliography ... 117

List of Tables

Table 1 Scoping review: Study characteristics ... 13

Table 2 Scoping review: Participant characteristics ... 15

Table 3 Scoping review: Outcome measures ... 19

Table 4 Scoping review: Risk of bias ... 20

Table 5 Scoping review: Interventions and effects ... 23

Table 6 ABLE intervention elements ... 36

Table 7 ABLE case series: Participant characteristics ... 42

Table 8 ABLE case series: Feasibility outcomes ... 44

Table 9 ABLE case series: Activity monitoring outcomes ... 45

Table 10 ABLE study: Participant characteristics ... 65

Table 11 ABLE study: Feasibility outcomes ... 67

Table 12 ABLE study: Change over time on primary and exploratory outcomes ... 69

Table 13 ABLE study: Linear mixed models of primary and exploratory outcomes ... 70

Table 14 ABLE intervention iterations ... 97

Table 15 Guiding principles for ActivPAL data reduction ... 103

List of Figures

Figure 1 Scoping review: Article selection 12

Figure 2 ABLE study: Study design 54

Figure 3 ABLE study: Participant flow 63

Figure 4 ABLE study: Change over time on prolonged sitting (≥30 minutes) 78

Figure 5 ABLE study: Change over time on mean daily sit-stand transitions 79

Figure 6 ABLE study: Change over time on mean daily total sitting time 109

Figure 7 ABLE study: Change over time on mean daily prolonged sitting (≥60 minutes) 110

Figure 8 ABLE study: Change over time on typical weekday sitting time (SBQ) 111

Figure 9 ABLE study: Change over time on total weekly sitting (SBQ) 112

Figure 10 ABLE study: Change over time on mean daily step count 113

Figure 11 ABLE study: Change in participation over time 114

Preface

This work would not have been successful without support from my community. There are too many individuals to name. I am grateful for my mentors, my colleagues, my patients, and my family and friends who encouraged me to choose this path and supported me along this journey. I am also grateful for the thoughtful guidance from each of my committee members throughout this process. The dedicated staff of the Occupational Therapy Cognitive Performance Laboratory were critical to the completion of these studies. Finally, to the people who participated in the studies described here—thank you. Your time, commitment, curiosity, and wisdom made a difference.

This work was supported by the School of Health and Rehabilitation Sciences PhD Student Pilot Award and Department of Occupational Therapy Research Development Funds. Publications, presentations, and awards associated with this work are listed in Appendix D.

1.0 Introduction

Nearly one third of the 7.2 million Americans who currently live with chronic stroke-related impairments will sustain a recurrent stroke within their lifetime (American Heart Association et al., 2017). Recurrent stroke is costly to individuals and healthcare systems, resulting in poor functional outcomes, poor health outcomes, and high monetary expenses. Lifestyle modification is an important component for managing health conditions associated with risk for recurrent stroke (i.e., diabetes, hypertension, obesity) (Hankey & Warlow, 1999). Traditional post-stroke rehabilitation approaches focus on remediating impairments and training people in compensatory strategies to support independence in daily living activities. Rehabilitation approaches may also contribute to lifestyle modification and engagement in health behaviors that can reduce the risk for recurrent stroke.

Physical activity behavior patterns over the full 24-hour day can have a powerful influence on the health conditions that are associated with recurrent stroke. Traditional physical activity interventions promote adherence to a recommended dose or program of exercise. (Billinger et al., 2014). These interventions do not address activity patterns during remaining hours of the day. That is, despite achieving the recommended dose of exercise (30 minutes of moderate-to-vigorous physical activity daily), low physical activity levels over the remaining 23-1/2 waking hours can contribute to poor health. Stroke survivors spend a large portion of these hours in prolonged sitting, or *sedentary*, behaviors (19.3 to 22.1 hours per day) (Moore et al., 2013b; Tieges et al., 2015). Modifying these full-day physical activity patterns to incorporate reduced time in prolonged sitting could influence health and reduce the risk for recurrent stroke.

1.1 Sedentary Behavior

High levels of sedentary behavior are detrimental to health. *Sedentary behavior* is defined as *waking time* spent in a *seated or reclined position*, engaged in activities which require an *energy expenditure ≤1.5 METS* (Tremblay et al., 2017). Sedentary behavior is associated with health risks even after controlling for lack of adherence to exercise recommendations (Healy et al., 2008b). Among heathy older adults, high levels of sedentary behavior are associated with poor cardiometabolic health, depression, obesity, and morbidity (Buman et al., 2013; de Rezende, Lopes, Rey-López, Matsudo, & do Carmo Luiz, 2014; Thorp, Owen, Neuhaus, & Dunstan, 2011). For people with vascular disease, as in the case of many people who have had a stroke, high levels of sedentary behavior may elevate the risk for recurrent stroke (Ford & Caspersen, 2012). Thus, reducing sedentary behavior holds promise to promote health among people with stroke.

Prior approaches to sedentary behavior modification have taken two approaches: 1) displacing time spent in sedentary behavior with physical activity (English et al., 2016b), and 2) modifying the pattern of sedentary behavior accumulation throughout the day (Ezeugwu & Manns, 2018). Sedentary behavior accumulation can be described by examining the lengths of the time periods spent in uninterrupted sitting. Each period of time spent in uninterrupted sitting is referred to as a *bout* (Tremblay et al., 2017). Among healthy adults, sedentary behavior accumulated in short bouts (<30 minutes) was associated with better cardiometabolic health outcomes than that which was accumulated in prolonged bouts (>30 minutes) (Healy et al., 2008a).

Persistent motor, cognitive, and affective impairments post-stroke provide unique challenges to modifying sedentary behavior and promoting physical activity. Motor impairments may limit stroke survivors' mobility and result in difficulty engaging in moderate-to-vigorous intensity activities or exercise (Langhorne, Coupar, & Pollock, 2009). Cognitive impairments are associated with difficulty generating ideas, organizing daily activities, and engaging in previously enjoyed activities (Douiri, Rudd, & Wolfe, 2013). Affective impairments, in particular depressive symptoms, have been associated with low physical activity levels (Robinson & Jorge, 2015). Displacing high volumes of sedentary behavior with moderate-to-vigorous physical activities or exercise may not be feasible or safe for stroke survivors (Morton et al., 2018). In addition, stroke survivors with cognitive or affective impairments may have difficulty generating or initiating strategies to engage in high levels of physical activity. Therefore, it is necessary to consider all of these factors when designing post-stroke sedentary behavior and physical activity interventions.

1.2 Full-Day Engagement in Meaningful Activities

1.2.1 Full-day view of sedentary behavior patterns

Breaking up sedentary behavior into short bouts of sitting has been associated with positive health outcomes among people with cardiovascular disease. Sedentary behavior is broken into short bouts of sitting by moving from a seated or reclined position into an upright position at selected intervals (Tremblay et al., 2017). The duration and frequency of bouts of sedentary behavior can be measured through wearable monitors within the context of the full day in which people live. Studies examining sedentary behavior accumulation demonstrated that sedentary time interrupted by upright activity was associated with lower waist circumference, body mass index, glucose levels, and insulin levels relative to uninterrupted sedentary time among overweight adults (Chastin, Egerton, Leask, & Stamatakis, 2015a; Dunstan et al., 2012; Healy et al., 2008a; Healy, Winkler, Brakenridge, Reeves, & Eakin, 2015). In addition, displacing sedentary time with light, moderate, or vigorous intensity physical activity was associated with cardiometabolic risk, obesity, all-cause mortality and quality of life (Balboa-Castillo, León-Muñoz, Graciani, Rodríguez-Artalejo, & Guallar-Castillón, 2011; Buman et al., 2013; Chastin, Palarea-Albaladejo, Dontje, & Skelton, 2015b; Hamer, Stamatakis, & Steptoe, 2014; Stamatakis et al., 2015). While moderate-to-vigorous intensity physical activities was associated with greater health outcomes, displacing 30 minutes of sedentary time with light intensity physical activity was sufficient for reduced cardiometabolic risk factors (i.e., insulin, insulin sensitivity, triglycerides) (Buman et al., 2013). Thus, breaking up sedentary behavior with varied intensities of physical activity based on stroke survivors' abilities and interest may be associated with positive health outcomes.

1.2.2 Activity engagement and participation in meaningful activities after stroke

People living with disability describe participation as *being part of* life situations of their choosing, in which *access and opportunities* allow *choice and control* over which activities they decide to engage in, while fulfilling *personal and societal responsibilities* (Hammel et al., 2008). *Participation* is defined by the World Health Organization as purposeful and meaningful activities that occur within a personally meaningful context (World Health Organization, 2001). That is, the ability to stand in one place for fifteen minutes may carry little meaning in and of itself. Yet, the standing in one place for fifteen minutes while singing with the church choir gives meaning and purpose to the individual who chooses to engage in that role. Participation restrictions and limited activity engagement post-stroke are well-documented (Desrosiers et al., 2006; Hartman-Maeir, Soroker, Ring, Avni, & Katz, 2007; Mayo, Wood-Dauphinee, Coˆte, Durcan, & Carlton, 2002; Viscogliosi et al., 2011). Low levels of participation persist through the chronic phase of stroke (Desrosiers & Bourbonnais, 2005; Desrosiers et al., 2006; Hartman-Maeir et al., 2007). In addition, stroke survivors report high levels of dissatisfaction with participation outcomes (Hartman-Maeir et al., 2007). Contemporary stroke rehabilitation programs focus on skills required to complete activities associated with participation (e.g., ability to fold a sheet of paper in half). Data suggest, however, that without interventions directed at promoting participation, these skills do not generalize to the contexts within which people live (Atler, Malcolm, & Greife, 2015).

Complex cognitive and behavioral intervention approaches show promise for promoting activity engagement and participation after stroke. A metacognitive approach (Cognitive Orientation to Occupational Performance) promoted generalization of task specific training to untrained tasks (McEwen et al., 2015). During one-on-one intervention sessions, stroke survivors learned to apply a 4-step problem solving strategy to any activity in which they desired to participate. The therapist guided the process by asking probing questions to promote the stroke survivors' problem solving and generalization of approaches to other activities. This approach resulted in a moderate to large change in participation over time (McEwen et al., 2015). Self-management programs apply social cognitive theory to teach participants skills for setting individualized goals, action planning, and problem solving. Self-management approaches delivered during rehabilitation day programs (Lee, Fischer, Zera, Robertson, & Hammel, 2017) and in community-based settings (Wolf, Baum, Lee, & Hammel, 2016) resulted in moderate to large effects on community participation. These approaches demonstrate that goal setting, a structured planning process, and problem-solving skills may be important components of interventions that promote community participation after stroke.

1.2.3 *Activity engagement* to break up sedentary behavior

Promoting engagement in individually valued activities holds promise to reduce sedentary behavior after stroke. To engage in activities within context frequently requires movement to an upright position to either access the environment or engage in the activity itself. Engagement in valued activities may occur at any time throughout the day. Frequent activity engagement throughout the day can distribute activity and break up prolonged bouts of sitting. The intensity of movement required during engagement in valued activities can range from light intensity (e.g., standing to answering the door), to vigorous intensity (e.g., completing a landscaping project). Evidence for sedentary behavior modification suggests that even brief upright periods during prolonged sitting can be beneficial to health (Benatti & Ried-Larsen, 2015). Interventions that promote activity engagement can be tailored to the person's preferences and abilities while achieving these interruptions to sedentary behavior. Promoting engagement in meaningful activities within the context of the full day may, therefore, be an effective approach to promote daily activity patterns that support health after stroke.

1.3 Objective and Aims

The overarching objective of this dissertation is to identify intervention elements that hold promise to reduce sedentary behavior and promote activity engagement among people with chronic stroke. This will be accomplished through three aims:

1. Identify intervention approaches and effects of these interventions for modifying physical activity behaviors post-stroke.

2. Assess the feasibility of a theoretically-driven intervention that aims to reduce sedentary behavior using an activity engagement-focused approach.
3. Estimate the effects of a theoretically-driven intervention that aims to reduce sedentary behavior using an activity engagement-focused approach.

The development of post-stroke sedentary behavior interventions is in its infancy. Few existing interventions specify sedentary behavior as the primary outcome. Among these, no interventions explored the role of engagement in meaningful activities in promoting reductions in sedentary behavior. Identifying the effects of current approaches on the frequency of engagement in daily life activities may inform intervention elements that could contribute to reducing sedentary behavior. Overall, the present work will advance knowledge of intervention elements that may contribute to reducing post-stroke sedentary behavior.

2.0 Do Interventions Influence Sedentary Behavior and Daily Physical Activity After Stroke? A Scoping Review

The contents of this chapter are included in the following manuscript, currently under review: Kringle EA, Barone Gibbs B, Campbell G, Terhorst L, McCue M, Kersey J, Skidmore ER. Do interventions influence daily living physical activity and sedentary behavior after stroke? A narrative review.

Despite recommendations, stroke survivors engage in low levels of physical activity and high levels of sedentary behavior, or sitting time, relative to healthy community-dwelling populations (Damush, Plue, Bakas, Schmid, & Williams, 2007; Michael, Allen, & Macko, 2005; Rimmer, Wang, & Smith, 2008; Tudor-Locke, Craig, Thyfault, & Spence, 2012). In addition, stroke survivors achieve fewer than 3,000 steps per day, and do not meet the daily step count recommendation of 7,500 steps per day (English et al., 2016a; English, Manns, Tucak, & Bernhardt, 2014; Tudor-Locke et al., 2012). Physical activity recommendations are frequently unmet due to stroke-related impairments (e.g., motor function), motivation, transportation challenges, cost, and health concerns (Cleland et al., 2015; Damush et al., 2007; Rimmer et al., 2008). These barriers are difficult to overcome and result in sedentary lifestyles that place stroke survivors at risk for recurrent stroke. Advances in the field of inactivity physiology suggest that displacing sedentary behavior with frequent engagement in physical activity in the course of daily routines (e.g., housework, yardwork) acts on biological mechanisms that may produce positive health outcomes for individuals with impaired cardiovascular function (e.g., stroke) or obesity (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008). Frequent engagement in physical activity during daily routines, hereafter *daily physical activity* may be an achievable aim of intervention for stroke survivors, as these activities are typically low cost, do not require transportation to a fitness center, and may be safely performed despite residual stroke-related impairments.

Prior reviews of physical activity post-stroke described levels of physical activity (English et al., 2014), approaches to measuring physical activity (Gebruers, Vanroy, Truijen, Engelborghs, & De Deyn, 2010), and interventions promoting long-term adherence to physical activity or exercise programs (Moore et al., 2018; Morris, MacGillivray, & Mcfarlane, 2014). However, intervention approaches that are effective to reduce sedentary behavior and promote engagement in daily physical activity other than exercise remains unclear. Thus, our goals in conducting this review were to:

1) Describe current intervention approaches in which changes in sedentary behavior or daily physical activity were detected.
2) Identify effects of post-stroke interventions on sedentary behavior daily physical activity.

This knowledge will support the advancement of intervention development and implementation for promoting healthy lifestyles among stroke survivors who are at risk for recurrent stroke.

2.1 Methods

We queried OVID/Medline, CINAHL, PsycINFO, and the Cochrane database using combinations of the following search terms: physical activity, sedentary, stroke, rehabilitation, intervention, self-management, exercise, lifestyle (e.g., "physical activity AND stroke rehabilitation AND intervention"). No date restrictions were applied. Studies were included if they: 1) examined an intervention post-stroke, 2) contained primary or secondary outcome measures of sedentary behavior or daily physical activity, and 3) used a randomized or non-randomized experimental design. *Sedentary behavior* was defined by measurement of posture (i.e., seated or reclined). *Daily physical activity* was defined by measurement of duration, volume, or dichotomous report (yes/no) of engagement in daily physical activities not associated with exercise (e.g., childcare, employment, housework). Studies were excluded if they: 1) did not measure sedentary behavior or daily physical activity, 2) reported on descriptive studies, 3) were non-data based, 4) were unavailable in English, 5) delivered intervention to hospitalized patients, and 6) did not include people with stroke. Review articles were examined to identify additional intervention studies that contained measures of sedentary behavior or daily physical activity. One author (EAK) reviewed abstracts and articles to determine inclusion. Data extraction (participant characteristics, outcome measures, intervention effects, intervention approaches) was conducted by two authors (EAK and JK). Discrepancies were resolved through discussion. Effect sizes (e.g., Cohen's *d*) were calculated for within group change over time (baseline to post-intervention and baseline to 3-months) and within-between interaction effects. Unreported data required for these calculations were requested from the authors. Results were summarized to identify interventions and their effects on sedentary behavior effects and daily physical activity after stroke ($p<.05$). The Cochrane Systems Risk of Bias Tool was used to examine risk for bias within studies (randomization sequence, allocation concealment, participant blinding, therapist blinding, blinded assessor, attrition reported) (*Cochrane handbook for systematic reviews of interventions*, 2011). Two authors (EAK and ERS) conducted independent reviews and resolved discrepancies through discussion.

2.2 Results

2.2.1 Study Characteristics

The search was last conducted in January 2019. After removing duplicates, we reviewed 765 abstracts (Figure 1). Of these, 715 were excluded because they: 1) did not measure sedentary behavior or daily physical activity (n=187), 2) reported on descriptive studies (n=73), 3) were non-data based (n=137), 4) were unavailable in English (n=2), 5) were conducted in a non-stroke population (n=176), or were review articles (n=140). An additional 18 studies were identified through review articles and hand searching. The remaining 50 articles were reviewed and 19 were excluded because they did not measure sedentary behavior or daily physical activity (n=8), was non-data-based (n=3), was conducted in a non-stroke population (n=1) or delivered the intervention to hospitalized patients (n=7). We identified 31 intervention studies that measured change in sedentary behavior or daily physical activity after stroke.

Studies were randomized controlled trials (n=17) and non-randomized trials (parallel groups, n=4 and single-group, n=10). Sample sizes ranged from 9 to 408 (median=44). Study endpoints were post-intervention (n=13), 1-month (n=1), 2-months (n=1), 3-months (n=9), 6-months (n=1) and greater than 6-months (n=6) following intervention. Usual care (n=6), inactive control intervention (n=11), and no intervention (n=4) were used as control conditions (Table 1).

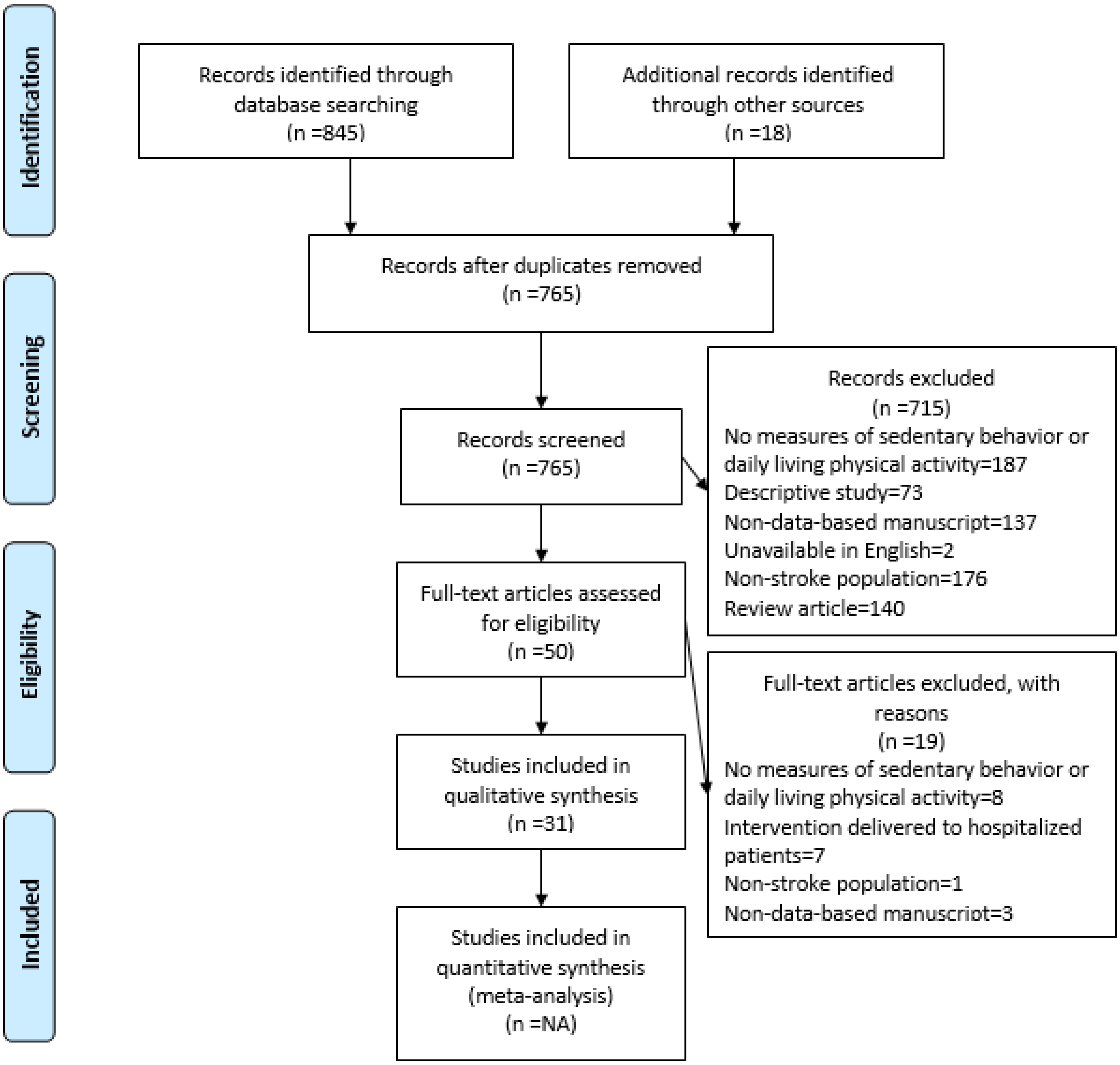

Figure 1 Scoping review: Article selection

Table 1 Scoping review: Study characteristics

	Number of studies
Clinical Population	
Stroke	29
Mixed neurological impairments (inclusive of stroke)	2
Stage of recovery	
Acute (≤90 days post-stroke)	5
Chronic (>90 days post-stroke)	26
Study Design	
Randomized controlled trial	17
Non-randomized, parallel groups	4
Non-randomized, single group	10
Study Endpoint	
Post-intervention	13
1 month post-intervention	1
2 months post-intervention	1
3 months post-intervention	9
6 months post-intervention	1
>6 months post-intervention	6
Role of daily physical activity level	
Primary outcome	11
Secondary outcome	20
Approach to intervention[a]	
Education	12
Exercise	22
Behavior Change Strategies	15
Multi-Component	17
Single Component	14
Control Intervention	
Usual care	6
Inactive control	11
No intervention	4
No control group (single group design)	10
Risk for Bias[b]	
Random Sequence	16
Allocation Concealment	13
Participant Blinding	0
Therapist Blinding	0
Assessor Blinding	16
Attrition Reported	29
Attrition >20%	11

[a]Number of interventions in which exercise, behavior change techniques, or education were included. Multi-component interventions included at least 2 different approaches. Single component interventions included only exercise, behavior change techniques, or education.
[b]Based on Cochrane Risk for Bias Reporting Tool (*Cochrane handbook for systematic reviews of interventions*, 2011)

2.2.2 Participant Characteristics

Mean participant age ranged from 36.9 to 76.0 years (Table 2). Studies were conducted in the acute (≤90 days post-stroke, n=5) and chronic (n=25) phases of rehabilitation. One study did not report stroke chronicity. Participants in studies conducted during the acute phase of stroke met inclusion criteria related to chronicity (Kirk et al., 2014). Mean chronicity among participants in the chronic phase ranged from 111.3 days to 12.2 years. Stroke severity was reported in 5 studies. Four reported that participants had mild impairments (Askim et al., 2018; Boysen et al., 2009; English et al., 2016b; Severinsen, Jakobsen, Pedersen, Overgaard, & Andersen, 2014), and one reported that participants had moderate to severe impairments (Duncan et al., 2011).

2.2.3 Outcome Measures

Measures of sedentary behavior or daily physical activity were identified as the primary clinical outcome among 11 studies and the secondary outcomes among 20 studies. These outcomes were assessed using questionnaire-based measures or device-based measures (Table 3). One study included both questionnaire-based and device-based measures of daily physical activity (Mudge, Barber, & Stott, 2009).

2.2.3.1 Questionnaire-Based Measures

The CHAMPS Physical Activity Questionnaire for Older Adults (n=1) (Mayo et al., 2015), Human Activity Profile (n=2) (Olney et al., 2006; Sharp & Brouwer, 1997), International Physical Activity Questionnaire (n=2) (Askim et al., 2018; Faulkner et al., 2015), Minnesota Leisure-Time Physical Activity Questionnaire (n=1) (Pang & Lau, 2010), Multimedia Activity Recall for

Table 2 Scoping review: Participant characteristics

Randomized Controlled Trials					
Author, Year	Stroke Phase	Sample Size	[a]Age (years)	[a]Stroke Chronicity	[ab]Stroke Severity
Logan, 2004	Chronic	Control (n=82) Experimental (n=86)	74.0 (8.6) 74.0 (8.4)	10 (9.0) months 11 (8.4) months	NR
Pang, 2005	Chronic	Control (n=31) Experimental (n=32)	64.7 (8.4) 65.8 (9.1)	5.1 (3.6) years 5.2 (5.0) years	NR
Olney, 2006	Chronic	Control (n=35) Experimental (n=37)	65.8 (11.6) 63.5 (12.0)	3.5 (3.9) years 4.1 (4.4) years	NR
Boysen, 2009	Acute	Control (n=157) Experimental (n=157)	[c]69.4 (59.6-75.8) [c]69.7 (60.0-77.7)	NR	[cd]54.0 [cd]54.0
Mudge, 2009	Chronic	Control (n=27) Experimental (n=31)	[e]71.0 (44.0-86.0) [e]76.0 (39.0-89.0)	[e]5.8 (0.5-18.7) years [e]3.3 (0.6-13.3) years	NR
Duncan, 2011	Acute	Control (n=126) Experimental 1 (n=139) Experimental 2 (n=143)	62.6 (13.3) 60.1 (12.3) 63.3 (12.5)	62.9 (8.0) days 64.1 (8.3) days 64.2 (9.0) days	[f]≤2=16.7%; >2=83.3%[i] [f]≤2=8.6%; >2=91.4%[i] [f]≤2=16.1%; >2=83.9%[i]
Dean, 2012	Chronic	Control (n=75) Experimental (n=76)	67.5 (10.2) 66.7 (14.3)	5.2 (5.4) years 6.7 (6.7) years	NR
Shaughnessy, 2012	Chronic	Control (n=56) Experimental (n=57)	NR	NR	NR
Severinsen, 2013	Chronic	Control (n=16) Experimental 1 (n=13) Experimental 2 (n=14)	[e]66 (52-80) [e]69 (50-80) [e]68 (57-78)	[e]16 (9-38) months [e]14 (11-29) months [e]19 (8-36) months	[de]53 (33-58) [de]54 (41-58) [de]53 (32-55)
Kirk, 2014	Acute	Control (n=12) Experimental (n=12)	66.8 (7.3) 67.5 (11.4)	NR	NR
Faulkner, 2015	Acute	Control (n=28) Experimental (n=27)	68.0 (10.0) 65.0 (11.0)	NR	[g]NR
Mayo, 2015	Chronic	Control (n=93) Experimental (n=93)	65.0 (11.0) 61.0 (12.0)	3.1 (3.1) years 2.5 (2.2) years	NR
English, 2016	Chronic	Control (n=14) Experimental (n=19)	67.8 (13.8) 65.4 (12.3)	4.1 (4.3) years 2.8 (2.6) years	[h]≤4=71.4%; >4=28.6% [h]≤4=73.7%; >4=26.3%
Givon, 2016	Chronic	Control (n=23) Experimental (n=24)	62.0 (9.3) 56.7 (9.3)	2.6 (1.8) years 3.0 (1.8) years	NR

Table 2 continued

Vahlberg, 2017	Chronic	Control (n=33) Experimental (n=34)	73.7 (5.3) 72.6 (5.5)	13.0 (2.0) months 13.0 (4.0) months	NR
Dean, 2018	Chronic	Control (n=22) Experimental (n=23)	71.00 (10.0) 70.0 (12.0)	>12 mo=86% >12 mo=87%	NR
Askim, 2018	Chronic	Control (n=194) Experimental (n=186)	72.3 (11.3) 71.7 (11.9)	112.0 (17.2) days 111.3 (24.5) days	1.6 (2.5) 1.5 (2.3)
Non-randomized, parallel groups					
Author, Year	Stroke Phase	Sample Size	Age (years)	Stroke Chronicity	Stroke Severity
Sit, 2007	Chronic	Control (n=83) Experimental (n=107)	64.0 (12.0) 62.8 (10.2)	NR	NR
Pang, 2010	Chronic	Control (n=11) Experimental (n=10)	64.5 (6.2) 64.6 (7.2)	7.3 (4.2) years 9.3 (3.2) years	NR
Clanchy, 2016	Chronic	Control (n=20) Experimental (n=23)	36.9 (11.4) 39.2 (12.5)	NR	NR
Paul, 2016	Chronic	Control (n=8) Experimental (n=15)	55.3 (12.6) 56.3 (8.7)	4.9 (6.1) years 3.8 (2.5) years	NR
Non-randomized, single group					
Author, Year	Stroke Phase	Sample Size	[a]Age (years)	[a]Stroke Chronicity	[ab]Stroke Severity
Sharp, 1997	Chronic	n=15	67.0 (10.0)	[i]0.9 to 18.0 years	NR
Bastien, 1998	NR	n=24	Male: 64.2 (9.0) Female: 67.4 (7.6)	NR	NR
Michael, 2009	Chronic	n=10	71.0 ([i]61.0-79.0)	7.5 ([i]4.0-22.0) years	NR
Touillet, 2010	Chronic	n=9	46.3 (7.2)	7.2 (5.1) months	NR
Heeren, 2013	Chronic	n=16	54.8 (10.8)	17.0 (11.0) months	NR
Danks, 2014	Chronic	n=16	66.1 (11.3)	49.7 (38.5) months	NR
Sullivan, 2014	Chronic	n=11	60.4 (12.1)	12.2 (7.7) years	NR
Jones, 2016	Chronic	n=24	51.1 (16.5)	[c]4.42 (1.4-7.4) years	NR
Preston, 2017	Acute	n=20	68.0 (12.0)	16 (7) days	NR
Ezeugwu, 2018	Chronic	n=34	64.6 (12.5)	3.5 (1.1) months	NR

[a]Mean (standard deviation) age, chronicity, and severity unless otherwise indicated. [b]National Institutes of Health Stroke Scale unless otherwise indicated. [c]Median (interquartile range). [d]Scandinavian Stroke Scale. [e]Median (range). [f]Categorical reporting of severity using Modified Rankin Score. Percentage of group with scores indicating no or slight disability, greater than slight disability. [g]Inclusion criteria required new diagnosis of transient ischemic attack or mild stroke within previous 7 days. [h]Categorical reporting of severity using NIHSS. Percentage of group with scores indicating mild stroke, greater than mild stroke. [i]Range.

Children and Adolescents (n=1) (English et al., 2016b), Physical Activity and Disability Survey (n=1) (Mudge et al., 2009), Physical Activity Scale (Danish Version, n=1) (Severinsen et al., 2014), Physical Activity Scale for Individuals with Physical Disabilities (n=1) (Pang, Eng, Dawson, McKay, & Harris, 2005), Physical Activity Scale for the Elderly (n=2) (Boysen et al., 2009; Vahlberg, Cederholm, Lindmark, Zetterberg, & Hellström, 2017), and Yale Physical Activity Survey (n=1) (Shaughnessy, Michael, & Resnick, 2012) were used to measure daily physical activities. In addition, 4 studies used activity checklists that asked participants to report their level of engagement in specific daily physical activities (Bastien, Korner-Bitensky, Lalonde, LeBrun, & Matte, 1998; Kirk et al., 2014; Logan et al., 2004; Sit, Yip, Ko, Gun, & Lee, 2007). The International Physical Activity Questionnaire, Physical Activity Scale (Danish Version), Physical Activity Scale for Individuals with Disability, and Physical Activity Scale for the Elderly each contain one item in which participants are asked to report on time spent engaged in sitting or stationary activities, thus also measuring sedentary behavior if item-level scores are reported (Aadahl & JØrgensen, 2003; Craig et al., 2003; Washburn, Smith, Jette, & Janney, 1993; Washburn, Zhu, McAuley, Frogley, & Figoni, 2002). No studies that used theses questionnaires reported item-level scores.

2.2.3.2 Device-Based Measures

Fourteen studies measured changes in step count using a variety of devices: pedometer (Dean et al., 2012; Heeren et al., 2013; Sullivan, Espe, Kelly, Veilbig, & Kwasny, 2014), ActiCal (Philips, Netherlands) (Givon, Zeilig, Weingarden, & Rand, 2016), ActivPAL (Pal Technologies, Glasgow) (English et al., 2016b; Ezeugwu & Manns, 2018; Jones, Dear, Hush, Titov, & Dean, 2016; Paul et al., 2016; Touillet, Guesdon, Bosser, Beis, & Paysant, 2010), Step Activity Monitor (Cyma Corporation, Mountlake Terrace) (Danks, Roos, McCoy, & Reisman, 2014; Duncan et al., 2011; Michael et al., 2009; Mudge et al., 2009), and Sensewear Armband (Body Media, San Francisco) (Preston et al., 2017). Activity counts were assessed in three studies using the ActiGraph (Actigraph Corp, Pensacola) (Clanchy, Tweedy, & Trost, 2016), Senswear Armband(Body Media, San Francisco) (Preston et al., 2017), or GENEACTiv (ActivInsights, Cambridge) (Dean et al., 2018). These devices sample activity counts associated with the user's rate of acceleration, and established cut-points determine time spent in varying intensities of physical activity. Time spent in sitting, standing, and stepping was measured in four studies using the ActivPAL (English et al., 2016b; Ezeugwu & Manns, 2018; Jones et al., 2016; Paul et al., 2016). The ActivPAL measures the user's position and acceleration.

2.2.3.3 Risk of Bias

Risk of bias within studies was assessed using the Cochrane Risk of Bias Tool (Table 4) (*Cochrane handbook for systematic reviews of interventions*, 2011). Sixteen studies reported randomization, 13 studies described allocation concealment, 16 studies used blinded assessors, and 18 of 29 trials reported attrition less than 20%. Eleven studies reported attrition greater than 20%. Blinding of the therapist and the participants is challenging in behavioral intervention research. No studies among the included studies blinded therapists or participants.

2.2.4 Interventions

Intervention components were classified as exercise, behavior change techniques (Michie, Fixsen, Grimshaw, & Eccles, 2009), and education. These components were delivered individually and in combination. We examined approaches to interventions that were associated with within-between interaction effects and within-group effects (baseline to post-intervention, baseline to 3-

Table 3 Scoping review: Outcome measures

	Measurement Tool	Sedentary Behavior	Amount of Physical Activity	N
Questionnaire-Based	Activity Checklist (Bastien et al., 1998; Kirk et al., 2014; Logan et al., 2004; Sit et al., 2007)		X	4
	CHAMPS Physical Activity Questionnaire for Older Adults (Mayo et al., 2015)		X	1
	Human Activity Profile (Olney et al., 2006; Sharp & Brouwer, 1997)		X	2
	International Physical Activity Questionnaire (Askim et al., 2018; Faulkner et al., 2015)	X	X	2
	Minnesota Leisure-Time Physical Activity Questionnaire (Pang & Lau, 2010)		X	1
	Multimedia Activity Recall for Children and Adolescents (English et al., 2016b)		X	1
	Physical Activity and Disability Survey (Mudge et al., 2009)		X	1
	Physical Activitiy Scale, Danish Version (Severinsen et al., 2014)	X	X	1
	Physical Activity Scale for Individuals with Physical Disabilities (Pang et al., 2005)	X	X	1
	Physical Activity Scale for the Elderly (Boysen et al., 2009; Vahlberg et al., 2017)	X	X	2
	Yale Physical Activity Survey (Shaughnessy et al., 2012)		X	1
Device-Based	Activity counts (Actigraph, Senswear Armband, GENEActiv) (Clanchy et al., 2016; Dean et al., 2012; Preston et al., 2017)		X	3
	Time spent sitting, standing, stepping (ActivPAL) (English et al., 2016b; Ezeugwu & Manns, 2018; Jones et al., 2016; Paul et al., 2016)	X		4
	Step Count (Pedometer, ActiCal, ActivPAL, Step Activity Monitor, Sensewear Armband) (Danks et al., 2014; Dean et al., 2012; Duncan et al., 2011; English et al., 2016b; Ezeugwu & Manns, 2018; Givon et al., 2016; Heeren et al., 2013; Jones et al., 2016; Michael et al., 2009; Mudge et al., 2009; Paul et al., 2016; Preston et al., 2017; Sullivan et al., 2014; Touillet et al., 2010)		X	14

Table 4 Scoping review: Risk of bias

Exercise Only	Random Sequence	Allocation Concealment	Participant Blinding	Therapist Blinding	Assessor Blinding	Attrition
Sharp, 1997	-	-	-	-	-	*
Olney, 2006	+	+	-	-	-	*
Michael, 2009	-	-	-	-	-	-
Mudge, 2009	+	+	-	-	+	+
Pang, 2010	-	-	-	-	-	+
Duncan, 2011	+	+	-	-	+	+
Dean, 2012	+	+	-	-	+	+
Shaughnessy, 2012	-	-	-	-	-	*
Severinsen, 2013	+	-	-	-	-	+
Heeren, 2013	-	-	-	-	-	+
Givon, 2016	-	-	-	-	+	-
Behavior Change Techniques Only						
Danks, 2014	-	-	-	-	-	*
English, 2016	+	+	-	-	+	+
Paul, 2016	-	-	-	-	-	+
Exercise + Education						
Touillet, 2010	-	-	-	-	-	+
Kirk, 2014	+	+	-	-	+	+
Faulkner, 2015	+	+	-	-	+	+
Behavior Change Techniques + Education						
Logan, 2004	+	+	-	-	+	+
Sit, 2007	-	-	-	-	-	-
Jones, 2016	-	-	-	-	-	+
Preston, 2017	-	-	-	-	-	*
Exercise + Behavior Change Techniques						
Vahlberg, 2017	+	+	-	-	+	-
Askim, 2018	+	+	-	-	+	-
Dean, 2018	+	+	-	-	+	+
Exercise + Behavior Change Techniques + Education						
Bastien, 1998	-	-	-	-	-	*
Pang, 2005	+	+	-	-	+	*
Boysen, 2009	+	+	-	-	+	+
Sullivan, 2014	-	-	-	-	-	+
Mayo, 2015	-	-	-	-	+	*
Clanchy, 2016	+	-	-	-	+	+
Ezeugwu, 2018	-	-	-	-	-	+

+Adequate, -Inadequate, * Attrition reported >20%

months follow-up) on outcomes of sedentary behavior or daily physical activity ($p<.05$, Table 5). For studies that did not conduct follow-up assessments at the 3-month time point, the next closest follow-up time point was selected (Duncan et al., 2011; Ezeugwu & Manns, 2018; Faulkner et al., 2015; Logan et al., 2004; Olney et al., 2006; Severinsen et al., 2014; Sharp & Brouwer, 1997).

2.2.4.1 Studies of Single Component Interventions

Studies of interventions that employed exercise alone and behavior change techniques alone measured outcomes of sedentary behavior or daily physical activity. No studies examined education alone.

Exercise

Seven randomized controlled trials (Dean et al., 2012; Duncan et al., 2011; Givon et al., 2016; Mudge et al., 2009; Olney et al., 2006; Severinsen et al., 2014; Shaughnessy et al., 2012), one non-randomized parallel groups study (Pang & Lau, 2010), and three single-group studies (Heeren et al., 2013; Michael et al., 2009; Sharp & Brouwer, 1997) examined the effects of exercise alone on post-stroke sedentary behavior and daily physical activity. Six of the seven RCTs reported no within-between interaction effects or within-group effects at post-intervention. One RCT (Duncan et al., 2011) reported a small within-between interaction effect on step count at post-intervention (Cohen's d=0.17, $p<.05$). The statistical significance of the moderate within-groups effect within this study was not reported (Cohen's d=0.61) (Duncan et al., 2011). Two of the four RCTs that assessed outcomes at 3-months follow-up reported within group effects on total level of daily physical activity. One of these studies detected small within-group effects (Cohen's d=0.25, $p<.05$).[Olney] The other study did not report the effect size (Severinsen et al., 2014). The non-randomized parallel groups study (Pang & Lau, 2010) detected moderate within-between effects (Cohen's d=0.48, p<.05) and large within-group effects (Cohen's d=1.60, p<.05) on total level of daily physical activity at post-intervention. No follow-up effects were reported. One of three single-group studies reported large within-group effects (Cohen's d=0.74, p<.05) on step count at post-intervention (Heeren et al., 2013). Only one of three single-group studies assessed outcomes at follow-up (4 weeks) and did not detect within-group effects at this time point (Sharp & Brouwer, 1997).

Behavior Change Techniques

One randomized controlled trial (English et al., 2016b), one non-randomized parallel groups study (Paul et al., 2016), and one single group study (Danks et al., 2014) examined the effects of behavior change techniques on sedentary behavior and daily physical activity. All three studies assessed outcomes at post-intervention. No studies assessed outcomes at follow-up time points. The RCT detected no within-between interaction effects, but did detect a small within-group decline in sedentary behavior (Cohen's d=0.21 to 0.33, p<.05) at post-intervention (English et al., 2016b). The non-randomized parallel groups study (Paul et al., 2016) detected large within-between interaction effects on step count (Cohen's d=1.57, p<.05) and time spent stepping (Cohen's d=1.35, p<.05). The single group study (Danks et al., 2014) detected moderate within-group effects on step count (Cohen's d=0.42, p<.05).

2.2.4.2 Studies of Multi-Component Interventions

Studies of multi-component interventions that employed exercise, behavior change techniques, and education in varying combinations have examined effects on sedentary behavior

Table 5 Scoping review: Interventions and effects

		Post-Intervention		Follow-Up			
Exercise Only	Measurement	Interaction	Within-Group	Interaction	Within-Group	Follow-up timepoint	Study Design
Olney, 2006	PA	NR	0.22	NR	**0.25***	6-months	RCT
**Mudge, 2009	PA	NS	0.00 and 0.05	NS	0.11	3-months	RCT
Duncan, 2011[a]	PA	**0.17***	0.61	-	-	-	RCT
Dean, 2012	PA	0.29	0.31	-	-	-	RCT
Shaughnessy, 2012	PA	0.04	-0.11 to **-0.21***	-	-	-	RCT
Severinsen, 2013[b]	PA	NS	**Effect size unavailable***	NS	**Effect size unavailable***	12-months	RCT
Givon, 2016	PA	NR	0.11	NR	-0.05	3-months	RCT
Pang, 2010	PA	**0.48***	**1.60***	-	-	-	Parallel Groups
Sharp, 1997	PA	-	0.30	-	0.46	1-month	Single Group
Michael, 2009	PA	-	0.34	-	-	-	Single Group
Heeren, 2013	PA	-	**0.74***	-	-	-	Single Group
Behavior Change Techniques Only							
**English, 2016	PA/SB	0.04 to 0.25	0.11 to **0.33*** **(0.21, 0.23)***	-	-	-	RCT

Table 5 continued

**Paul, 2016	PA/SB	**1.35*** and **1.57***	0.47 and 0.64	-	-	-	Parallel Groups
**Danks, 2014	PA	-	**0.35*** and **0.42***	-	-	-	Single Group
Exercise and Education							
Kirk, 2014	PA	**0.39***	-0.20	-	-	-	RCT
Faulkner, 2015	PA/SB	NS	-	NS	-	12-months	RCT
**Touillet, 2010	PA	-	0.66 and 0.71	-	-0.16 and -0.31	3-months	Single Group
Behavior Change Techniques and Education							
Logan, 2004	PA	Data unavailable		Data unavailable		6-months	RCT
Sit, 2007	PA	**2.07***	0.00	**2.64***	-0.02	3-months	Parallel Groups
Jones, 2016	PA/SB	-	0.08 and 0.21	-	-0.01 and -0.10	3-months	Single Group
**Preston, 2017	PA	-	0.39	-	0.07	3-months	Single Group
Exercise and Behavior Change Techniques							
Vahlberg, 2017	PA	-0.02	0.17	-0.59	-0.21	3-months	RCT
Askim, 2018	PA/SB	NS	NS	-	-	-	RCT
Dean, 2018[c]	PA	NR	-0.25 to 0.03	-	-	-	RCT
Exercise, Behavior Change Techniques, and Education							
Pang, 2005	PA	-1.04	**0.62***	-	-	-	RCT
**Boysen, 2009	PA	NS	-0.17	-	-	-	RCT

Table 5 continued

**Mayo, 2015[d]	PA	-0.02	-0.46	-	-	-	RCT
**Clanchy, 2016	PA	**0.75***	**3.97***	0.30	2.23	3-months	Parallel Groups
Bastien, 1998	PA	-	NR	-	NR	3-months	Single Group
Sullivan, 2014	PA	-	-0.06	-	-	-	Single Group
**Ezeugwu, 2018	PA/SB	-	-0.08 to **1.53* (0.31)***	-	-0.15 to 1.21	2-months	Single Group

Note. Range of effect sizes is reported for studies that examined multiple relevant outcomes. Statistically significant effect sizes that fall within this range reported in parentheses. NR=Statistical significance of interaction effects not reported and mean change scores not reported. NS=Effects reported to be not statistically significant ($p<.05$) and mean change scores not reported. PA=Physical activity. SB=Sedentary behavior.

*Statistical significance at $p<.05$. **Moderate to light physical activity or sedentary behavior defined as primary clinical outcome measure.

[a]6-month delayed intervention design. Treated baseline to 6-months as pre-post. [b]Statistically significant within-group change, effect size unavailable. [c]Statistical significance of change over time not assessed. [d]Waitlist control study, within-group effects for pre-test to 3 month time point with waitlist group as control. Statistical significance not reported.

and/or daily physical activity. Within-between interaction effects and within-group effects were explored at post-intervention and follow-up (3-months where possible).

Exercise and Education

Two randomized controlled trials (Faulkner et al., 2015; Kirk et al., 2014) and one single group study (Touillet et al., 2010) examined approaches that combined exercise and education. One of two RCTs detected small to moderate within-between interaction effects on the level of daily living physical activity (Cohen's d=0.39, p<.05) (Kirk et al., 2014). One of two RCTs reported on follow-up effects, and did not detect within-between interaction or within-group effects at follow-up (Faulkner et al., 2015). The single group study did not detect within-group effects at post-intervention or follow-up (Touillet et al., 2010).

Behavior Change Techniques and Education

One randomized controlled trial (Logan et al., 2004), one non randomized parallel groups study (Sit et al., 2007), and two single group studies (Jones et al., 2016; Preston et al., 2017) employed interventions that combined behavior change techniques and education. The RCT reported between-group differences on number of outdoor journeys in the past month at post-intervention and follow-up. We were unable to calculate within-between interaction effects or within-group effect sizes (Logan et al., 2004). The non-randomized parallel groups study detected small within-between interaction effects on daily physical activity at post-intervention (OR=2.07, p<.05) and follow-up (OR=2.64, p<.05) (Chen, Cohen, & Chen, 2010; Sit et al., 2007). These effects were attributed to decline in activity levels in the control group, while the intervention group maintained activity levels. No within-group effects were detected at post-intervention or follow-up among the two single group studies (Jones et al., 2016; Preston et al., 2017).

Exercise and Behavior Change Techniques

Three randomized controlled trials examined interventions that combined exercise with behavior change techniques. Two of the three studies did not detect within-between interaction or within-group effects at post-intervention (Askim et al., 2018; Vahlberg et al., 2017). One pilot study reported on effect sizes, but not statistical significance of change over time on a device-based measure of daily physical activity (Dean et al., 2018). One study reported on follow-up effects, and did not detect within-between interaction or within-group effects at the follow-up timepoint (Vahlberg et al., 2017).

Exercise, Behavior Change Techniques, and Education

Three randomized controlled trials (Boysen et al., 2009; Mayo et al., 2015; Pang et al., 2005), one non-randomized parallel groups study (Clanchy et al., 2016), and three single group studies (Bastien et al., 1998; Ezeugwu & Manns, 2018; Sullivan et al., 2014) employed interventions that contained exercise, behavior change techniques, and education. Among the three RCTs, no within-between interaction effects were detected at post-intervention. One of three RCTs detected moderate within-group effects on daily physical activity at post-intervention (Cohen's d=0.62, p<.05) (Pang et al., 2005). No RCTs assessed intervention effects at follow-up time points. The non-randomized parallel groups study detected large within-between interaction effects (Cohen's d=0.75, p<.05) and large within-group effects (Cohen's d=3.97, p<.05) on activity counts at post-intervention (Clanchy et al., 2016). No follow-up assessments were reported. One of three single group studies detected a range of small to large post-intervention within-group effects on measures of sedentary behavior (Cohen's d=0.31 to 1.51, p<.05) (Ezeugwu & Manns, 2018). Two of three single group studies assessed, but did not detect follow-up effects (Bastien et al., 1998; Sullivan et al., 2014).

2.3 Discussion

Our aim was to describe the effects of current interventions on sedentary behavior and daily physical activity after stroke. Only 14 interventions, which employed varied approaches to intervention, were associated with effects on questionnaire-based and device-based outcomes related to sedentary behavior and daily physical activity. The remaining 17 studies detected no effects on questionnaire-based and device-based outcomes related to sedentary behavior. These results demonstrate that sedentary behavior and daily physical activity may be modifiable after stroke. However, specific approaches to interventions that are effective to promote changes on these outcomes remain unclear. These findings provide insight into the need for development of carefully specified complex interventions and precisely defined outcomes related to sedentary behavior and daily physical activity outcomes.

2.3.1 Complex Interventions

Exercise, behavior change techniques, and education were employed individually and in various combinations to achieve change in sedentary behavior or daily physical activity. The complex sequelae of stroke may demand complex interventions to effect change on daily physical activity. Seventeen of the 31 studies included in this review detected no effects on sedentary behavior and/or daily physical activity behavior, and also employed complex interventions (Askim et al., 2018; Bastien et al., 1998; Boysen et al., 2009; Dean et al., 2012; Faulkner et al., 2015; Givon et al., 2016; Jones et al., 2016; Logan et al., 2004; Mayo et al., 2015; Michael et al., 2009; Mudge et al., 2009; Preston et al., 2017; Sharp & Brouwer, 1997; Shaughnessy et al., 2012; Sullivan et al., 2014; Touillet et al., 2010; Vahlberg et al., 2017). Examining the approach to combining specific intervention components in future studies may provide insight into the heterogeneous outcomes of interventions.

2.3.1.1 Exercise

Exercise was a common intervention component used to promote daily physical activity. Low physical activity levels post-stroke may lead to deconditioning and depressed mood. Reviews examining the effects of exercise after stroke have identified that exercise may improve aerobic capacity, balance, mobility, depressive symptoms, and cognitive functions.(Adamson, Ensari, & Motl, 2015; Cumming, Tyedin, Churilov, Morris, & Bernhardt, 2012; Kendall & Gothe, 2016) Enhancing these abilities through exercise could improve stroke survivors' ability to engage in a greater amount of daily physical activity. Conversely, one study included in this review detected within-group decline (p<.05) on a measure of daily physical activity (Kirk et al., 2014). It is possible that the physical demands of traveling to the research center and engaging in exercise influenced fatigue and engagement in physical activities during the remainder of the day. Further examination of the effects of exercise approaches to intervention on sedentary behavior and daily physical activity is warranted.

2.3.1.2 Behavior Change Techniques

Behavior change techniques were common, while specific approaches varied. There is currently insufficient evidence regarding specific behavior change techniques that are most effective to promote engagement in daily physical activity following stroke. Numerous theoretical approaches support the use of specific behavior change techniques to promote engagement in physical activity among healthy populations (Bandura, 2004; Hutchison, Breckon, & Johnston, 2009). Application of these strategies within the post-stroke population is complicated by persistent impairments (motor, cognition). Researchers in the field of health promotion have called for studies that compare interventions based in health models to elucidate mechanisms of health behavior change associated with these interventions (Noar & Zimmerman, 2005). Application of behavior change techniques may support stroke survivors' more frequent engagement in daily physical activity, however specific approaches should be explored further.

2.3.1.3 Education

Education was frequently included in promising interventions, in combination with exercise and/or behavior change strategies. Theories of health behavior support provision of foundational knowledge associated with certain behaviors to promote change (Prochaska & Velicer, 1997; Rosenstock, 1974). In addition, education combined with exercise is a component of cardiac rehabilitation programs, in which the goal of the program is to promote optimal cardiovascular health through lifestyle change (Kirk et al., 2014; ter Hoeve et al., 2017). Although the specific role of education in the interventions included in this review is unclear, the provision of foundational knowledge related to the benefits of engaging in daily physical activity may support interventions developed to achieve that goal.

2.3.2 Intervention Outcomes

A dearth of interventions specifically aimed to reduce sedentary behavior or promote daily physical activity after stroke. Among the 31 studies included in this review, only 11 identified sedentary behavior or daily physical activity as the primary outcome of intervention. Literature suggests that stroke survivors may derive health benefits from interventions that promote daily living physical activity (Hamilton et al., 2008; Manns, Dunstan, Owen, & Healy, 2012). In addition, modifying the pattern in which sedentary behavior is accumulated throughout the day may be powerful to promote health after stroke. Breaking up prolonged bouts of sitting into short bouts may be associated with improved cardiometabolic health (Healy et al., 2008a). Thus, introducing breaks from sitting, in which stroke survivors establish patterns of regularly moving out of a seated or reclined position to engage in standing or ambulatory activity for short periods of time may be a meaningful focus of physical activity interventions after stroke.

2.3.3 Limitations

We are mindful of several limitations associated with this review. Due to the heterogeneous approaches to outcomes measurement and interventions, we did not statistically assess the heterogeneity of intervention effects. Grey literature was not identified, thus additional interventions may exist in which our outcomes of interest were assessed. Many studies were pilot studies and were likely not powered to detect change on sedentary behavior or daily physical activity measures. Risk for bias within studies varied, with elevated risk among the non-randomized studies included in this review. Finally, descriptors of behavior change techniques are inconsistent within the field of health behavior change. We were restricted to classify intervention approaches based on the authors' descriptions of the interventions. Double data extraction was conducted to reduce the risk of misclassification, yet this risk remains.

2.3.4 Future Directions

Although engagement in physical activity is set forth as a key element of recurrent stroke risk reduction, interventions that specifically aim to reduce sedentary behavior and promote frequent engagement in daily physical activity have received limited attention for individuals with chronic stroke. Advances in sedentary behavior and inactivity physiology research suggest that modifying full-day activity patterns may positively affect chronic health conditions after stroke. Clearly specified interventions that view physical activity from a full-day perspective hold promise for reducing sedentary behavior, facilitating frequent engagement in daily physical activity, and promoting health after stroke.

3.0 Activating Behavior for Lasting Engagement (ABLE) to Reduce Sedentary Behavior After Stroke: A Descriptive Case Series

The contents of this chapter are included in the following publication currently under review: Kringle EA, Campbell G, McCue M, Barone Gibbs B, Terhorst L, Skidmore ER. Development and feasibility of a sedentary behavior intervention for stroke: A descriptive case series. This study was also presented at the UPMC Rehabilitation Institute Research Day on June 13, 2018 and received the *Best Research Award* in the pre-doctoral category.

A scoping review of current evidence (Section 2.0) suggests that interventions designed to modify sedentary behavior after stroke are scarce. Two interventions are in early phases of feasibility testing in chronic (English et al., 2016b) and sub-acute stroke rehabilitation (Ezeugwu & Manns, 2018). These studies have demonstrated that sedentary behavior interventions are feasible and may be promising to reduce sedentary behavior. Specific theories of health behavior change that are best suited to reduce post-stroke sedentary behavior are unclear. Behavioral activation may be a promising approach to promote engagement in daily physical activity and reduce sedentary behavior. To date, no interventions have applied behavioral activation to reduce sedentary behavior after stroke.

Behavioral activation is an effective treatment for reducing depressive symptoms by promoting engagement in pleasurable activities (Cuijpers, Van Straten, & Warmerdam, 2007; Mazzucchelli, Kane, & Rees, 2009). Within this framework, people learn to schedule activities, monitor engagement in scheduled activities, and develop skills for problem solving (Kanter et al., 2010). Behavioral activation has been adapted to promote quality of life and well-being among people with brain injury and caregivers of people with dementia (Bradbury et al., 2008; Doering & Exner, 2011; Losada, Márquez-González, & Romero-Moreno, 2011; Moore et al., 2013a). Behavioral activation was identified as a promising approach to reduce post-stroke sedentary behavior because of its focus on scheduling and monitoring engagement in activities. Skills in activity scheduling and activity monitoring provide tangible strategies for overcoming cognitive and affective barriers to engagement in frequent daily physical activity (e.g., planning, mood). Further, self-assessment and problem solving skills may be important to support stroke survivors' identification of strategies to overcome barriers related to motor impairments to support engagement daily physical activities. These skills can be tailored for people with varying impairments in cognitive, affective, and motor domains. Although initially developed for scheduling and monitoring engagement in discrete activities, we anticipated that this framework could be expanded to influence physical activity patterns over all waking hours.

To our knowledge, ABLE is the first intervention that applies a behavioral activation framework to break up prolonged periods of sedentary time. Complex behavioral interventions, such as ABLE, must be carefully specified prior to deployment in efficacy and effectiveness trials (Bellg et al., 2004; Hildebrand et al., 2012). Our goal was to specify the ABLE intervention protocol and explore the feasibility (tolerability, acceptability, reliability, safety) of the ABLE intervention among participants in the chronic phase of stroke.

3.1 Case Description

3.1.1 Study Design

We conducted a descriptive case series to allow for refinement of the intervention protocol. This study design was selected in alignment with best practices for complex behavioral intervention development (Craig et al., 2008; Patient-Centered Outcomes Research Institute, 2018). Our goal was to describe and define the adaptation of behavioral activation intervention approaches to reduce sedentary behavior among people with stroke. Participants completed pre-intervention assessments, 12 ABLE intervention sessions, and post-intervention assessments. Study procedures were approved by the University of Pittsburgh Institutional Review Board and conducted in compliance with the requirements of the Helsinki Declaration. Participants provided written informed consent. Results are reported following the CARE guidelines for reporting results from case reports (Gagnier et al., 2013).

3.1.2 Participants

Participants who were over 18 years of age, 6 to 24 months post-stroke, ambulatory without physical assistance of another person, self-reported sitting time 6 hours or more on a typical weekday using the Sedentary Behavior Questionnaire (Rosenberg et al., 2010), and resided within 50 miles of Pittsburgh, Pennsylvania were included in this study. Those who were currently participating in occupational, physical, or speech therapy, concurrently enrolled in another intervention study, and reported comorbid neurodegenerative disorder, current cancer treatment (i.e., chemotherapy or radiation), major depressive disorder (Patient Health Questionnaire-9)

(Gilbody, Richards, Brealey, & Hewitt, 2007; Kroenke, Spitzer, & Williams, 2001), or untreated psychiatric conditions (PRIME-MD/Mini International Neuropsychiatric Interview) (Spitzer et al., 1994) were excluded from this study. Participants were recruited from a pool of participants who had previously participated in research in the Department of Occupational Therapy at the University of Pittsburgh and from the community via the University of Pittsburgh Clinical and Translational Science Institute Research Registry.

3.1.3 Intervention

Prior to enrolling the first participant, we specified key structural elements and theoretically driven essential elements of the ABLE intervention (Michie et al., 2009). We anticipated that the intervention protocol would be refined based on feedback from the therapist and the participants, but that the essential elements would remain constant (Table 6).

Table 6 ABLE intervention elements

Structural Elements	*Clinician*	Occupational Therapist
	Environment	Home-based
	Dose	3x/week for 4 weeks (12 sessions)
	Materials	ABLE Participant Workbook
Essential Elements	*Activity Scheduling*	Plan established to complete a specific activity at a specific time.
	Activity Monitoring	Identification of activity that actually occurred during waking hours.
	Self-Assessment	Explicit identification of positive and negative outcomes of activities (e.g., somatic, mood)
	Collaborative Problem Solving	Participant-generated solutions to challenges identified during activity monitoring.

3.1.3.1 Structural Elements

The ABLE intervention was delivered in participants' homes by an occupational therapist with 7 years of experience in stroke rehabilitation (EK). The ABLE intervention was designed to be delivered at a frequency of 3 sessions per week, for 4 weeks. Guided by a workbook, the first 1 to 2 sessions of the ABLE intervention included brainstorming to generate activities meaningful to the participant and to identify times during the day when the participant is at-risk for prolonged sitting. The Activity Card Sort (Katz, Karpin, Lak, Furman, & Hartman-Maeir, 2003) was selected to facilitate this brainstorming process. Remaining sessions included an iterative process containing the essential elements of the ABLE intervention (defined below).

3.1.3.2 Essential Elements

The ABLE intervention contains 4 essential elements: activity scheduling, collaborative problem solving, activity monitoring, and self-assessment. During each session, the therapist guided the participant to schedule personally meaningful activities throughout the day at times when the participant spends time sitting (*activity scheduling*). The therapist then facilitated problem solving to establish a clear plan for engaging in the activity. Rather than providing the participant with strategies directly, the therapist used a collaborative approach in which barriers and potential solutions were elicited from the participant (*collaborative problem solving*). Collaborative problem solving builds the participants' skills in identifying and overcoming barriers to activities. If the selected activity was a sedentary activity (e.g., reading), the therapist facilitated problem solving aimed to identify strategies to break up prolonged sitting time (e.g., set a timer to move to a different chair every 30 minutes). The participant then monitored adherence to the plan and physical activity patterns between intervention sessions (*activity monitoring)*. Activity monitoring was documented in the participant workbook. At the following session, the activity monitoring worksheet was reviewed and the participant was asked to identify positive (e.g., more energy, elevated mood) and negative (e.g., changes in spasticity, muscle fatigue) outcomes during engagement in physical activities (*self-assessment*). When negative outcomes were identified, solutions were pursued using collaborative problem solving. Participants could decide to continue with the same activity schedule or schedule new activities for the next sessions. This process was repeated iteratively during each intervention session.

3.1.4 Measures

Our primary outcomes were tolerability, acceptability, reliability, and safety of the ABLE intervention. We also measured changes in sedentary behavior at baseline and 4 weeks.

3.1.4.1 Tolerability

Session attendance was calculated and compared with our established benchmark of 90% attendance. We also examined the frequency and mean session duration for each participant to identify the feasibility of delivering this intervention at the specified frequency of 3 times per week for 4 weeks and establish expectations for duration of intervention sessions.

3.1.4.2 Acceptability

Acceptability of the intervention approach was assessed using the Client Satisfaction Questionnaire-8 (CSQ) (Attkisson & Greenfield, 2004). The CSQ-8 consists of 8 questions rated on a 4-point Likert-type scale. Scores were summed and compared with our established benchmark of ≥28.8. We also examined the degree to which participants valued and expected positive results of this treatment using the Healing Encounters and Attitudes Lists Treatment Expectancy Short

Form (HEAL-TE). The HEAL-TE was developed using PROMIS methodologies and consists of 6 statements rated on a 5-point Likert type scale (Greco, Glick, Morone, & Schneider, 2013; Greco et al., 2016). Scores were summed and converted to T-scores. The CSQ and HEAL-TE questionnaires were administered by an independent assessor at the post-intervention time point.

3.1.4.3 Reliability

We assessed reliability using a fidelity review checklist developed in our laboratory (Bellg et al., 2004; Hildebrand et al., 2012). An independent assessor reviewed the first two intervention sessions and selected 2 sessions per participant from sessions 3 through 12 using a random numbers table. Sessions were rated to identify presence (1) or absence (0) of structural elements, activity scheduling, activity monitoring, collaborative problem solving, and self-assessment. Results on tests of reliability were compared against our established benchmark of 90% adherence for sampled sessions.

3.1.4.4 Safety

Falls that occurred during intervention sessions or a fall reported by the participant that occurred while a participant was completing a scheduled activity between sessions were documented as *intervention related falls*. We also documented injuries that occurred during intervention sessions or scheduled activities.

3.1.4.5 Sedentary Behavior

Sedentary behavior was assessed at baseline and 4 weeks using the ActivPAL micro3 (Pal Technologies, Glasgow). The ActivPAL micro3 is a small device (1.5 inches x 0.75 inches x 0.25, 10 grams) that assesses time spent sitting, standing, and stepping. This device was validated among stroke survivors (Gebruers et al., 2010). We implemented a 7-day, 24-hour wear protocol. The ActivPAL micro3 was waterproofed and adhered each participant's unaffected thigh. Participants documented wake time, time went to bed, nap time, and device non-wear time in a diary for each day of ActivPAL micro3 wear. Sleep time and non-wear time were removed from the data using a diary-informed approach (Barone Gibbs & Kline, 2018; Edwardson et al., 2017). We calculated prolonged sitting time accumulated in bouts of ≥30 minutes, percent waking time spent in prolonged sitting, number of transitions between sitting or reclined and upright (*transitions*), and step count.

3.1.4.6 Sample Characteristics

Mobility and arm function were assessed using the Stroke Impact Scale (SIS) (Duncan et al., 2003). The SIS is a valid and reliable self-report assessment of stroke-related sensorimotor impairments among people with chronic stroke. Cognition was measured using the National Institutes of Health Toolbox Cognition Battery (NIH Toolbox-Cognition) (Heaton et al., 2014; Weintraub et al., 2013; Weintraub et al., 2014). The NIH Toolbox-Cognition is a performance-based assessment of cognitive functions that has been validated in population-based studies. Mood was assessed using the Patient Health Questionnaire-9 (PHQ-9), a valid and reliable screening tool that assesses e severity of depressive symptoms (Gilbody et al., 2007; Kroenke et al., 2001). Fatigue was measured using the PROMIS Fatigue Scale 8a. The PROMIS Fatigue Scale 8a was developed using item response theory and validated among people with chronic conditions (Cella et al., 2016). Pain was described using the Numeric Pain Rating Scale, in which participants were asked to rank their worst pain in the past 24 hours on a scale of 0 to 10. This is a common and validated approach to pain assessment (Williamson & Hoggart, 2005).

3.1.5 Analyses

We generated descriptive statistics to describe our sample and outcomes. Tolerability, acceptability, and reliability data for each participant were compared against benchmarks established a priori (described above). We described safety outcomes. Sedentary behavior at baseline and 4 weeks are described for each participant.

3.2 Results

3.2.1 Participants

Participant characteristics are described in Table 7. Participants ranged from 51 to 73 years old. During baseline testing, 4 participants reported lower current activity levels relative to their pre-stroke activity levels. One participant felt that his physical activity level was the same as prior to his stroke. Participants' mobility ranged from moderate impairment to intact (SIS, Mobility subscale range 38.89 to 100.00). Arm function during daily activities ranged from severe impairment to intact (SIS, Arm Function subscale range 25.00 to 100.00). Impaired cognitive function was defined as those with scores greater than or equal to 1 standard deviation below the mean on the NIH Toolbox Cognition Battery (age-corrected standard score). Three participants had impaired cognitive functions and two participants had intact cognition. Participants had mild to no depressive symptoms (PHQ-9, range 0 to 6)

Table 7 ABLE case series: Participant characteristics

Participant	1	2	3	4	5
Age	63	73	52	51	64
Gender	M	F	M	M	M
Race	White	White	Black	Black	White
Education	High School	High School	Bachelors	Bachelors[a]	Bachelors
Social Support	No caregiver	Part-time caregiver	Full-time caregiver	No caregiver	Full-time caregiver
Residential Status	Alone	Spouse	Assisted Living	Spouse	Spouse
Type of Stroke	Ischemic	Hemorrhagic	Hemorrhagic	Ischemic	Ischemic
Hemisphere of Stroke	Right	Right	Right	Right	Bilateral
Current physical activity level relative to pre-stroke	Lower	Lower	Lower	The same	Lower
Mood (PHQ-9)	5	0	0	0	6
Mobility (SIS, Mobility Subscale)[b]	63.89	94.44	52.78	100.00	38.89
Arm Function (SIS, Arm Function Subscale)[b]	25.00	95.00	25.00	100.00	35.00
Cognition Composite (NIH Toolbox)[c]	83	78	56	123	103

[a]Master's degree completed during intervention period; [b]Range 0 to 100, 100 indicates no residual impairment; [c]Mean 100, SD 15

3.2.2 Intervention Refinement

The structural elements of the ABLE intervention were refined based on feedback from participants and intervention therapist (EK). This feedback led to greater emphasis on foundational knowledge of sedentary behavior patterns during session #1. At the end of session #1, participants were asked to monitor their activity for 1 day to build awareness of times when they sit for a prolonged time period. We also identified that participants may experience both positive (e.g., more energy) and negative (e.g., muscle aches) outcomes as they become more active. With the first participant, we problem solved strategies to manage negative outcomes. With subsequent participants, we placed greater emphasis on explicitly acknowledging both the positive and negative outcomes of reduced sitting time. We continued to use collaborative problem solving to manage negative symptoms. Further details regarding refinement of the ABLE intervention may be found in Appendix A.

3.2.3 Feasibility

3.2.3.1 Tolerability

Feasibility outcomes are described in Table 8. All participants met our benchmark for session attendance (≥90% of sessions). Mean session duration was 9.1 to 30.8 minutes. Participants who established plans to engage in concrete activities that required minimal problem solving (e.g., walk at a specified time during the workday) had short sessions. Those who sought to engage in complex tasks that required problem solving had long sessions (e.g., prepare a meal). Four of five participants had a mean session length ≥25.0 minutes. Sessions occurred every 2.0 to 3.2 days.

Table 8 ABLE case series: Feasibility outcomes

	Benchmark	#1	#2	#3	#4	#5
Attendance	*90%*	*100%	*100%	*100%	*91.67%	*100%
Session Frequency (days/session)	*NA*	2.3	2.0	3.0	3.2	2.9
Session Length (minutes)	*NA*	30.8	25.0	27.5	9.1	27.5
Client Satisfaction Questionnaire-8	*≥28.8*	25.0	*29.0	*32.0	27.0	*31.0
HEAL-Treatment Expectancy	*NA*	50.9	56.9	70.8	55.3	70.8
Intervention-related falls or injuries	*NA*	0	0	0	0	0
Reliability	*90%*	65%	*91%	*96%	87%	*96%

*Met benchmark

3.2.3.2 Acceptability

Three participants identified that the ABLE intervention had high acceptability relative to our benchmark (Client Satisfaction Questionnaire-8 ≥28.8). Two participants identified low acceptability relative to our benchmark. Low need for the intervention (i.e., low baseline sedentary behavior) may have influenced acceptability rating for one participant. The other participant who did not meet the acceptability benchmark received the very early, loosely structured version of the ABLE intervention. Feedback from this participant was incorporated as the intervention was refined, to enhance acceptability. All participants identified positive expectations for this intervention to support outcomes that they value, indicated by HEAL-TE t-scores greater than the population mean (50.0).

3.2.3.3 Safety

No intervention-related falls or injuries were reported.

3.2.3.4 Reliability

Rates of treatment reliability ranged from 65% to 96%. Our benchmark for treatment reliability was met for three participants (structural elements and essential elements present in

≥90% of sampled sessions). Our benchmark for treatment reliability was not met for two participants. One of these participants received the earliest, loosely structured version of the ABLE intervention. The other had a very low amount of baseline sedentary behavior. These may have influenced treatment reliability.

Table 9 ABLE case series: Activity monitoring outcomes

		#1	#2	#3	#4	#5
[a]Daily prolonged sitting time (*minutes*)	Pre:	623.98	370.59	701.51	124.94	718.23
	Post:	430.24	392.33	723.61	162.36	734.89
		+	-	-	-	-
[a]Waking time spent in prolonged sitting (*%*)	Pre:	61.17	37.57	87.63	14.57	78.38
	Post:	48.77	41.92	84.58	17.55	72.61
		+	-	+	-	+
Daily number of sit-stand transitions	Pre:	42.83	39.28	18.57	66.14	23.43
	Post:	47.14	36.86	23.14	70.57	27.43
		+	-	+	+	+
Daily step count	Pre:	917.17	2861.57	67.43	5081.29	562.86
	Post:	916.71	2707.00	67.43	5494.00	592.71
		-	-	-	+	+

[a]Prolonged sitting: accumulated in bouts ≥30 minutes, + improvement on outcome, -null or negative effect on outcome

3.2.4 Sedentary Behavior Outcomes

Activity monitoring outcomes are reported in Table 9. One valid day of monitoring was considered that for which the participant wore the monitor during all waking hours. Participants had 6 to 7 valid wear days at each time point. Three participants had a high amount of prolonged sitting (623.98 to 718.23 minutes) and two participants had a low amount of prolonged sitting (124.94 to 370.59 minutes) at baseline. One participant had a reduction in daily prolonged sitting time. The three participants who had high levels of sitting at baseline had a reduction in the percent waking time spent in prolonged sitting and mean sedentary bout length. Four participants had a greater number of postural transitions after intervention. Two participants had a slight increase in step count from baseline to 4 weeks.

3.3 Discussion

Our goal with this case series was to describe the feasibility of the ABLE intervention, a novel approach for reducing sedentary behavior among people with chronic stroke. We also examined individual changes on sedentary behavior outcomes and participant characteristics to guide future development of the ABLE intervention. This study design allowed us to refine the ABLE intervention protocol, examine trends in sedentary behavior that may be associated with the ABLE intervention, and identify additional intervention components that may support reduction in sedentary behavior after stroke.

We revised the application of the ABLE intervention elements. Our initial version contained a loose structure with brief background information on sedentary behavior. The final refined version contained specific information on patterns of sedentary behavior. Healthcare providers and clients must clearly understand this unique aim of the ABLE intervention as they engage in the intervention protocol. Breaking up prolonged bouts of sedentary behavior is an innovative approach to physical activity interventions. Prior physical activity interventions in stroke emphasize prescribed doses of walking or exercise programs (Moore et al., 2018; Morris et al., 2014). The ABLE intervention represents a shift in our approach to physical activity interventions, emphasizing patterns of activity engagement over the full day. The addition of an overview describing the full-day approach and health risks of prolonged sitting patterns, coupled with an activity monitoring assignment designed to identify prolonged periods of sitting appeared to establish a foundation from which the intervention protocol could progress.

3.3.1 Change in Sedentary Behavior

Although the primary purpose of this study was to establish a refined intervention protocol, we also described sedentary behavior change over time. Change in sedentary behavior varied across participants in both direction and magnitude. There may be several explanations that should be explored in future studies (e.g., age, gender, comorbidities) (O'Donoghue et al., 2016; van Nassau et al., 2017; Vancampfort et al., 2018). Among the five participants in the present study, the social environment and varied baseline levels of sedentary behavior may have influenced change on sedentary behavior over time.

3.3.2 Social Environment

The varied social environments among these participants may have played a role in their response to the ABLE intervention. Three participants had a high level of sedentary behavior at baseline and varied magnitude of response to intervention. Residual stroke-related deficits frequently include motor and balance impairments, and place individuals at risk for falls (Hyndman, Ashburn, & Stack, 2002; Mackintosh, Goldie, & Hill, 2005; Mackintosh, Hill, Dodd, Goldie, & Culham, 2006). Despite demonstrating the ability to safely mobilize in a familiar environment, those participants who resided with a caregiver or within a system (i.e., assisted living facility) that placed a high emphasis on fall risk demonstrated a smaller response to intervention than the participant who resided alone. Caregivers and care systems play a critical role in providing social, emotional, and physical support post-stroke (Cameron & Gignac, 2008; Harris, Eng, Miller, & Dawson, 2016). These supports that place high emphasis on safety and reduce the demand for engagement in daily tasks beyond basic self-care tasks may influence stroke survivors' prolonged sitting time (Brach et al., 2018; Kane & Cutler, 2015). People with stroke have elevated risk for falls and more frequent falls than healthy community dwelling populations (Jørgensen, Engstad, & Jacobsen, 2002). Strategies to help stroke survivors, caregivers, and care systems manage fall risk should be considered when developing interventions that promote upright time after stroke. An additional component of the ABLE intervention that involves the caregiver or care system in managing these safety concerns may support reductions in sedentary behavior.

3.3.3 Assessing Need for Sedentary Behavior Intervention

People with low levels of sedentary behavior at baseline may not need the ABLE intervention. Two participants reported high levels of sedentary behavior on study screening but had low levels of sedentary behavior when measured with the ActivPAL during baseline assessments. This may have contributed to low satisfaction and reliability of the ABLE intervention for one participant. Despite low need to reduce sedentary behavior, the participants' perceptions of high levels of sedentary behavior should be considered. People who participated in active lifestyles prior to their stroke may perceive high levels of sedentary behavior relative to previous lifestyles. These participation restrictions after stroke are well documented (Desrosiers & Bourbonnais, 2005; Desrosiers et al., 2008; Desrosiers et al., 2006; Mayo et al., 2002). Overcoming participation restrictions may require an intervention approach that supports personal control over participation in the activities that people desire to engage in (Hammel et al., 2015; Heinemann et al., 2011; Heinemann et al., 2013)

3.3.4 Limitations

The goal of this early intervention development stage was to specify the intervention protocol and generate hypotheses for future development (Craig et al., 2008; Patient-Centered Outcomes Research Institute, 2018). Our descriptive case series design was optimal to accomplish this goal (Gagnier et al., 2013). However, these results must be interpreted cautiously. After further refinement of this intervention approach (e.g., addition of a social environment component), the magnitude of effects of the ABLE intervention on sedentary behavior should be examined through randomized controlled trials. Further, reducing sedentary behavior is a proximal goal of the ABLE intervention. The scope of this study did not support long-term follow-up of health outcomes (e.g., hypertension, blood glucose control) and recurrent stroke occurrence. Future studies should explore these distal outcomes.

3.3.5 Future Directions

Despite limitations of this descriptive case series design, this study leads to many future research directions. Understanding the role of the social environment in physical activity and sedentary behaviors may guide us to additional essential elements that can lead to greater reductions in sedentary behavior. Clarifying the relationship between sedentary behavior, participation, and activity engagement restrictions among individuals with low levels of sedentary behavior will support precision in identifying those for whom the ABLE intervention is appropriate. In addition, this may lead to greater understanding of participation and activity engagement restrictions and the development of interventions that can promote activity engagement and participation. Ultimately, this work will lead to interventions that can promote activity engagement, participation and healthy lifestyles among people with chronic stroke.

4.0 ABLE After Stroke: Feasibility and Preliminary Effects of a Behavioral Activation-Based Intervention on Sedentary Behavior

The contents of this chapter are included in the following manuscript currently under review: Kringle EA, Terhorst L, Barone Gibbs B, Campbell G, McCue M, Skidmore ER. Preliminary effects of the ABLE intervention on sedentary behavior after stroke.

The goal of the case series study presented in Section 3.0 was to specify the essential and structural interventions elements of the ABLE intervention. The ABLE intervention is among a small group of interventions that aim to reduce sedentary behavior among people with stroke (English et al., 2016b; Ezeugwu & Manns, 2018). One pilot randomized controlled trial detected reductions on objectively measured sedentary behavior over time. However, this change did not differ from the control group which received an inert attention control intervention (English et al., 2016b). A single group pre-post-test pilot study also detected a range of small to large reductions on objectively measured sedentary behavior over time (Ezeugwu & Manns, 2018). These pilot studies are in early phases and suggest that it may be possible to modify post-stroke sedentary behavior. However, the varied effect sizes in this early phase work suggest a need for ongoing exploration of essential elements that may result in change in sedentary behavior over time among people with chronic stroke.

Distinct from these prior approaches, the ABLE intervention that was previously specified (Section 3.0) applies behavioral activation to reduce sedentary behavior. This is a complex behavioral intervention which contains multiple essential elements (Craig et al., 2008). The development of complex behavioral interventions requires a rigorous pilot testing stage that informs the design of future study design (Moore, Carter, Nietert, & Stewart, 2011). Assessments of feasibility can be used to inform recruitment and retention strategies, participant safety and tolerance during intervention, and the ability to deliver the intervention uniformly across therapists and participants (Bellg et al., 2004; Hildebrand et al., 2012; Moore et al., 2011). Feasibility assessment can also inform ongoing intervention refinement and the development of therapist training procedures. Estimates of effect sizes can be used to inform sample size estimations that assure clinical trials have sufficient statistical power to detect meaningful change on primary outcomes. Thus, during the present pilot study, our goals were to assess the feasibility and to calculate preliminary estimates of change in sedentary behavior over time that may be associated with the ABLE intervention.

Thoughtful pilot testing is not only important to inform the planning of future trials, but also in determining the intervention's readiness for definitive clinical trials. Combined, assessments of feasibility and estimates of preliminary effects can lead to intervention refinement prior to scaling up to clinical trials to assess efficacy of the intervention. Thus, the goals of this pilot study are to inform ongoing development of the ABLE intervention through:

1. Assessment of the feasibility of the ABLE intervention among people with chronic stroke.
2. Estimation of preliminary effects on measures of sedentary behavior and participation that may be associated with the ABLE intervention.

4.1 Methods

We conducted a single group pre-post-test study to examine the feasibility and estimate change on measures of sedentary behavior that may be associated with the ABLE intervention among people with chronic stroke. A dose-matched, no-intervention delay was implemented during baseline assessments to describe within-person variability on outcomes of sedentary behavior (Figure 2). Follow-up assessments were completed 8 weeks following the conclusion of intervention. All study procedures were approved by the University of Pittsburgh Institutional Review Board and the study was conducted in compliance with the Helsinki Declaration.

4.1.1 Participants

Participants were recruited from the local community (i.e., outpatient clinics, stroke support groups, community centers, posted flyers) and a pool of people who had previously participated in research within our research institution. People who met the following criteria were included: 1) greater than or equal to 18 years of age; 2) diagnosis of stroke; 3) between 6 months 5 years post-stroke; 4) ambulatory (with or without an assistive device) within the community; 5) reported greater than or equal to 6 hours sitting per day (Sedentary Behavior Questionnaire, Weekday (Rosenberg et al., 2010)); 6) resided within 50 miles of our research institution. People who met the following criteria were excluded: 1) severe aphasia (Boston Diagnostic Aphasia Evaluation severity score less than or equal to 1 (Borod, Goodglass, & Kaplan, 1980)); 2) current participation in prescribed rehabilitation (occupational therapy, physical therapy, speech therapy); 2) current cancer treatment (i.e., chemotherapy, radiation); 3) current untreated major depressive disorder, psychiatric disorder or substance abuse disorder (Patient Health Questionnaire-9, PRIME-MD/Mini International Neuropsychiatric Interview (Gilbody et al., 2007; Kroenke et al., 2001; Spitzer et al., 1994)); 4) diagnosis of neurodegenerative disorder. Participants provided written informed consent prior to completion of study procedures. Proxy consent was obtained for people who were unable to provide written informed consent (e.g., those with aphasia).

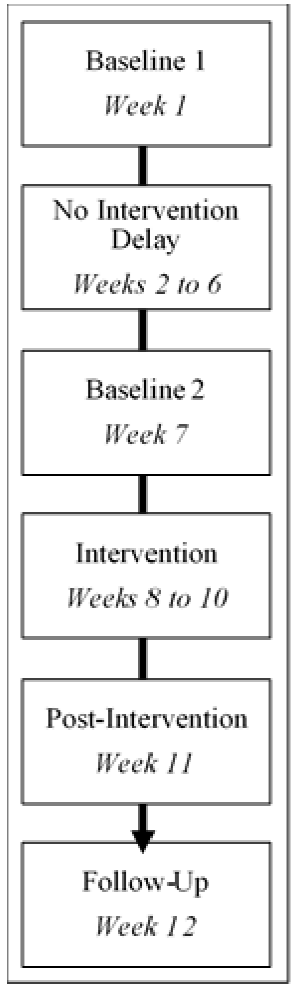

Figure 2 ABLE study: Study design

4.1.2 Intervention

4.1.2.1 ABLE Intervention Protocol

The ABLE intervention has been described in detail in section 3.1.3. In brief, participants were engaged in 12 in-home intervention sessions delivered by trained occupational therapists (EAK, SAR). Sessions were delivered at a frequency of 3 times per week for 4 weeks. If the participant missed a scheduled session, a make-up session was scheduled. We anticipated that each session would be approximately 45 minutes in duration. Guided by the therapist and the ABLE intervention workbook (developed by our team, Appendix A), participants monitored daily activity and sitting patterns, scheduled personally meaningful activities to break up prolonged sitting time, collaboratively problem solved with the therapist to identify barriers to and strategies for breaking up prolonged sitting time, and self-monitored to identify positive and negative responses (physical, affective) to changes in activity levels.

4.1.2.2 Feasibility Measures

We assessed the reliability of intervention delivery, participants' ratings of intervention acceptability, participants' tolerability of the intervention, and safety of the intervention.

Reliability

Reliability of the intervention delivery was assessed through fidelity review (Hildebrand et al., 2012). These were conducted by an independent research assistant trained by the principal investigator. Video recorded sessions were reviewed against fidelity checklists created specifically for the ABLE intervention (Appendix A). The first 2 intervention sessions included activity brainstorming and an introduction to sedentary behavior and the ABLE approach. These sessions were reviewed against the ABLE Foundations Fidelity Checklist. The remaining intervention 10 sessions included an iterative process that consisted of activity scheduling, activity monitoring, self-assessment, and collaborative problem solving. A random numbers table was used to select 20% of sessions for each participant (2 sessions per participant). The selected sessions were reviewed against the ABLE Intervention Checklist to assess the presence or absence of activity scheduling, activity monitoring, self-assessment, and collaborative problem solving. We considered the ABLE intervention to be feasible if each of the active ingredients (activity scheduling, activity monitoring, self-assessment, collaborative problem solving) were present in greater than or equal to 90% of sampled intervention sessions.

Acceptability

Acceptability of the ABLE intervention was assessed using the Client Satisfaction Questionnaire-8 (CSQ) (Attkisson & Greenfield, 2004). The CSQ consists of 8 questions rated on a 4-point Likert-type scale. Scores are summed (range 8 to 32). Participants completed these questions over the telephone during post-intervention assessments, completed with an independent assessor. High scores indicate high satisfaction. The CSQ has acceptable validity and reliability. We considered the ABLE intervention to be acceptable if the group mean was greater than or equal to 28.8.

Tolerability

Tolerability of the ABLE intervention was assessed through documentation of session attendance and duration of intervention session. We also calculated the frequency of intervention sessions attended as a descriptor of the intervention intensity. We anticipated that intervention sessions would last for 45 minutes and occur at a frequency of 1 session every 2.33 days. We considered the ABLE intervention to be tolerated by participants if they completed greater than or equal to 90% (10.8) of the intervention sessions.

Safety

Adverse events were documented throughout the study. We anticipated that the ABLE intervention may pose minimal risk of falls, with or without injury. People with stroke experience more falls during their daily activities than healthy populations (Jørgensen et al., 2002). We discussed all reported adverse events with participants, to determine if they were related to the intervention (e.g., if a fall occurred during an activity planned during the intervention sessions or within the participant's typical routine). No safety-related benchmark was established.

4.1.3 Clinical Measures

Descriptive characteristics were assessed at week 1 (baseline 1). Outcomes were assessed at week 1 (baseline 1), week 6 (baseline 2), week 11 (post-intervention), and week 18 (follow-up). The primary outcomes were objectively measured mean daily minutes of prolonged sitting (accumulated in uninterrupted bouts ≥30 minutes) and mean daily number of sit-stand transitions. Exploratory outcomes were mean daily minutes of sitting, mean daily minutes of prolonged sitting (accumulated in uninterrupted bouts ≥60 minutes), self-reported typical weekday sitting time and total weekly sitting time, objectively measured mean daily step count, and community participation. Descriptive characteristics (i.e., demographics, clinical characteristics) were assessed during baseline 1 by a trained independent assessor.

4.1.3.1 Descriptive Characteristics

Demographic information was collected via participant interview. Stroke characteristics were assessed via medical record review. We also described comorbidity frequency and severity (Self-Administered Comorbidity Index (Sangha, Stucki, Liang, Fossel, & Katz, 2003)), fatigue (PROMIS Fatigue Scale 8a, (Cella et al., 2016)), pain (Numeric Pain Rating Scale, (Williamson & Hoggart, 2005)), mood (Patient Health Questionnaire-9, (Gilbody et al., 2007; Kroenke et al., 2001)), cognitive functions (NIH Toolbox, (Heaton et al., 2014; Weintraub et al., 2013; Weintraub et al., 2014)), and motor functions (Stroke Impact Scale, (Duncan et al., 2003)).

4.1.3.2 Primary Outcomes

Mean daily minutes of prolonged sitting (accumulated in uninterrupted bouts ≥30 minutes) and mean daily number of sit-stand transitions were measured using the ActivPAL micro3 (Pal Technologies, Glasgow) (Barone Gibbs & Kline, 2018; Dowd, Harrington, Bourke, Nelson, & Donnelly, 2012; Edwardson et al., 2017; Winkler et al., 2016). The ActivPAL micro3 has demonstrated good validity and reliability for measuring sedentary behavior among people with stroke (Gebruers et al., 2010). Each participant wore the ActivPAL on the upper one-third of the anterior aspect of the unaffected thigh for 7 days, 24 hours per day, at each time point (baseline 1, baseline 2, post-intervention, follow-up). The device was waterproofed to allow participants to bathe. Participants were instructed to remove the device only if they experienced skin irritation or immersed in water (e.g., swimming). During each day of wear, participants documented the times in which they woke, got out of bed, went to bed, went to sleep, daytime sleep times, and device non-wear time on a worksheet provided by the study team. Data were retrieved from the device using ActivPAL3 Software (version 7.2.38, Pal Technologies, Glasgow). Sleep and non-wear times were removed manually, guided by a diary-informed protocol established prior to data collection (Appendix B). Data were assessed for validity and each day was considered valid if the monitor was worn during all waking hours. Time points with 4 or more valid days were included in analyses. Time points with 3 or fewer valid days were counted as missing data.

The mean daily number of minutes of prolonged sitting (accumulated in uninterrupted bouts ≥30 minutes) was calculated for each time point (i.e., baseline 1, baseline 2, post-intervention, follow-up). Prolonged sitting duration was adjusted to standardize within-person waking time over all time points. The standardized duration of prolonged sitting was used in all analyses. We also calculated the mean daily number of sit-stand transitions.

4.1.3.3 Exploratory Outcomes

Exploratory outcomes included: mean daily total sitting time (ActivPAL), mean daily prolonged sitting (accumulated in ≥60 minute bouts, ActivPAL), self-reported typical weekday and total weekly sitting time (Sedentary Behavior Questionnaire (Rosenberg et al., 2010)), participation (Stroke Impact Scale-Participation (Duncan et al., 2003)), and objectively measured mean daily step count (ActivPAL). Mean daily total sitting time and mean daily prolonged sitting (≥60 minute bouts) were measured using the ActivPAL micro3, following the same procedures for assessment and standardization as described in section 4.2.3.2. Self-reported typical weekday and total weekly sitting time were measured using the Sedentary Behavior Questionnaire (SBQ). The SBQ contains 9 sedentary activities in which participants are asked to report time spent doing each activity on a typical weekday and weekend day. We followed an established protocol to compute the typical weekday sitting time and total weekly sitting time (Rosenberg et al., 2010). The SBQ demonstrates validity and reliability for assessing adults' sedentary behavior. Participation was measured using the Stroke Impact Scale-Participation Subscale (SIS-P). The SIS-P is a valid and reliable measure in which participants are asked to report the degree to which they feel limited in various activity domains (e.g., work or volunteer, social activities, active participation). These scores were used to calculate the percentage of participation in meaningful activities (Duncan et al., 2003). Mean daily step count was measured using the ActivPAL micro3 (Pal Technologies, Glasgow). The ActivPAL micro3 has demonstrated validity and reliability for assessing step count among people with stroke (Gebruers et al., 2010).

4.1.4 Analyses

4.1.4.1 Descriptive Characteristics

We examined the mean, distribution, and patterns of missingness for all descriptive characteristics, primary outcomes, and secondary outcomes. To understand the baseline stability of sedentary behavior, we calculated the coefficient of variation between baseline 1 and baseline 2 (Atkinson & Nevill, 1998). Baseline mean and standard deviation were computed for each outcome, using data from baseline 1 and baseline 2. The coefficient of variation for each outcome was then calculated using the following equation:

$$\left(\frac{SD}{\bar{X}}\right)100$$

Low coefficients of variation indicate low within-person variability. We considered outcomes with a coefficient of variation ≤10% to be stable over time (Atkinson & Nevill, 1998).

4.1.4.2 Change on primary and exploratory outcomes over time

The ABLE intervention is in the early phase of intervention development. Thus, the goal of the following analysis is to estimate the effects of change over time on primary and exploratory outcomes. These estimates will be used to plan for future definitive trials (Moore et al., 2011). For each outcome, the mean of baseline 1 and baseline 2 was calculated and coded T0. Post-intervention was coded as T1, and the 8-week follow-up was coded as T2. Change over time was assessed by visual assessment of spaghetti plots, computation of Cohen's *d* effect sizes, and applications of linear mixed modeling to assess change over time and potential covariates of change over time.

Plots of change over time

We created individual plots for each outcome to assess change over time from T0 to T1 and from T1 to T2. Plots and change scores were examined to assess direction and magnitude of individual change. For measures of sedentary duration (i.e., minutes or hours), reduction of 60 minutes per day (7 hours per week) or greater were considered clinically meaningful. We also examined the number of participants who had a reduction of 30 to 59 minutes per day. There are not currently published clinically meaningful change over time on sit-stand transitions or step count per day. Thus, we assessed the direction of change on these outcomes. On the Stroke Impact Scale-Participation Subscale, a change of 10% or greater was considered clinically meaningful (Fulk et al., 2010).

Cohen's d effect sizes

A modified version of Cohen's *d* was used to calculate effect sizes that accounts for within-person repeated measures (Morris, 2008). Effect sizes from 0.10 to 0.50 were considered small, 0.51 to 0.70 were considered moderate and greater than 0.71 were considered large (Cohen, 1988).

Within-group change over time

Linear mixed modeling was used to model within-group change over time. Individual growth models were developed that accounted for dependency associated with within-person repeated measures and between-person variability at baseline (Singer, 1998). Models were developed for each primary and exploratory outcome using the SAS PROC MIXED procedure (v. 9.4, SAS Institute, Cary, NC). Subject was treated as a random effect. Time (T0, T1, T2) was treated as a fixed effect. For each outcome (dependent variables), we fit an unconditional growth model to assess baseline differences followed by a conditional growth model to detect change over time. The T0 score was then added to the model to control for baseline levels. The F-test statistics, *p*-value were assessed to determine if change over time was statistically significant. Prior to specifying the final model, we considered the covariance structure that best accounts for within-subject dependency of the data and examined model fit statistics (i.e., AIC) associated with these structures.

Covariates of change over time

Potential covariates of change over time were also examined using linear mixed modeling. Simple linear regression analyses were conducted to determine if clinical characteristics (i.e., mobility, motor function, pain, fatigue) or clients' perspectives (i.e., patient-provider connection, treatment expectancy) were associated with our primary and secondary outcomes at $p<0.10$. Due to the exploratory nature of these analyses, we prioritized avoidance of a Type II error and selected $\alpha=0.10$ (Jaeger & Halliday, 1998). Factors that were identified as potential covariates of treatment response were added to the linear effects models previously specified. We examined model fit statistics (i.e., AIC, BIC), the F-test statistics, and the *p*-values (relative to $\alpha=0.05$) to better understand the relationship between the identified covariate and response to treatment. Models were then reduced based on statistical significance of individual predictors and model fit statistics to identify parsimonious models.

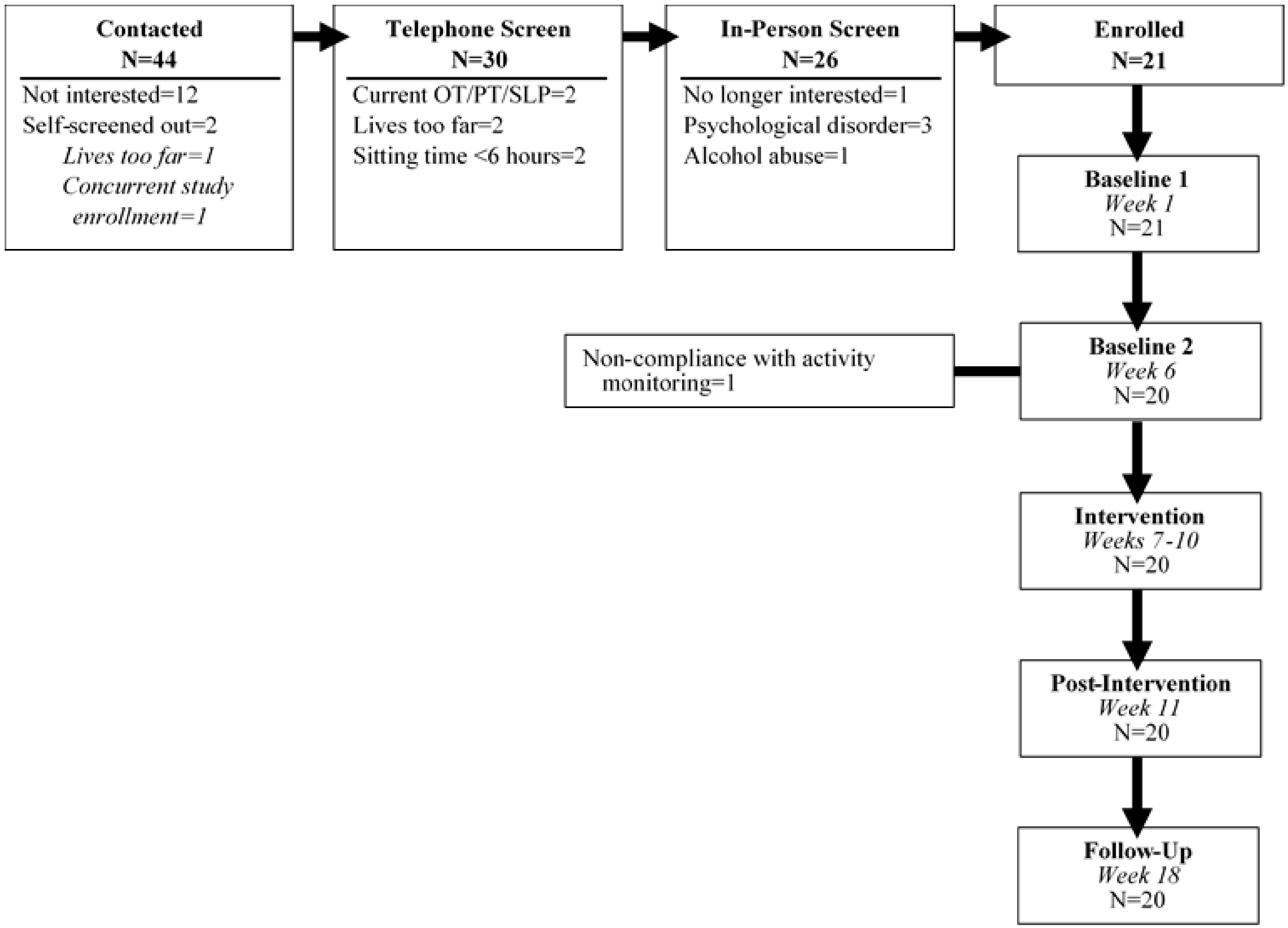

Figure 3 ABLE study: Participant flow

4.2 Results

4.2.1 Recruitment and Retention

The flow of participants through the study is reported in Figure 3. Forty-four people were contacted to assess interest in the study. Twelve people were not interested in the study and 2 people self-screened out prior to completing the formal telephone screen (resided >50 miles from our research institution=1, concurrent enrollment in an intervention study=1). Six people were deemed ineligible during the telephone screen (current occupational, physical, or speech therapy=2, resided >50 miles from our research institution=2, reported sitting less than 6 hours per day=2). Twenty-six people scheduled in-person screening, and twenty-five people completed in-person screening procedures (no longer interested=1). Four people were deemed ineligible at in-person screening (psychological disorder=3, alcohol abuse=1) and 21 people were enrolled in the study. Twenty-one participants complete baseline 1. One participant was withdrawn during baseline 2 due to non-compliance with activity monitoring. Twenty participants completed baseline 2, intervention, post-intervention assessments, and 8-week follow-up assessments.

4.2.2 Participants

Baseline demographic and descriptive clinical data are described in Table 10. Twenty-one participants completed baseline testing. The mean age was 70.81 (SD=10.92 years) and the majority were female (61.9%). Most participants were retired (61.9%) and reported no caregiver

Table 10 ABLE study: Participant characteristics

N=21	Mean (SD) or % (n)
Age	70.81 (10.92)
Gender, *male*	38.1 (8)
Race	
White	81.0 (17)
Black/African American	14.3 (3)
American Indian/Alaskan Native	4.8 (1)
Employment Status	
Employed full-time	14.3 (3)
Employed part-time	9.5 (2)
Retired	61.9 (13)
Unemployed/Social Security Disability Income	14.3 (3)
Social Support	
Full-time caregiver	28.6 (6)
Part-time caregiver	4.8 (1)
No caregiver	66.7 (14)
Education	
Less than high school	4.8 (1)
High school	42.9 (9)
Associate's degree or greater	52.4 (11)
Stroke Type, i*schemic*	90.5 (19)
Stroke Hemisphere	
Left	57.1 (12)
Right	33.3 (7)
Bilateral	9.5 (2)
Chronicity, *months*	29.38 (14.34)
Post-Acute Rehabilitation	
Inpatient rehabilitation	85.7 (18)
Outpatient rehabilitation	52.4 (11)
Home healthcare	66.7 (14)
Participates in community wellness programs, *Yes*	9.5 (2)
Current activity level relative to pre-stroke	
Lower	76.2 (16)
The same	19.0 (4)
Higher	4.8 (1)
Comorbidities, *Self-Administered Comorbidity Index Total*	6.71 (3.36)
Fatigue, *PROMIS Fatigue 8a T-score*	49.93 (8.12)
Worst Pain, *Numeric Pain Rating Scale*	5.05 (3.04)
Mood, *Patient Health Questionnaire-9*	3.62 (3.25)
Positive Outlook, *HEAL Positive Outlook Short Form T-Score*	54.62 (9.26)
Cognition, *NIH Toolbox Total Composite Standard Score*	98.84 (12.67)
Physical Function, *Stroke Impact Scale-Physical Function Subscale*	60.71 (20.74)
ADL/IADL, *Stroke Impact Scale-ADL/IADL Subscale*	81.90 (17.32)
Mobility, *Stroke Impact Scale-Mobility Subscale*	77.25 (17.43)
Hand Function, *Stroke Impact Scale-Hand Function Subscale*	69.52 (28.10)

(66.7%). Approximately half of participants had high school education or less (47.6%). Participants were, on average, 29.38 (SD=14.34) months post-stroke and had primarily sustained ischemic strokes (90.5%) affecting the left (57.1%), right (33.3%), and bilateral (9.5%) hemispheres. Participants reported that their current activity level was lower (76.2%), the same, (19.0%), and higher (4.8%) relative to their activity level prior to the stroke. Only 9.5% of participants reported current participation in a community wellness program at the time of enrollment in this research study.

4.2.3 Intervention Feasibility

The intervention was delivered by two occupational therapists trained to the ABLE intervention protocol. Sessions primarily occurred in participants' homes (n=228 sessions). On rare occasions, intervention was delivered via telephone (n=1 session) or in the occupational therapy clinic (n=10 sessions) to accommodate participants' schedules and preferences. Feasibility outcomes are described in Table 11. Participants attended an average of 11.95 (SD=0.22) intervention sessions that occurred at an average frequency of 2.77 (SD=0.60) days between sessions. Sessions lasted an average of 34.22 (SD=8.76) minutes. Activity scheduling (95.0%), activity monitoring (97.5%), self-assessment (95.0%), and collaborative problem solving (90.0%) met our pre-established benchmark for protocol adherence (each active ingredient would be present in greater than or equal to 90% of sampled sessions). Scores on the Client Satisfaction Questionnaire did not meet our benchmark of greater than or equal to 28.80 (M=28.75, SD=3.84). One participant experienced a non-injurious fall while completing a planned activity between intervention sessions.

Table 11 ABLE study: Feasibility outcomes

N=20	*Benchmark*	Result
Attendance	*10.80*	*11.95 (0.22)
Session Frequency (days/session)	-	2.77 (0.60)
Session Length (minutes)	-	34.22 (8.76)
Client Satisfaction Questionnaire-8	*≥28.8*	28.75 (3.84)
Intervention-related falls or injuries	-	**1
Reliability		
Activity scheduling	*90.00*	*95.00
Activity monitoring	*90.00*	*97.50
Self-assessment	*90.00*	*95.00
Collaborative problem solving	*90.00*	*90.00

*Benchmark met, **Non-injurious fall

4.2.4 Change over time on primary and exploratory outcomes

Prior to conducting analyses of effects, the distributions of dependent variables against test assumptions were examined. No severe deviations were identified, and parametric analyses were conducted. All analyses were conducted with α=0.05 unless otherwise specified. For each primary and secondary outcome, individual change over time was plotted and effect sizes were calculated (i.e., Cohen's *d*, Table 12). A positive Cohen's *d* indicates change in the expected direction of change. A negative Cohen's *d* indicates change in the unexpected direction of change. The coefficient of variation between baseline 1 and baseline 2 on each outcome was also examined. On outcomes assessed using the ActivPAL micro3, 20 participants completed T0 activity monitoring (1=non-compliance with study procedures), 20 participants completed T1 activity monitoring, and 18 participants completed T2 activity monitoring (1=hospitalized during assessment week, 1=did not return activity monitor). On questionnaire-based measures, 21 participants completed T0 assessments, and 20 participants completed assessments at T1 and T2 (1=non-compliance with study procedures).

4.2.4.1 Primary Outcomes

Mean daily prolonged sitting (≥30 minutes)

Plots of change over time (T0 to T1, T0 to T2) on mean daily prolonged sitting (≥30 minutes) are displayed in Figure 4. We considered a mean daily reduction of 60 minutes or greater to be clinically meaningful. Seven participants achieved this at post-intervention and 4 participants achieved this at follow-up. We also examined the number of participants who achieved a mean daily reduction of 30 to 59 minutes. Four participants achieved this at post-intervention and 5 participants achieved this at follow-up. Nine participants did not demonstrate clinically meaningful change at post-intervention and 9 participants did not demonstrate clinically meaningful change at follow-up. Two participants did not complete follow-up activity monitoring (1=hospitalized during week of monitoring, 1=did not return activity monitor). A moderate post-intervention effect (Cohen's d=0.70) and small follow-up effect (Cohen's d=0.18) was observed. After controlling for baseline levels of prolonged sitting and comorbidity severity (>30 min), change over time was not statistically significant ($F[37, 1]=0.94$, $p=0.34$, Table 13).

Mean daily sit-stand transitions

Plots of change over time (T0 to T1, T0 to T2) on mean daily number of sit-stand transitions are displayed in Figure 5. We considered an increase over time of 1 or more mean daily sit-stand transitions to be clinically meaningful. Eight participants achieved this at post-intervention and 9 participants achieved this at follow-up. Twelve participants did not demonstrate clinically meaningful change at post-intervention and 9 participants did not demonstrate clinically meaningful change at follow-up. On mean daily number of sit-stand transitions, a small reduction was detected at post-intervention (Cohen's d=-0.11) and no change was detected at 8-weeks

Table 12 ABLE study: Change over time on primary and exploratory outcomes

	Baseline (T0) Mean (SD)		Post-Intervention (T1) Mean (SD)		8-Week Follow-Up (T2) Mean (SD)	
Primary Outcomes	Raw	Standard.	Raw	Standard.	Raw	Standard.
Mean daily minutes of prolonged sitting (≥30 minutes), ActivPAL micro3	466.56 (168.65)	476.30 (177.49)	437.72 (147.34)	427.52 (137.03)	454.95 (181.12)	457.19 (188.91)
	CV=8.81%, n=20		n=20		n=18	
Cohen's *d* (95% CI)			0.70 (-0.01, 1.24)		0.18 (-0.47, 0.84)	
Mean daily count of sit-stand transitions, ActivPAL micro3	45.79 (19.27)	-	46.21 (20.88)	-	48.35 (21.97)	-
	CV=9.68%, n=20		n=20		n=18	
Cohen's *d* (95% CI)			-0.11 (-0.73, 0.51)		-0.08 (-0.73, 0.57)	
Exploratory Outcomes						
Mean daily total minutes of sitting, ActivPAL micro3	716.29 (122.90)	729.59 (129.94)	695.75 (103.93)	683.24 (97.85)	722.05 (131.34)	723.08 (148.12)
	CV=4.81%, n=20		n=20		n=18	
Cohen's *d* (95% CI)			0.67 (-0.03, 1.24)		0.30 (-0.32, 0.99)	
Mean daily minutes of prolonged sitting (≥60 minutes), ActivPAL micro3	290.04 (158.00)	296.34 (164.02)	266.06 (151.33)	258.74 (143.58)	269.37 (161.89)	271.39 (166.55)
	CV=21.13%, n=20		n=20		n=18	
Cohen's *d* (95% CI)			0.43 (-0.23, 1.02)		0.18 (-0.47, 0.84)	
Typical daily weekday hours of sitting time, Sedentary Behavior Questionnaire	11.55 (4.12)	-	11.56 (4.61)	-	10.02 (3.27)	-
	CV=17.49%, n=20		n=20		n=20	
Cohen's *d* (95% CI)			-0.03 (-0.59, 0.65)		0.40 (-0.31, 1.01)	
Typical weekly hours of sitting time, Sedentary Behavior Questionnaire	79.72 (28.79)	-	79.34 (32.10)	-	69.72 (23.18)	-
	CV=17.40%, n=20		n=20		n=20	
Cohen's *d* (95% CI)			0.04 (-0.58,0.66)		0.47 (-0.25,1.07)	
Mean daily step count, ActivPAL micro3	3911.12 (2769.30)	-	4026.05 (2649.07)	-	3754.44 (2410.96)	-
	CV=10.43%, n=20		n=20		n=18	
Cohen's *d* (95% CI)			0.20 (-0.43,0.81)		-0.47 (-1.10,0.22)	
Participation (%), Stroke Impact Scale-Participation Subscale	73.36 (22.26)	-	75.16 (21.45)	-	75.00 (25.87)	-
n	CV=8.32%, n=20		n=20		n=20	
Cohen's *d* (95% CI)			0.12 (-0.50, 0.74)		0.23 (-0.41, 0.90)	

Note. ActivPAL micro3 sedentary minutes standardized to mean within-person waking time over all time points. Standardized scores used to calculate Cohen's *d* effect sizes. Positive effect sizes indicate change in expected direction. CV=Coefficient of variation over delayed baseline.

Table 13 ABLE study: Linear mixed models of primary and exploratory outcomes

Outcome	Model	Factor	β	SE
Mean Daily Prolonged Sitting Over 7 Days (≥30-minute bouts)	Conditional Growth + Baseline	Intercept	35.57	24.68
		Baseline (prolonged sitting ≥30 minutes)	0.89**	0.04
		Time per time point	-8.54	9.36
	Conditional Growth + Covariate	Intercept	14.73	24.30
		Baseline (prolonged sitting ≥30 minutes)	0.85**	0.04
		Comorbidity severity	6.30**	0.01
		Time per time point	-8.68	0.34
Mean Daily Sit-Stand Transitions Over 7 Days	Conditional Growth + Baseline	Intercept	-2.12	1.67
		Baseline (sit-stand transitions)	1.04**	0.03
		Time per time point	0.02	0.63
	Conditional Growth + Covariate	Intercept	2.11	2.20
		Baseline (sit-stand transitions)	0.97**	0.04
		Gender (female relative to male)	-2.54*	1.25
		Time per time point	-0.18	0.64
Mean Daily Total Sitting Over 7 Days	Conditional Growth + Baseline	Intercept	70.78	60.40
		Baseline (total sitting)	0.88**	0.08
		Time per time point	-9.09	10.62
	Conditional Growth + Covariate	Intercept	61.76	53.30
		Baseline (total sitting)	0.82**	0.07
		Comorbidity severity	7.62**	2.62
		Time per time point	-8.73	10.36
Mean Daily Prolonged Sitting Over 7 Days (≥60-minute bouts)	Conditional Growth + Baseline	Intercept	23.39	20.50
		Baseline (prolonged sitting ≥60 minutes)	0.89**	0.05
		Time per time point	-9.65	9.33
	Conditional Growth + Covariates	Intercept	9.58	62.26
		Baseline (prolonged sitting ≥60 minutes)	0.85**	0.07
		Age	-0.06	0.98
		Comorbidity severity	4.19	2.91
		Time per time point	-9.79	9.34
Mean Daily Step Count Over 7 Days	Conditional Growth + Baseline	Intercept	384.82*	192.21
		Baseline (step count)	0.91**	0.036
		Time per time point	-174.63*	89.94
	Conditional Growth + Covariate	Intercept	-1008.29*	535.48
		Baseline (step count)	0.87**	0.03
		Positive Outlook	28.33**	10.31
		Time per time point	-165.07*	89.90
Typical Weekday Sitting (SBQ) Over 7 Days	Conditional Growth + Baseline	Intercept	3.58**	1.25
		Baseline (typical daily sitting)	0.71**	0.10
		Time per time point	-0.80*	0.41
	Conditional Growth + Covariate	Intercept	9.48**	2.83
		Baseline (typical daily sitting)	0.67**	0.09
		Fatigue	-0.11**	0.05
		Time per time point	-0.75*	0.42
Total Weekly Sitting (SBQ) Over 7 Days	Conditional Growth + Baseline	Intercept	23.94**	8.98
		Baseline (total weekly sitting)	0.72**	0.10
		Time per time point	-5.26*	2.73
Participation (SIS-P) Over 7 Days	Conditional Growth + Baseline	Intercept	5.41	5.64
		Baseline (participation)	0.93**	0.07
		Time per time point	0.68	1.35
	Conditional Growth + Covariates	Intercept	7.57	11.19
		Baseline (participation)	0.91**	0.12
		Cognition (Total Composite)	-0.02**	0.00
		Mood	0.80	0.73
		Time per time point	0.76	1.52

Note. SBQ=Sedentary Behavior Questionnaire. SIS-P=Stroke Impact Scale-Participation Subscale. No covariates associated with Total Weekly Sitting (SBQ) on screening. Factor Time=per time point (T0, T1, T2). **p*<.10 ***p*<.05

follow-up (Cohen's *d*=-0.08). After controlling for the baseline number of sit-stand transitions and gender, change over time was not statistically significant (F[35,1]=0.08, *p*=0.78).

4.2.4.2 Exploratory Outcomes

Our exploratory outcomes were: mean daily total sitting time, mean daily prolonged sitting time (≥60 minute bouts), self-reported typical weekday sitting time and total weekly sitting time (SBQ), mean daily step count, and participation (SIS-P). Change over time from T0 to T1 and T0 to T2 was plotted for each outcome and are located in Appendix C.

Mean daily total sitting time

On mean daily total sitting time, a moderate effect was detected at post-intervention (Cohen's *d*=0.67) and a small effect was detected at 8-weeks follow-up (Cohen's *d*=0.30). After controlling for the baseline mean daily accumulated sitting time and comorbidity severity, change over time was not statistically significant (F[37,1]=0.71, *p*=0.40).

Mean daily prolonged sitting time (≥60 minute bouts)

On mean daily prolonged sitting time (≥60 minute bouts), a moderate effect was detected at post-intervention (Cohen's *d*=0.43) and a small effect was detected at 8-weeks follow-up (Cohen's *d*=0.18). After controlling for the baseline mean daily prolonged sitting time (≥60 minute bouts), age, and comorbidity, change over time was not statistically significant (F[37,1]=1.10, *p*=0.30).

Typical weekday self-reported sitting time

On typical weekday self-reported sitting time, no effect was detected at post-intervention (Cohen's *d*=-0.03) and a moderate effect was detected at 8-weeks follow-up (Cohen's *d*=0.40).

After controlling for the baseline typical weekday self-reported sitting time and fatigue, change over time was not statistically significant (F[39,1]=3.25, *p*=0.08).

Total weekly self-reported sitting time

On total weekly self-reported sitting time, no effect was detected at post-intervention (Cohen's *d*=0.04) and a moderate effect was detected at 8-weeks follow-up (Cohen's *d*=0.47). After controlling for the baseline typical weekday self-reported sitting time, these effects were statistically significant (F[39,1]=3.71, *p*=0.06).

Mean daily step count

On mean daily step count, a small effect was detected at post-intervention (Cohen's *d*=0.20) and a moderate negative effect was detected at 8-weeks follow-up (Cohen's *d*=-0.47). After controlling for the baseline mean daily step count and positive outlook, these effects were not statistically significant (F[37,1]=3.37, *p*=0.07).

Participation

On participation, a small effect was detected at both post-intervention (Cohen's *d*=0.12) and 8-weeks follow-up (Cohen's *d*=0.23). After controlling for baseline participation, cognition, and mood, these change were not statistically significant (F[33,1]=0.25, *p*=0.62).

4.3 Discussion

The goal of this study was to assess the feasibility and to describe change on measures of sedentary behavior that may be associated with the ABLE intervention. This work adds to an emerging body of work focused specifically on reducing sedentary behavior after stroke. The ABLE intervention was deemed safe, reliably delivered, and tolerated by participants. The benchmark for satisfaction was unmet. It is possible that satisfaction was related to need for intervention (e.g., baseline levels of sedentary behavior) or readiness for change (Prochaska & Velicer, 1997). Though not statistically significant, preliminary estimates of effects on a device-based measure of sitting time (ActivPAL) were moderate at post-intervention (prolonged sitting in bouts of ≥30 minutes and ≥60 minutes, total sitting) and small to moderate at 8-week follow-up (prolonged sitting in bouts of ≥30 minutes and ≥60 minutes, total sitting, self-reported typical weekday and total weekly sitting time). These results suggest that the ABLE intervention may be promising for reducing prolonged sitting time. However, further pilot work is necessary before advancing to clinical efficacy trials of this approach.

Distinct from previous intervention approaches, the ABLE intervention is grounded in behavioral activation. Behavioral activation emphasizes skill development for self-monitoring, activity scheduling, self-assessment, and problem solving to promote engagement in activities (Cuijpers et al., 2007; Kanter et al., 2010). We extended these elements to promote frequent engagement in meaningful activities over the full 24-hour day. Two previous intervention studies that aimed to reduce post-stroke sedentary behavior applied motivational interviewing (English et al., 2016b) and social cognitive theory in combination with prompting devices (Ezeugwu & Manns, 2018). Also deemed feasible, these studies detected a range of small to large effects on objectively measured sedentary behavior. The present study adds to the body of evidence that suggests behavioral interventions to reduce sedentary behavior after stroke are feasible. Although effect sizes associated with the ABLE intervention on objective measures of sedentary behavior were moderate to large, these estimates were unstable (p>.05). Future intervention studies should seek to further establish the association between these theoretically-driven active intervention elements (activity scheduling, activity monitoring, self-assessment, problem solving) and sedentary behavior outcomes.

Ecological models of health behavior suggest that correlates of sedentary behavior exist over a wide spectrum that ranges from the intrapersonal level (e.g., demographics, biological) to the policy level (Owen, Salmon, Koohsari, Turrell, & Giles-Corti, 2014; Owen et al., 2011). These correlates can moderate response to intervention. Our assessment of potential covariates of response to the ABLE intervention only included intrapersonal factors. Comorbid medical conditions, age, gender, fatigue, mood, and cognition were identified as potential covariates of change on sedentary behavior over time. Correlates of post-stroke sedentary behavior remain unclear (English et al., 2016a; English et al., 2014). However, among older adults and a population with high medical comorbidity (i.e., chronic obstructive pulmonary disease) comorbidity was associated with physical activity behaviors (McNamara, McKeough, McKenzie, & Alison, 2014; Pitta et al., 2005). In addition, the association of physical inactivity with age, gender, and mood among community-dwelling adults is well established (Bauman et al., 2012; King et al., 2000; Marshall et al., 2007; O'Donoghue et al., 2016). The correlates identified in the present study suggest that these associations may also exist among people with stroke. Fatigue and cognition were not previously identified as predictors of sedentary behavior among healthy adults. However, stroke-related impairments in these domains are common (Douiri et al., 2013; Lerdal et al., 2009). Further exploration into the influence of fatigue and cognition on sedentary behavior is warranted.

Although intrapersonal factors co-varied with sedentary behavior over time, it is possible that unmeasured characteristics of the health, social, or built environment also influenced this outcome. Inpatient health settings accessed for acute stroke management and post-acute rehabilitation are associated with greater sitting durations than home settings (Simpson et al., 2018). Even so, sedentary behavior persists at a high level after return to home settings (Tieges et al., 2015). Stroke survivors experience changes in social networks (e.g., avoidance of social interactions associated with changes in function, less participation in social groups after stroke, dependence on family or friends as informal caregivers), that may influence the frequency of engagement in daily activities (Cameron & Gignac, 2008; Harris et al., 2016; Haslam et al., 2008). Characteristics of the built environment (e.g., non-accessible bathroom at friend's home) may also influence the degree to which stroke survivors choose to engage in activities outside their home. To develop interventions that effectively reduce sedentary behavior, we must further clarify the influence of factors at all levels of the ecological model.

4.3.1 Limitations

The preliminary effects presented here must be interpreted with caution. The goal of this study was to assess the feasibility and obtain preliminary estimates of change over time that may be associated with the ABLE intervention. To that end, the ABLE intervention was tested using a single group pre-post-test design. The study design was strengthened by the inclusion of a dose-matched delayed baseline to assess stability of objectively measured sedentary behavior over time. This assessment revealed acceptable stability of objectively measured sedentary behavior over time (Atkinson & Nevill, 1998). Although this allows us to infer that individual changes in sedentary behavior over time may be associated with the ABLE intervention, we cannot definitively conclude that changes in sedentary behavior over time were caused by the intervention.

4.3.2 Future Directions

The development of complex behavioral interventions requires careful protocol specification through multiple iterations of pilot testing (Craig et al., 2008; Michie et al., 2009; Moore et al., 2011). Results of the present study suggest that ongoing refinement of the ABLE intervention is necessary to further understand the role of participation in meaningful activities as a potential mechanism of change in sedentary behavior over time. The ABLE intervention used behavioral activation to promote engagement in frequent bouts of personally meaningful activity. However, a greater number of participants demonstrated clinically meaningful reduction in sedentary behavior over time than those who demonstrated meaningful increase on our measure of participation over time. Further exploration of the relationship between sedentary behavior and different types of participation or activity engagement (e.g., seated vs. upright) may inform future iterations of the ABLE intervention. In addition, ecological models of health behavior suggest that environmental factors may influence sedentary behavior. Studies of environmental determinants will inform active intervention elements to bolster the effects of the intervention. Descriptive studies examining the relationship among participation, activity engagement, sedentary behavior, and environmental determinants will inform ongoing specification of the ABLE intervention. After thorough specification, clinical trials and implementation studies will be important to establish the efficacy and effectiveness of the ABLE intervention.

4.3.3 Conclusions

Results of this preliminary efficacy study of the ABLE intervention add to an emerging body of intervention development that aims to reduce sedentary behavior among people with stroke. Collectively, this small body of pilot work supports the feasibility of behavioral interventions and suggests that sedentary behavior can be modified. However, active intervention elements that are critical for reducing sedentary behavior among people with stroke remain unclear. Further exploration of these elements and environmental elements that may influence response to interventions is necessary to advance this body of work.

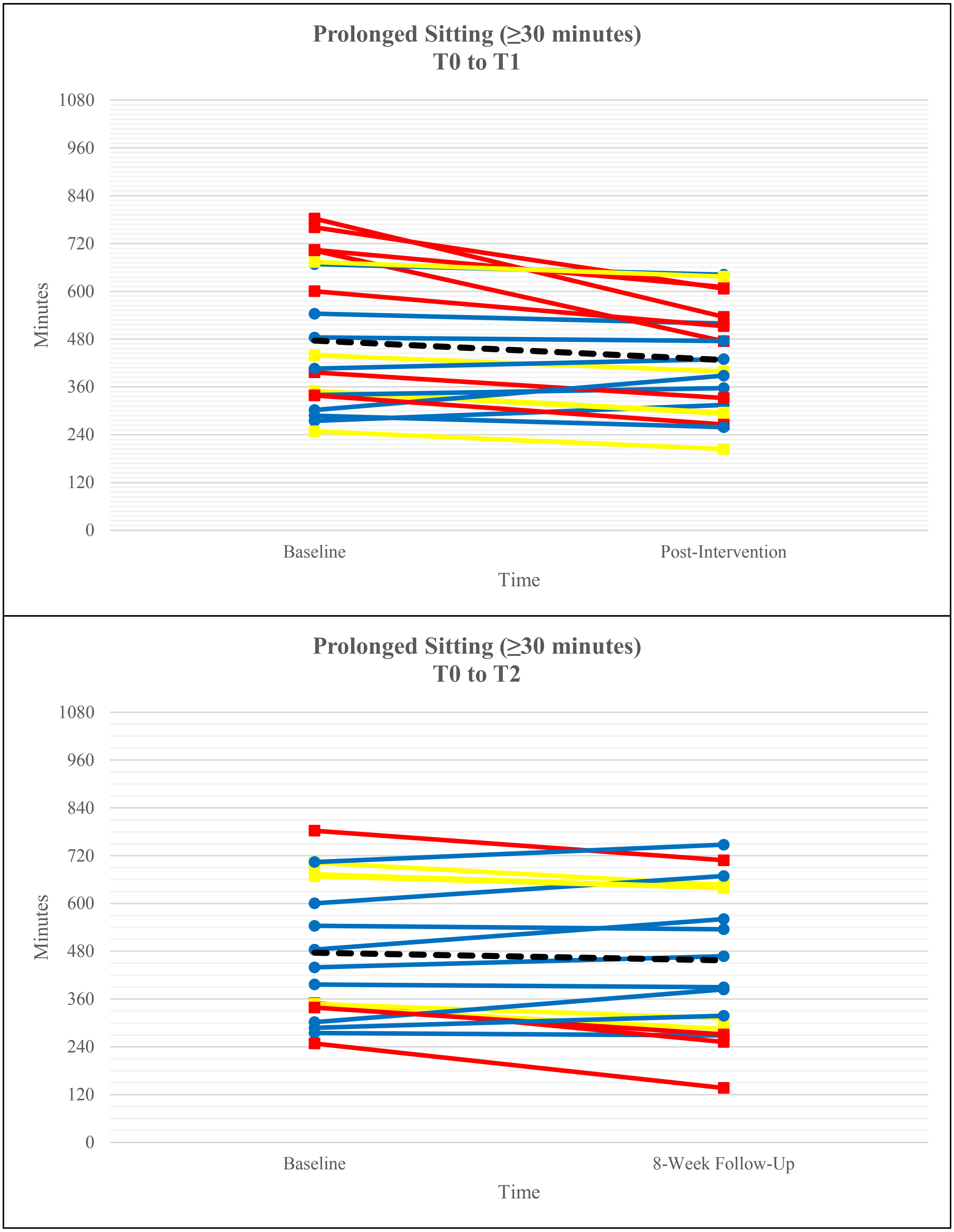

Figure 4 ABLE study: Change over time on prolonged sitting (≥30 minutes)

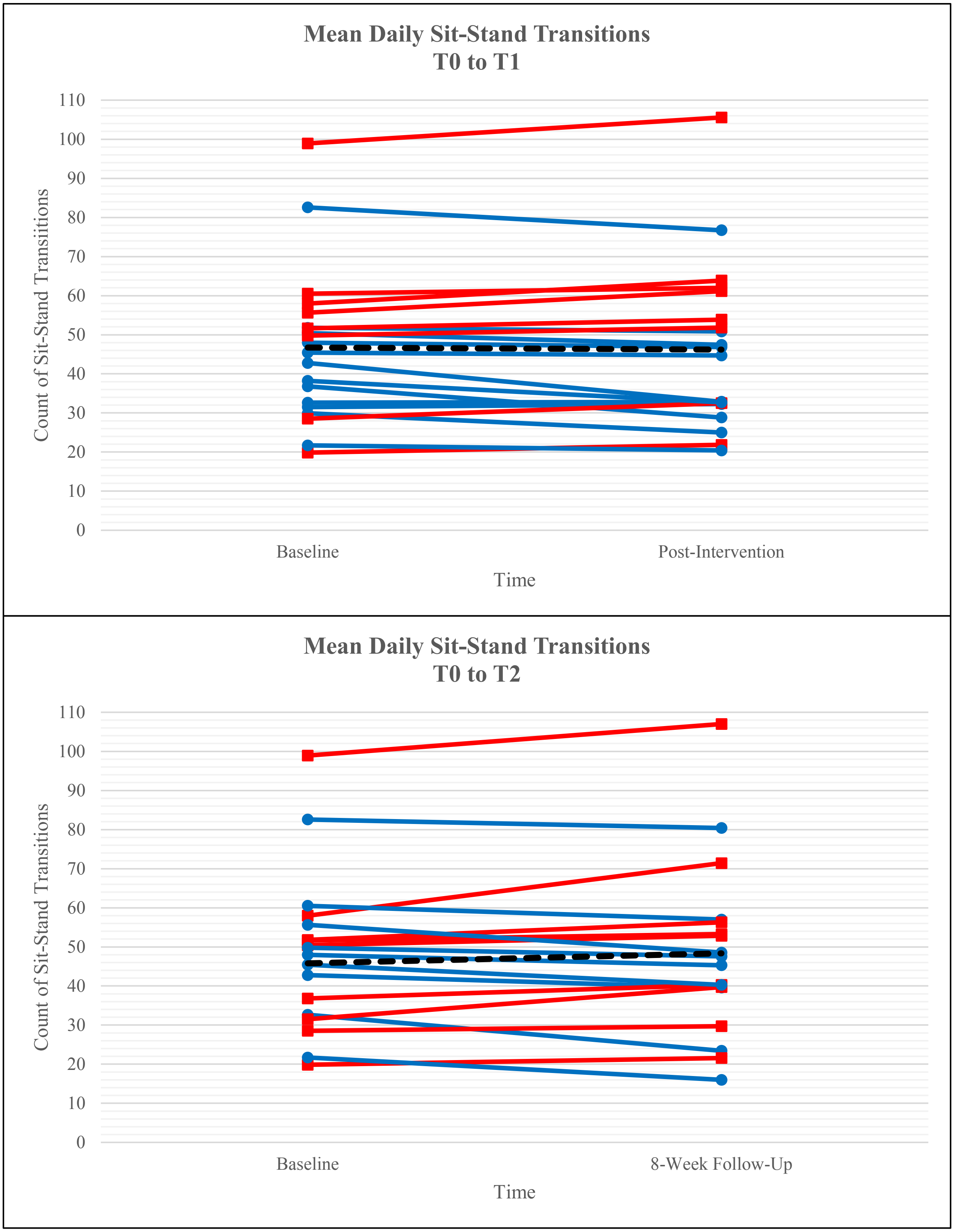

Figure 5 ABLE study: Change over time on mean daily sit-stand transitions

5.0 Discussion

Leading an active lifestyle is particularly important for returning to and maintaining health after stroke (Billinger et al., 2014). Interventions have been developed to combat inactivity through prescribed exercise and physical activity programs. However, these interventions fail to produce long-term effects among people with stroke (Moore et al., 2018; Morris et al., 2014). Mobility impairments, inaccessible exercise facilities, and cost are frequently cited as barriers to achieving physical activity (Damush et al., 2007; Rimmer et al., 2008). Sedentary behavior has emerged as a health behavior positioned within the same class as physical inactivity, but as a distinct construct from the physical activity spectrum (Tremblay et al., 2017). Physical activity interventions promote engagement in a prescribed volume of activity (e.g., minutes of activity at a particular intensity), at a particular frequency (e.g., daily). These physical activity interventions do not regard the remaining hours during the full 24-hour day during which participation in daily activities can influence health.

Interventions that specifically aim to reduce sedentary behavior during the full 24-hour day through frequent engagement in daily activities may be promising to yield lasting effects on health among people with stroke (Morton et al., 2018). The overarching aim of this work was to examine intervention approaches that may be promising to reduce sedentary behavior after stroke. Through a review of existing interventions and two studies that examined the feasibility and preliminary efficacy of the Activating Behavior for Lasting Engagement intervention, we identified that future exploration of the contexts in which daily activity engagement and sedentary behavior occur are important to advance the science of health promoting interventions for people with chronic stroke.

5.1 Participation: Daily activities in context

Activities such as buttoning a button, placing a cake pan in the oven, and lifting a box do not carry great meaning in and of themselves. However, within community or social contexts, engagement in these activities becomes meaningful. Being able to button a shirt while preparing to attend a concert, bake a cake to serve at a family gathering, and lift a box to help a friend move are meaningful. Stroke-related impairments in motor, cognitive, and affective functions can restrict engagement in these and other meaningful daily life activities (Desrosiers & Bourbonnais, 2005; Desrosiers et al., 2008; Desrosiers et al., 2006; Mayo et al., 2002). The ultimate goal of rehabilitation is return to participation. However, traditional interventions focus on the ability to carry out activities rather than the actual engagement in activities. That is, perhaps an individual has demonstrated that she can place a cake pan in the oven during a therapy session but has not actually baked a cake in 4 years because she is fearful of burning herself. While regaining ability is important in early stages of post-acute rehabilitation, promoting activity engagement within the context of daily lives may reduce sedentary behavior and lead to long-term health benefits.

Our review of existing interventions and the development of the ABLE intervention was based in the assumption that engagement in daily activities requires movement away from a seated position, thereby breaking up sedentary behavior. Studies of existing interventions rarely measure both activity engagement and sedentary behavior (Section 2.2.3). The ABLE intervention studies are among a small group of studies that assess change in both sedentary behavior and activity engagement over time (Section 4.2.4). Our results suggest that distinguishing active versus inactive activity engagement and further clarifying patterns of engagement in meaningful activities throughout the day and may advance this work.

5.1.1 Sedentary and non-sedentary participation

Although we recognized that ABLE intervention participants may select activities that involved sitting, we did not restrict the activities that they selected. The therapist's approach to problem solving during intervention was directed by the type of activity the participant desired to participate in. If an activity was selected that involved sitting (e.g., reading, playing bridge, work or volunteer at a desk job), the therapist guided the participant to select strategies for adjusting this activity in a manner that broke up sitting time. If a non-sedentary activity was selected (e.g., home maintenance, attend community event), the therapist guided the participant to schedule a specific time to participate in that activity. Our measure of participation (Stroke Impact Scale-Participation Subscale) was a summary measure that did distinguish sedentary from non-sedentary participation. Thus, participants who modified their approach to engagement or participation in a sedentary activity may report no change or reduction in participation over time.

To further clarify the roles of activity engagement and participation in reducing sedentary behavior, it is imperative to distinguish sedentary from non-sedentary participation. A previous study that assessed participation in activities one-year post-stroke classified low physical and high physical using the Activity Card Sort (Hartman-Maeir et al., 2007). At one-year post-stroke, participants were engaged in only 25.74% of their prior high physical activities and 59.72% of their prior low physical activities. These results suggest that low participation and low physical activity levels may be related. No studies have examined the trajectories of return to participation in high physical and low physical activities after stroke. Distilling these trajectories and participant-identified barriers to return to these types of activities may inform intervention development for reducing sedentary behavior through activity engagement and participation.

5.1.2 Participation and activity patterns

In addition to clarifying trajectories of return to low physical and high physical participation, describing day-to-day variability in participation within peoples' daily lives may inform approaches to intervention. It is well established that post-stroke participation is low relative to community-dwelling peers and remains low over time. However, current assessments of participation were not designed to assess within-person variability and frequency of day-to-day participation. Post-stroke activity engagement and participation are commonly assessed using summary measures that require recall over a specified time period (Salter et al., 2005; Salter, Foley, Jutai, & Teasell, 2007). In some cases, participants are asked to compare engagement in specific activities before and after the stroke (Katz et al., 2003). Although these measurement approaches contain risk for recall bias, self-report is necessary because participation is highly individualized. Only the participant can place meaning on the activities in which s/he engages. Developing innovative approaches to assess within-person patterns of participation and activity engagement is important to advance this work.

Identifying within-person patterns of participation or activity engagement over time may further inform intervention approaches that promote active lifestyles through participation. Cluster analyses have been applied to identify social participation patterns among young adults with chronic conditions (Sattoe, Hilberink, van Staa, & Bal, 2014). Replicating this among people with stroke may be a starting point to identify people who are at risk for low levels of active participation. In addition, ecological momentary assessment affords researchers an opportunity assess participation and activity engagement in real time (Shiffman, Stone, & Hufford, 2008; Stone, Shiffman, Atienza, & Nebeling, 2007). These approaches would not only reduce the risk for recall bias, but also describe day-to-day variability and frequency of engagement in meaningful daily activities. These analyses would lead to development of interventions that leverage active participation after stroke within the context of peoples' daily lives.

5.2 Full-day physical activity: Sedentary behavior in context

It is unreasonable to expect that all time spent in a sitting position will eliminated from peoples' lives. Short bouts of sitting, in fact, may not exert harmful effects on health (Benatti & Ried-Larsen, 2015). Prolonged sitting, however, has clearly established associations with poor health outcomes (Balboa-Castillo et al., 2011; Buman et al., 2013; Chastin et al., 2015a; de Rezende et al., 2014; Ford & Caspersen, 2012; Healy et al., 2008a; Healy et al., 2008b; Moore et al., 2013b; Thorp et al., 2011). To specify the goals and outcomes of sedentary behavior interventions it is crucial to consider sedentary behavior as it exists within the context of all physical activity within the 24-hour day. Contextualizing sedentary behavior will guide to achievable, clearly defined intervention goals and precisely measured outcomes.

5.2.1 Contextualizing sedentary behavior

During each minute within a 24-hour day, people are engaged in some form of physical activity behavior or sleep. Sleep, sedentary behavior (seated or reclined), and physical activity along a spectrum of intensities are mutually exclusive categories of behaviors. Modifying the time spent in one category of behavior influences time spent in the other categories of behavior (Chastin et al., 2015b; Mekary, Willett, Hu, & Ding, 2009; Stamatakis et al., 2015). In addition to the total duration of time spent in each of these behaviors, the pattern by which the total duration is accumulated can influence health (Dunstan et al., 2012; Healy et al., 2008a). Patterns of sedentary behavior accumulation are of particular importance.

Patterns of sedentary behavior refer to the duration and frequency in which sedentary behavior is accumulated throughout the day. Accumulation of sedentary behavior in *prolonged bouts* is associated with greater health risk than accumulation of sedentary behavior in *short bouts* (Dunstan et al., 2012; Healy et al., 2008a). Guidelines that define the duration of *prolonged* and *short* bouts that may be optimal for promoting health do not currently exist (Hamilton et al., 2008; Morton et al., 2018). During the ABLE studies, we defined sedentary behavior as the mean daily waking time spent in *prolonged* sitting (bouts of greater than or equal to 30 minutes in duration). Mobility impairments are prevalent among people with stroke, at times requiring additional time and energy to move to a upright position. Thus, the feasibility of moving to an upright position every 30 minutes should be explored. We approached this matter by considering the mean daily waking time spent in prolonged sitting of bouts greater than or equal to 60 minutes in duration. Although the exploration of 30-minute bouts is consistent with prior stroke literature (English et al., 2016b; Ezeugwu & Manns, 2018), this definition bears further study. Epidemiologists and intervention researchers working with people with cardiovascular conditions have operationalized *prolonged* sitting defined by bouts of 10 minutes or 20 minutes (Benatti & Ried-Larsen, 2015; Tremblay et al., 2017). Future studies that specify the dose-response relationship between sitting bout length and health outcomes among people with stroke will be important to clarify clinically meaningful intervention goals and outcomes.

5.2.2 Modifying post-stroke sedentary behavior

People with stroke have varied levels of residual motor, cognitive, and affective impairments. These impairments frequently make engagement in physical activity behaviors more challenging than for healthy adult populations. Two intervention goals modifying sedentary behavior patterns among healthy adults have been explored: *displacement* and *breaking up sedentary time*. In some interventions, healthy adults are encouraged to *displace* sedentary behavior with physical activity (Shrestha et al., 2018). In these scenarios, healthy adults may displace 30 minutes of sitting by walking the family dog for the same duration of time. Displacing 30 minutes of sitting with physical activity of any intensity has been associated with cardiometabolic health outcomes (Stamatakis et al., 2015). In situations during which displacement of 30 minutes or more would be disruptive (e.g., office work that occurs while seated at desks), adults are encouraged to *break up sedentary time* by moving out of a sitting position to an upright position, thus disrupting a prolonged bout of sitting (Kendzor et al., 2016). This approach allows for sitting time throughout the day while modifying the pattern in which sitting time is accumulated. Intervention approaches that promote b*reaking up sedentary time* may more feasible for people with stroke-related mobility impairments relative to *displacing* sedentary time. Among people with impaired cardiovascular function, patterns of sedentary behavior that include many short bouts are associated with positive cardiometabolic health outcomes (Dunstan et al., 2012; Healy et al., 2008a).

Intervention design for modifying sedentary behavior to improve health post-stroke must be specific to the desired behavior change. Although physical activity and sedentary behaviors are related, interventions that influence engagement in physical activity do not exert equal effect on sedentary behaviors (Prince, Saunders, Gresty, & Reid, 2014). Our review of existing interventions led to development of the ABLE intervention among an early group of interventions that specifically aim to modify sedentary behavior (English et al., 2016b; Ezeugwu & Manns, 2018). Feedback from the treating therapist and participants during early iterations of the ABLE intervention, revealed that it was critical to make the goals of the intervention explicit for our participants. Modifying sitting time throughout the day is different than engaging in exercise or other physical activity at a specific time each day.

The degree of behavior change desired, and the feasibility of accomplishing that change is also important during intervention design. Theories of health behavior change suggest that small changes are necessary to initiate and sustain behavior change (Cuijpers et al., 2007; Kanter et al., 2010; Prochaska & Velicer, 1997). For many people with residual stroke-related impairments, directly displacing 30 minutes of sitting with 30 minutes of continuous physical activity represents a large change, which may not align with motivation or physical ability. Breaking up prolonged sitting bouts by moving to an upright position at a particular frequency requires the ability to complete a sit-stand transition. This is feasible for many stroke survivors and was identified as a feasible proximal intervention outcome in the ABLE studies.

5.2.3 Assessing post-stroke sedentary behavior

Assessment of post-stroke sedentary behavior change associated with intervention must also be conducted within the context of the 24-hour day. Our review of existing intervention studies revealed that a combination of device-based and questionnaire-based measures have been applied to detect change in amount of daily activity or sedentary behavior over time. To assess sedentary behavior within the context of the full 24-hour day, however, we must account for interactions among physical activity, sedentary behaviors, and sleep. Studies of 24-hour time use among non-stroke populations have applied isotemporal substitution (Mekary et al., 2009; Stamatakis et al., 2015) and compositional data analysis (Chastin et al., 2015b) to account for interactions among these behaviors. To our knowledge, these methods have not been applied among people with stroke. Further, studies examining change in physical activity or sedentary behaviors among people with stroke (including the ABLE studies) have not included assessments of sleep as primary or secondary outcomes. Future studies of interventions that aim to modify post-stroke sedentary behavior should assess behavior changes over the 24-hour day.

Although we did not measure sleep or volume of non-sedentary behavior during the ABLE studies, our device-based methodology allowed us to obtain preliminary estimates of sedentary behavior patterns. Device-based measures (e.g., ActivPAL or actigraphy) are viewed as the gold standard for assessing sedentary behavior. These devices (e.g., ActivPAL or actigraphy) eliminate recall bias and provide objective measurement. Although cumbersome, data processing associated with device-based assessment allows flexibility in assessing sedentary behavior *patterns*. The ABLE studies are an example of this. Four days of objective activity monitoring allow for the calculation of a valid daily mean (Edwardson et al., 2017). During the ABLE studies, data were collected over 7 days at each time point (to allow flexibility in the event of device malfunction or non-compliance). The mean daily time spent in sitting during these 7 days was calculated. From these data, we also assessed mean daily time spent in prolonged sitting of various bout lengths (e.g., 30 minute bouts, 60 minute bouts). In addition, continuous data collection via devices results in time-stamped data points that allow researchers to develop heat maps for visual inspection of sedentary behavior patterns (Edwardson et al., 2017). These heat maps may be useful tools for communicating goals and outcomes of interventions with participants, therapists, payers, and policymakers.

Although considered less rigorous than device-based measures, questionnaire-based measures of sedentary behavior can also provide valuable information during intervention development. Most questionnaire-based measures request participants to report time spent engaged in specific types of activities commonly associated with sitting (e.g., transportation, watching television, reading) (Craig et al., 2003; Rosenberg et al., 2010; Washburn et al., 1993; Washburn et al., 2002). Although these measures suffer from bias related to recall and social desirability, they may provide insight into stroke survivors' *perceptions* of their sedentary behavior and physical activity levels. Further, these perceptions may be influenced by perceived pre-stroke activity levels. For example, one participant in this research previously worked as a restaurant owner and spent many hours standing and walking each day. This participant reported a very high level of sedentary behavior, despite objective monitoring that revealed a very low level of sedentary behavior. Conversely, a different participant spent many hours studying and reading during the workday. Due to a newly added gym routine, this participant perceived a low level of sedentary behavior, despite objective monitoring that revealed a very high level of sedentary behavior. Health behavior models suggest that perceiving need for change is a prerequisite for enacting long-term behavior change (Prochaska & Velicer, 1997; Rosenstock, 1974). Discrepancies between device-based measures and questionnaire-based measures of activity levels may provide insight into prior activity levels and perceived need for change.

5.3 Future Directions: Contextualizing Post-Stroke Health Behaviors

Ecological models of health behaviors suggest that the context within which people live matters for health (Owen et al., 2014). To date, interventions that aim to promote physical activity and reduce post-stroke sedentary behaviors address intrapersonal factors (Moore et al., 2018; Morris et al., 2014). The present pilot studies included people with low levels of post-stroke impairments (i.e., motor, cognition, affect). Future studies that include people with a broader range of impairment levels will inform the role of specific impairments (e.g., gait speed, initiation, depressive symptoms) on response to behavioral interventions such as ABLE. Further, the rise of sedentary behavior as a distinct health risk occurred alongside cultural changes in vocational behaviors and reliance on technology (Owen, Healy, Matthews, & Dunstan, 2010). Although acute changes in sedentary behaviors may be directly associated with residual post-stroke impairments, factors external to the stroke may also influence these behaviors. Contextualizing sedentary behavior by exploring those life roles within which sitting occurs will advance the science of post-stroke sedentary behavior.

Clear understanding of changes in stroke survivors' life roles demands exploration of macro and meso-level factors within ecological models that may affect sedentary behaviors. At the macro level, policy-related factors can affect access to community resources, economic resources, and healthcare (Owen et al., 2014; Rosa & Tudge, 2013). These can each negatively influence opportunities for social engagement and health maintenance required to engage in meaningful life roles. At the meso-level, restrictions in access to the built environment and social restrictions may limit the degree to which people engage in life roles outside of their own home (Owen et al., 2014; Rosa & Tudge, 2013). Restrictions in these roles may influence sedentary behavior. Understanding the influence of macro and meso-level factors that influence post-stroke sedentary behavior will guide us to the development of robust interventions that can reduce sedentary behavior and promote health after stroke.

5.4 Conclusion

This dissertation serves as a foundation for ongoing investigation into the roles of activity engagement and participation to reduce sedentary behavior after stroke. Existing interventions that aim to promote daily physical activity or reduce sedentary behavior are not clearly specified and intended intervention outcomes are not well defined. The ABLE intervention was developed to promote frequent engagement in meaningful activity throughout the day using behavioral activation. We demonstrated that the ABLE intervention is feasible among people with chronic stroke. Further investigation of the relationships among activity engagement, participation, sedentary behavior, and health are required to enhance the intervention effects and promote optimal health among people with chronic stroke.

Appendix A Activating Behavior for Lasting Engagement (ABLE) Intervention Development

Early iterations of behavioral intervention are important for developing the intervention framework. Simultaneously, this work generates a plethora of hypotheses related to the intervention that may be tested in future research. The ABLE intervention is an example of this process. The following sections describe the theoretical framework that informed the active ingredients of the ABLE intervention, the iterative process undertaken in this early stage development of the ABLE intervention, and the role of fidelity review processes in the development of the ABLE intervention.

A.1 Theoretical Framework of the ABLE Intervention

The active ingredients in the ABLE intervention are grounded in a behavioral activation framework. People with chronic stroke demonstrate low patterns of engagement in meaningful daily life activities and high levels of sedentary behavior (Desrosiers & Bourbonnais, 2005; Desrosiers et al., 2008; Desrosiers et al., 2006; English et al., 2016a; English et al., 2014; Hartman-Maeir et al., 2007; Mayo et al., 2002; Tieges et al., 2015). Identifying individualized strategies to promote engagement in individually meaningful daily life activities may support reduction in sedentary behavior. Stroke results in persistent motor, cognitive, and affective impairments. These impairments influence peoples' ability to complete daily activities and may require long-term lifestyle changes. Lifestyle changes vary among people in both magnitude and domain. At the intrapersonal level, motor and mobility impairments are the most overt barriers to engagement in daily activities (Desrosiers et al., 2008; Desrosiers et al., 2006). Cognitive and affective impairments can lead to more subtle difficulty in engagement in daily activities (Robinson & Jorge, 2015; Viscogliosi et al., 2011). In addition, impairments can influence the interaction between cognitive and motor neural networks that lead to difficulty completing complex tasks in dynamic environments (Anticevic et al., 2012; Dacosta-Aguayo et al., 2015; Ding et al., 2014; Nomura et al., 2010; Zanto & Gazzaley, 2013). Community and social participation frequently consist of complex tasks in dynamic environments. We sought to identify an intervention framework that provided people with skills for overcoming barriers to complex activities within dynamic environments. It was also important that this framework afforded intervention therapists the flexibility to address between-person variability in residual stroke-related impairments. These requirements led to behavioral activation.

Behavioral activation is an intervention framework designed to reduce depressive symptoms by promoting engagement in pleasurable activities (Cuijpers et al., 2007; Kanter et al., 2010). Variations on behavioral activation interventions have demonstrated effectiveness for reduced depressive symptoms, reductions in cognitive impairments, and elevated quality of life over time among people with depression, dementia, acquired brain injury, and family caregivers (Alfonsson, Parling, & Ghaderi, 2015; Losada et al., 2011; Mazzucchelli et al., 2009; Mazzucchelli, Kane, & Rees, 2010; McEwen et al., 2015; Moore et al., 2013a). Core components of behavioral activation interventions are scheduling activities and monitoring engagement in activities. Because our aim was to modify sedentary behavior and activity engagement patterns throughout the full day, we framed activity scheduling and activity monitoring over the full day (rather than for the specific activity). Dependent on the population’s needs, various forms of skill development are implemented. Given subtle cognitive impairments common among people with stroke, we identified that skills for self-assessment and problem solving would be important to provide skills for identifying and overcoming barriers to engagement in meaningful activities.

A.2 ABLE Intervention: Iterations

The ABLE intervention was developed and tested using an iterative process. These iterations are described in Table 14. The first iteration of the ABLE intervention was implemented with 1 participant. We elicited participant feedback on the intervention approach, examined session notes, and the intervention therapist (EK) maintained a reflective log of observations. These data were used to further specify the active ingredients, refine the structural elements, and develop additional workbook materials to support the intervention process. The second iteration was then implemented with 4 participants. Data from these participants were analyzed individually. The intervention therapist (EK) maintained detailed session notes in which participant feedback to intervention process and materials and observed responses to intervention were documented. This iteration was deemed safe and feasible to implement among a cohort of 20 participants. Feasibility and preliminary efficacy were assessed using a pre-post-test (Section 4.0).

Active Ingredients

The ABLE intervention contains 4 active ingredients: 1) activity monitoring 2) activity scheduling 3) self-assessment, and 4) collaborative problem solving. Each of these ingredients are described below.

Activity monitoring: Explicit observations of one's engagement in activities. This can include observing activity patterns over a period of time or observing if one did or did not engage in a specific activity as planned.

Activity scheduling: Establishment of a plan to engage in a specific activity that includes a temporal aspect. This temporal aspect can be general (e.g. in the morning) or specific (e.g., at 3:00pm). Activity scheduling may also include a frequency of engagement in that particular activity (e.g., 3 times per week, or every day).

Self-assessment: Observations about one's response to engagement in activities. Responses include cognitive, affective, and physiological responses to engaging in activities. Both positive and negative responses are observed.

Collaborative problem solving: Engages the client in identifying solutions to regular engagement in activities that were scheduled. Problem solving can be used to identify solutions to negative responses, address environmental barriers, and establish safe approaches to engagement in personally meaningful activities. The therapist elicits strategies from the client, rather than directly telling the client how to solve the problem.

Structural Elements

Specified structural elements describe the process by which the active elements of ABLE are intended to be delivered. Characteristics of the dose, environment, interventionist, materials, and session processes are described below.

Dose: Three sessions per week for four weeks (total 12 sessions), 45 minutes per session.

Environment: Face-to-face at the participant's home or community location if appropriate.

Interventionist: Trained occupational therapist.

Materials: Participant workbook to guide intervention and for activity monitoring.

Session Process: Review prior plan and monitoring, document new plan in workbook.

A.3 Participant Workbook

The participant workbook was developed to provide:

1. Educational information on patterns and risks of sedentary behavior after stroke.
2. Overview of the ABLE intervention.
3. ICAN Plan Worksheet: This worksheet provides a place to document the participants' planning process. The ICAN plan is used to: **Identify** a time when the participant sits, **Choose** an activity that the participant wants to use to break up the identified sitting time, **Add or Adapt** the activity within his/her routine (includes problem solving anticipated challenges), and **Notice** how the participant feels during and after the plan is carried out.
4. Tools for monitoring the established ICAN Plan.

A.4 Fidelity Assessment

Details of the fidelity review process are located in Sections 3.2.3 and 4.1.2. The following pages contain the ABLE Foundations Checklist and the ABLE Fidelity Checklist. Scoring criteria for each checklist are also included. The ABLE Foundations Checklist was used to assess each participants' first two sessions. The goal of the first two sessions was to provide the participant with all necessary background information (sedentary behavior and ABLE overview) and engage the participant in activity monitoring. We also completed a structured brainstorming process to identify possible activities that could be used to break up prolonged sitting time. The ABLE Fidelity Checklist was used to assess two randomly selected sessions from each participant (sessions 3 through 12). The goal of these sessions was to deliver each of the active ingredients to break up prolonged sitting time by promoting engagement in personally meaningful activities.

Table 14 ABLE intervention iterations

Element	Version 1	Version 2
Foundational Knowledge	Briefly reviewed at the beginning of intervention session #1.	Emphasized during intervention session #1.
Activity Brainstorming	Select activities that participant wants to return to using Activity Card Sort at intervention session #1.	Prioritize activities that can be completed in the next month using Activity Card Sort at intervention session #2.
Activity Monitoring	Completed only within context of activity scheduling.	Moved to intervention session #1, in addition to activity scheduling.
Activity Scheduling	Completed using ICAN Plan process, started at intervention session #1.	Completed using ICAN Plan process, started at intervention session #2 or #3
Self-assessment	Addressed as negative symptoms arose.	Included in activity monitoring, involved positive and negative outcomes of activities.

ABLE Foundations Checklist

Structural Elements	Present in Session? Yes (1)	No (0)	Comments
1) Provides overview of sedentary behavior.			
2) Assigns monitoring homework.			
3) Generates brainstorming list of activities.			
4) Provides orientation to workbook.			
Active Ingredients	**Present in Session? Yes (1)**	**No (0)**	**Comments**
1) Activity scheduling: Any meaningful activity is scheduled to occur at a specific time of day.			
2) Activity monitoring: Therapist encourages participant to monitor time use during scheduled activity. A plan for monitoring is established.			
3) Self Assessment: Therapist asks client to identify positive and/or negative experienced results of engagement in activities.			

Study ID: _____________ **Session #1 Date:** ________________**Session #2 Date:** _________________

Therapist: ____________**Session #1 Length:** ______________**Session #2 Length:** _______________

Fidelity Reviewer: _____ **Missing Data Codes:** 888=Not applicable 999=Missing video

Additional Comments:

ABLE Foundations Checklist

Scoring Criteria

Structural Elements

1. Provides overview of sedentary behavior:
   a.1=Describes and defines sedentary behavior including patterns of sedentary behavior accumulation and associated risks.
   b.0=No description or definition of sedentary behavior occurs.

2. Assigns monitoring homework:
   a.1=Therapist requests that participant completes activity monitoring using worksheet for 1 day between sessions.
   b.0=Monitoring homework is not assigned.

3. Generates brainstorming list of activities.
   a.1=The therapist elicits meaningful activities from the client. This may be completed using the Activity Card Sort and/or brainstorming activities that the client enjoys during the day.
   b.0=No brainstorming list of activities is generated.
4. Provides orientation to workbook.
   a.1=The workbook is provided and referred to during the session.
   b.0=The workbook is not provided or referred to during the session.

Active Ingredients

5. Activity scheduling:
   a.1=An activity that is selected by the client is scheduled to occur at a specific time of day (specific can range from general "in the evening" to specific "at 7pm")
   b.0=No activity is scheduled to occur at a specific time of day.

6. Activity monitoring:
   a.1=The therapist encourages the participant to monitor time use during any session and a plan for monitoring is established.
   b.0=The therapist does not encourage the participant to monitor time use. No plan for monitoring is established.

7. Self-Assessment
   a.1=Positive and negative experienced results of engagement in activities are identified by either the client or at the request of the therapist.
   b.0=No discussion occurs surrounding positive and negative experienced results of engagement in activities.

ABLE Fidelity Checklist

Structural Elements	Present in Session? Yes (1)	No (0)	Comments
1) Review previous ICAN plan.			
2) Review monitoring. Verbal Written (circle all that apply)			
3) Establishes new or revised ICAN plan.			
4) Plan/monitoring written in workbook			
Active Ingredients	**Present in Session? Yes (1)**	**No (0)**	**Comments**
1) <u>Activity scheduling:</u> Any meaningful activity is scheduled to occur (includes temporal aspect).			
2) <u>Activity monitoring:</u> Therapist facilitates monitoring of time use during scheduled activity (for previous plan or future plan).			Single Activity Multiple Activities *Circle one*
3) <u>Self Assessment:</u> Therapist asks client to identify positive and/or negative experienced results of engagement in activities.			
4) <u>Collaborative problem solving:</u> Therapist promotes client engagement in problem solving. Avoids direction in problem solving unless appropriate.			

Study ID: _____________________ **Session #:** _____ **Session Date:** ____________________ **Session Length:** _____________

Therapist: _____ **Fidelity Reviewer:** _____ **Missing Data Codes:** 888=Not applicable 999=Missing video

Additional Comments:

ABLE Fidelity Checklist

Scoring Criteria

Structural Elements

1. Review previous ICAN plan:
    a.1=Discussion occurred surrounding activities and plans that were scheduled from the previous session.
    b.0=No discussion of previous session.

2. Review monitoring:
    a.1=Verbal or visual review of monitoring activities that occurred during the time between sessions. Any method of monitoring is acceptable (i.e., from memory, handwritten notes on any form).
    b.0=No review of monitoring activities that occurred between sessions.

3. Establishes new or revised ICAN plan:
    a.1=A time of day is chosen, activity is selected, and discussion surrounding considerations for that activity (if new) or considerations for revising the activity (if from previous plan) occurs. Okay to score 1 if the participant decides to continue the activity without revisions.
    b.0=No plan for activities is established.

4. Plan/monitoring written in workbook:
    a.1=The workbook is used at any point during the session.
    b.0=The workbook is not used at any point during the session.

Active Ingredients

5. Activity scheduling:
    a.1=An activity that is selected by the client is scheduled to occur at a specific time of day (specific can range from general "in the evening" to specific "at 7pm")
    b.0=No activity is scheduled to occur at a specific time of day.

6. Activity monitoring:
    a.1=The therapist encourages the participant to monitor time use during the scheduled activity and a plan for monitoring is established. Can include written or other monitoring strategies.
    b.0=The therapist does not encourage the participant to monitor time use during the scheduled activity. No plan for monitoring is established.

7. Self-Assessment
    a.1=Positive and negative experienced results of engagement in activities are identified by either the client or at the request of the therapist.
    b.0=No discussion occurs surrounding positive and negative experienced results of engagement in activities.

8. Collaborative problem solving:
    a.1=The therapist promotes client engagement in problem solving. Avoids direction in problem solving unless appropriate.
    b.0=The client is not engaged in collaborative problem solving. Unnecessary directives are provided.

Appendix B ActivPAL Procedures

Sedentary behavior was measured using the ActivPAL micro3 (PalTechnologies, Glasgow). The ActivPAL micro3 measures time spent in sitting, standing, and stepping using a triaxial accelerometer and inclinometer. At each time point, participants wore this device for 7 full days, following a 24-hour wear protocol. The device was waterproofed and adhered at midline in the upper 1/3rd of the thigh on the side that was unaffected by the stroke. Participants documented the time that they woke and went to sleep in a diary that was provided by researchers. Participants also documented any day-time napping and non-wear time in this diary.

B.1 ActivPAL Data Reduction

Data were uploaded to an events-based .csv file using a microUSB cable and ActivPAL3 Software v.7.2.38 (Pal Technologies, Glasgow). This file was converted to an .xlsx file. Expected waking hours were calculated using the diary. Sleep time was removed using a diary-informed approach, following principles that were established a priori (Table 15).

Table 15 Guiding principles for ActivPAL data reduction

Sleep/Non-Wear End Time	
Diary Time Situation	*Documentation/Calculation*
Diary time occurs within sedentary bout (coded 0) >1800	In Splitting Bouts sheet: Calculate difference between diary wake time and next detected motion. In data sheet: Create a new row marked at diary wake time. Enter the bout that was just calculated in the new row **in seconds**, and code the activity 0.
Diary time occurs within sedentary bout (coded 0) <1800	In data sheet: Search prior to diary wake time to identify sedentary bout >1800 prior to diary wake time. Follow procedure for diary time that occurs during an active bout.
Diary time occurs during an active bout (coded 1 or 2)	In data sheet: Locate the sedentary bout (coded 0) >1800 that occurs immediately prior to the diary wake time. Mark the first non-sedentary bout (coded 1 or 2) after that sedentary bout that was just identified as the beginning of the current day. In Splitting Bouts sheet: Indicate: *Used non-sedentary bout following sedentary bout >1800 just prior to diary wake time.* Delete formulas from the appropriate row.
Sleep/Non-Wear Start Time	
Diary Time Situation	*Documentation/Calculation*
Diary time occurs within sedentary bout (coded 0) >1800	In Splitting Bouts sheet: Calculate the difference between previous detected motion and diary sleep time. In data sheet: Create a new row marked at the time of previous detected motion. Enter the bout that was just calculated in the new row **in seconds**, and code the activity 0
Diary time occurs during an active bout (coded 1 or 2)	In data sheet: Locate the first sedentary bout (coded0) >1800 that occurs after the diary lights out time. In Splitting Bouts sheet: Indicate: *Used first sedentary bout >1800 after diary lights out time.* Delete formulas in the appropriate row.

Data remaining after sleep time was removed were used to derive specific data points that describe sedentary time, sit-stand transitions, and stepping. These data are coded as sedentary (includes sitting or reclined position, 0), standing (1), or stepping (2).

B.2 ActivPAL Variables

Specific metrics were derived that describe sedentary behavior patterns at each time point. Each metric is described below. Time points with 4 or more days of valid wear were included in analyses. A valid day was considered that for which the monitor was worn for all waking hours.

Mean daily total accumulated sedentary time

The sum of all time spent in sedentary positions (0) was calculated for each day of wear. The mean of all valid days of wear was calculated at each time point.

Mean daily prolonged (≥30 minutes) sedentary time

The sum of all time spent in sedentary positions (0) of greater than 1800 seconds (30 minutes) was calculated for each day of wear. The mean of all valid days of wear was calculated at each time point.

Mean daily prolonged (≥60 minutes) sedentary time

The sum of all time spent in sedentary positions (0) of greater than 3600 seconds (60 minutes) was calculated for each day of wear. The mean of all valid days of wear was calculated at each time point.

Standardization of sedentary time variables

To control for within-person variability in wake time across time points, we calculated standardized variables (mean daily total accumulated sedentary time, mean daily prolonged ≥30 minutes sedentary time, mean daily prolonged ≥60 minutes sedentary time). We used the following procedure to standardize these variables:

1. Within-person mean waking time across all time points was calculated (baseline, post-intervention, follow-up).
2. The multiplier for each time point was then derived using the following formula:

$$\frac{Waking\ time_{timepoint}}{Mean\ waking\ time\ across\ timepoints}$$

3. The raw score on each outcome (i.e., mean daily total accumulated sedentary time, mean daily prolonged ≥30 minutes sedentary time, mean daily prolonged ≥60 minutes sedentary time) at each time point was multiplied by the multiplier for the appropriate time point.

Mean daily step count

The ActivPAL only captures steps taken by the single leg on which it was worn. The total count of steps (coded 2) per day were multiplied by 2 to derive a total step count. The mean of all valid days of wear was calculated for each time point.

Mean daily count of sit-stand transitions

The total count of upright bouts (coded 1) was calculated for each day. The mean of all valid days of wear was calculated for each time point.

Appendix C ABLE Study: Change Over Time on Exploratory Outcomes

This appendix contains plots documenting individual change over time (T0 to T1 and T0 to T2) on exploratory assessments of sedentary behavior (ActivPAL and Sedentary Behavior Questionnaire), step count (ActivPAL), and participation (Stroke Impact Scale-Participation Subscale. On all plots, red lines indicate clinically meaningful change in the expected direction and blue lines indicate change that was not clinically meaningful. Black dotted lines indicate group change over time.

Objectively measured sedentary behavior

On plots of objectively measured sedentary behavior (Figures 6 and 7), red lines indicate individual reduction of 60 minutes or more, yellow lines indicate individual reduction of 30 to 59 minutes, and blue lines indicate change that was not clinically meaningful.

Self-reported sedentary time

On plots of self-reported sedentary time (Sedentary Behavior Questionnaire, Figures 8 and 9), red lines indicate individual daily reduction of 60 minutes or greater, or weekly reduction of 7 hours or greater. Blue lines indicate change that was not clinically meaningful.

Objectively measured step count

On plots of mean daily step count, red lines indicate an increase over time of any amount. Blue lines indicate a decrease over time of any amount.

Participation

On plots of participation (Stroke Impact Scale-Participation), red lines indicate an increase over time of 10% or more. Blue lines indicate change that was not clinically meaningful.

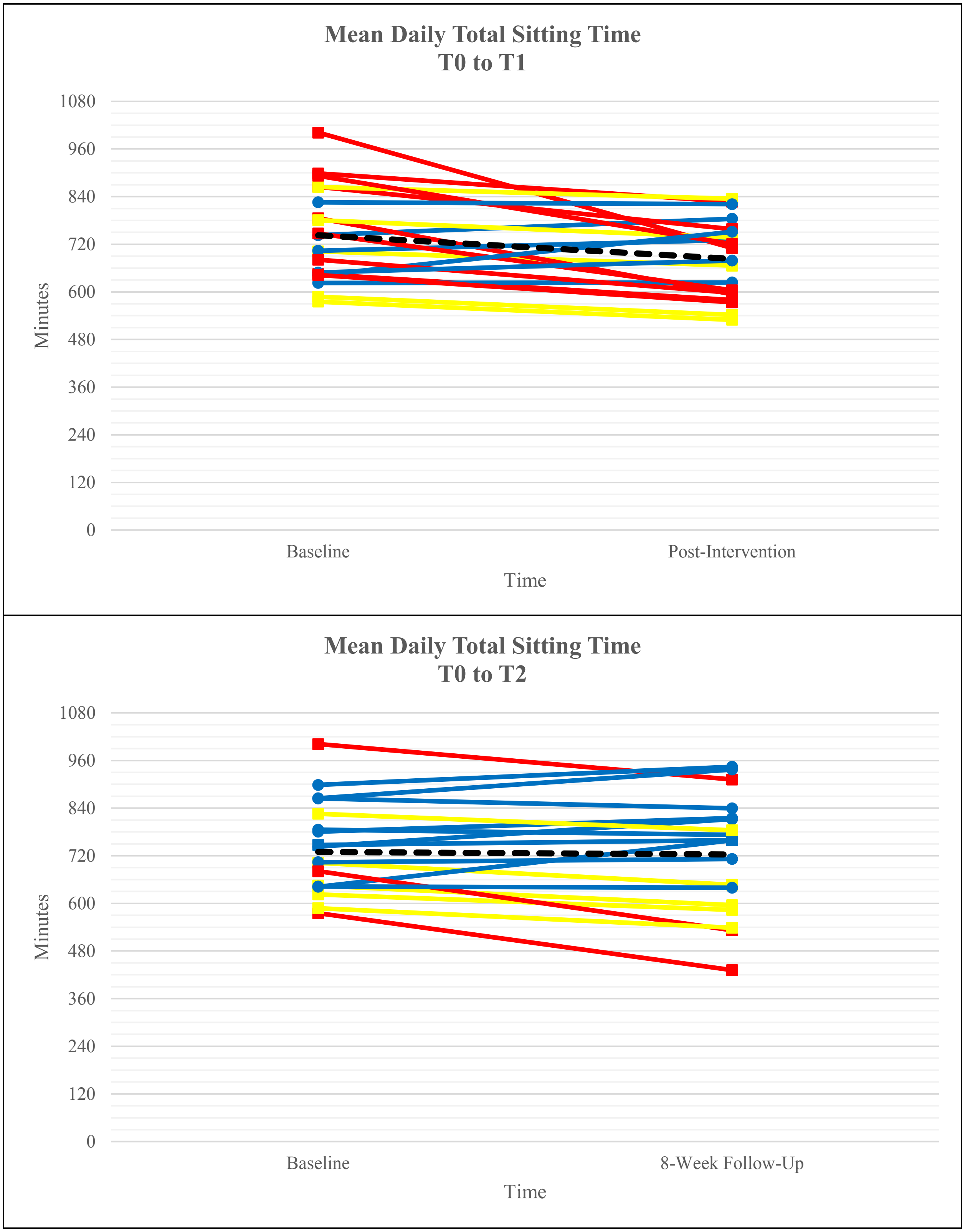

Figure 6 ABLE study: Change over time on mean daily total sitting time

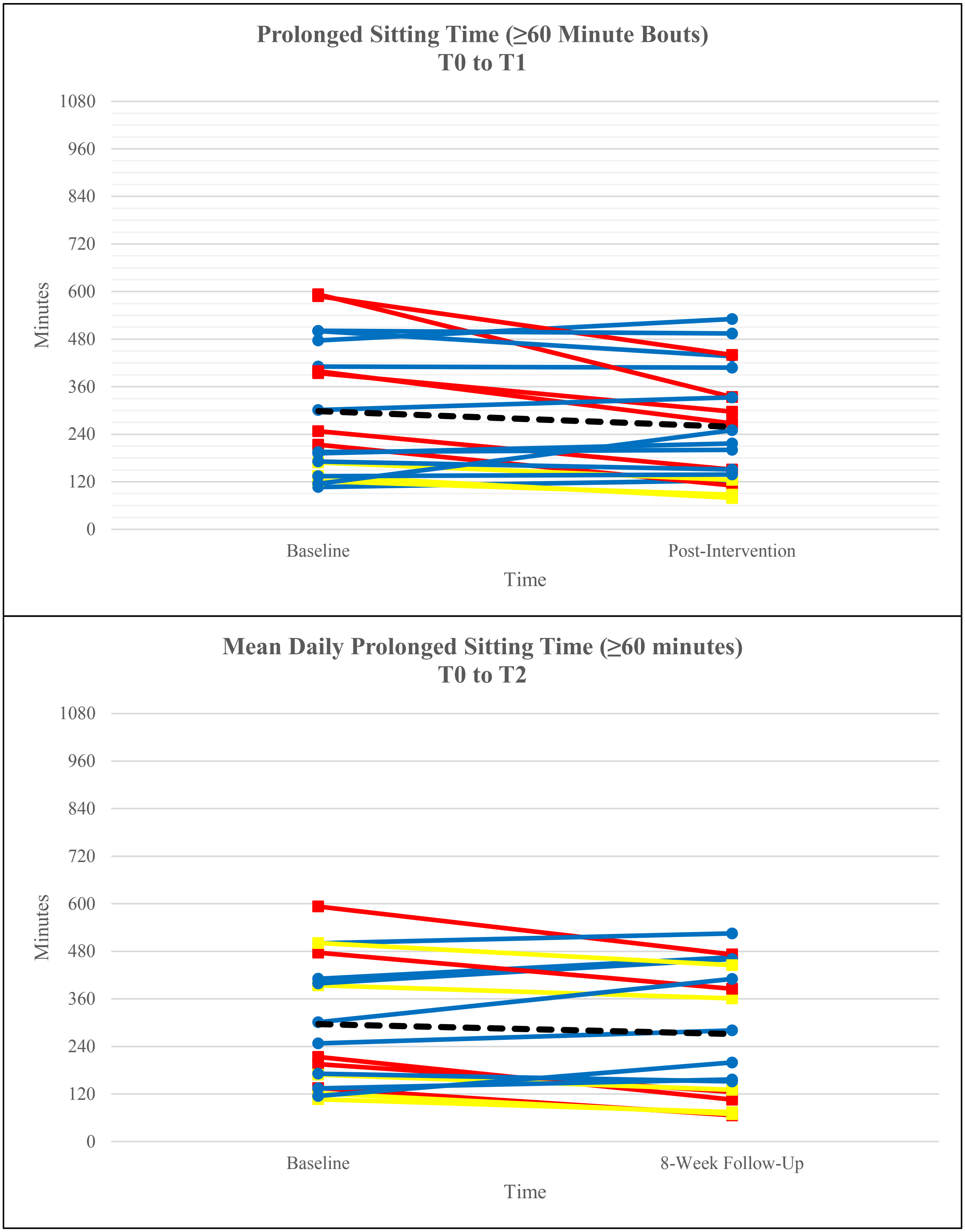

Figure 7 ABLE study: Change over time on mean daily prolonged sitting (≥60 minutes)

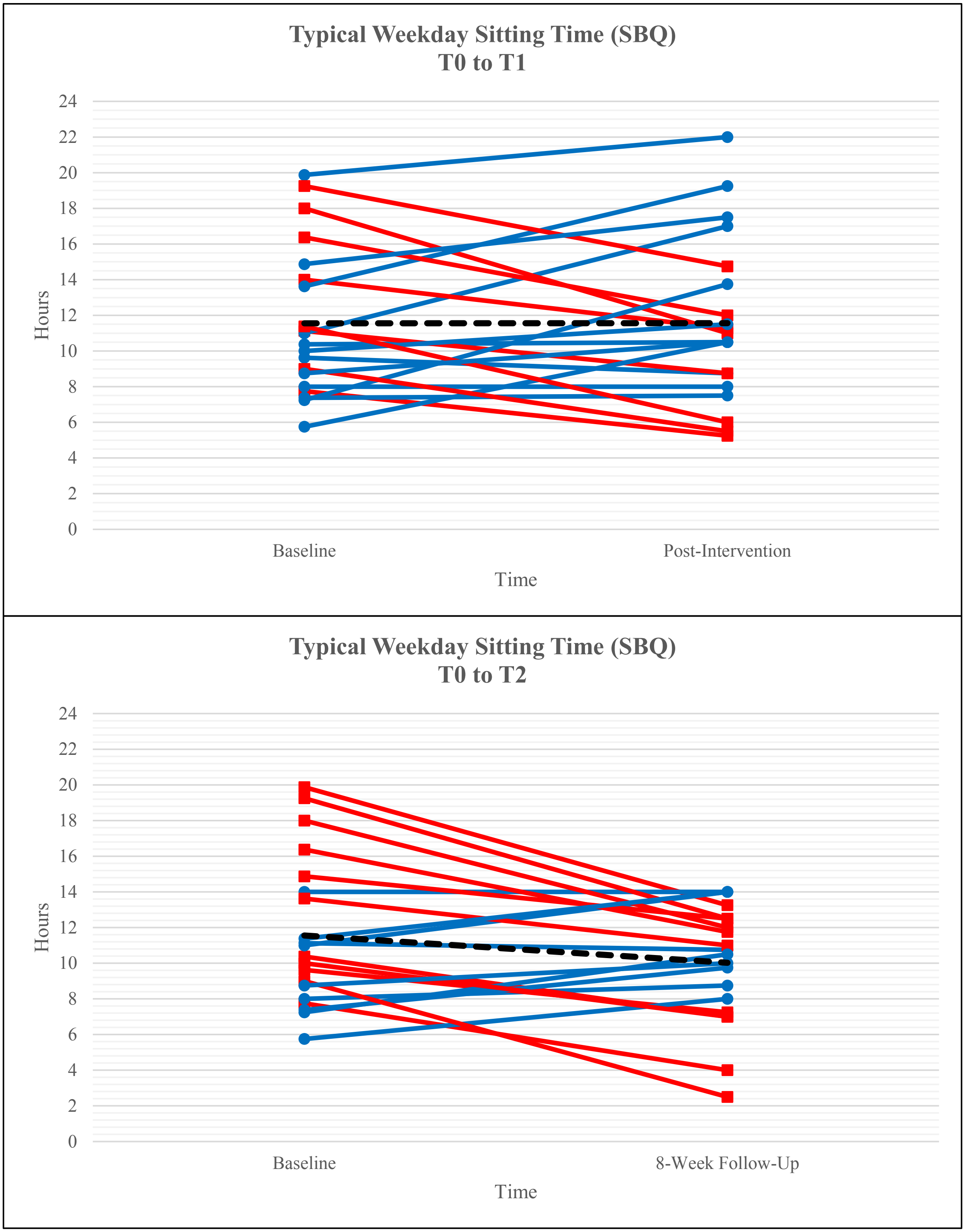

Figure 8 ABLE study: Change over time on typical weekday sitting time (SBQ)

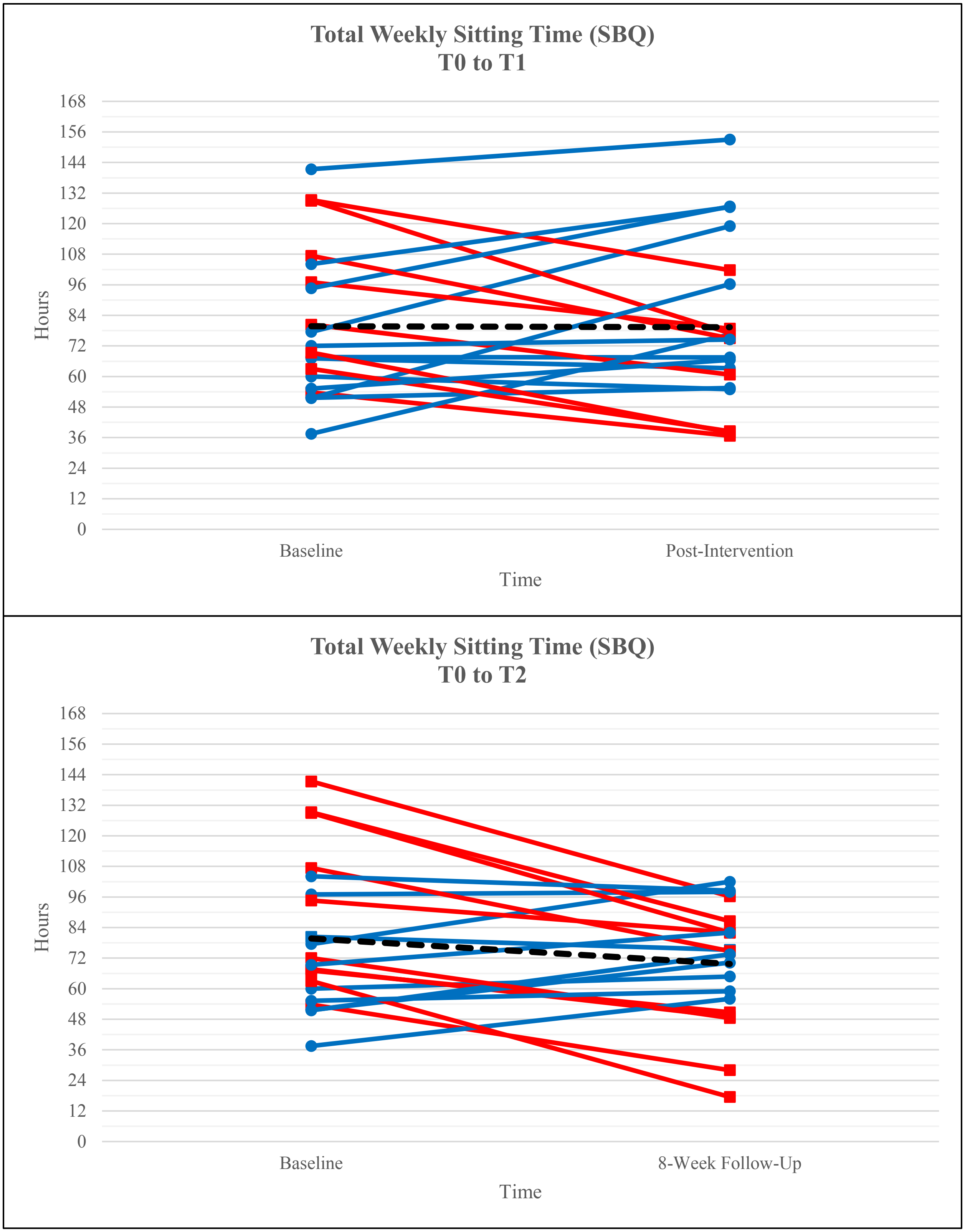

Figure 9 ABLE study: Change over time on total weekly sitting (SBQ)

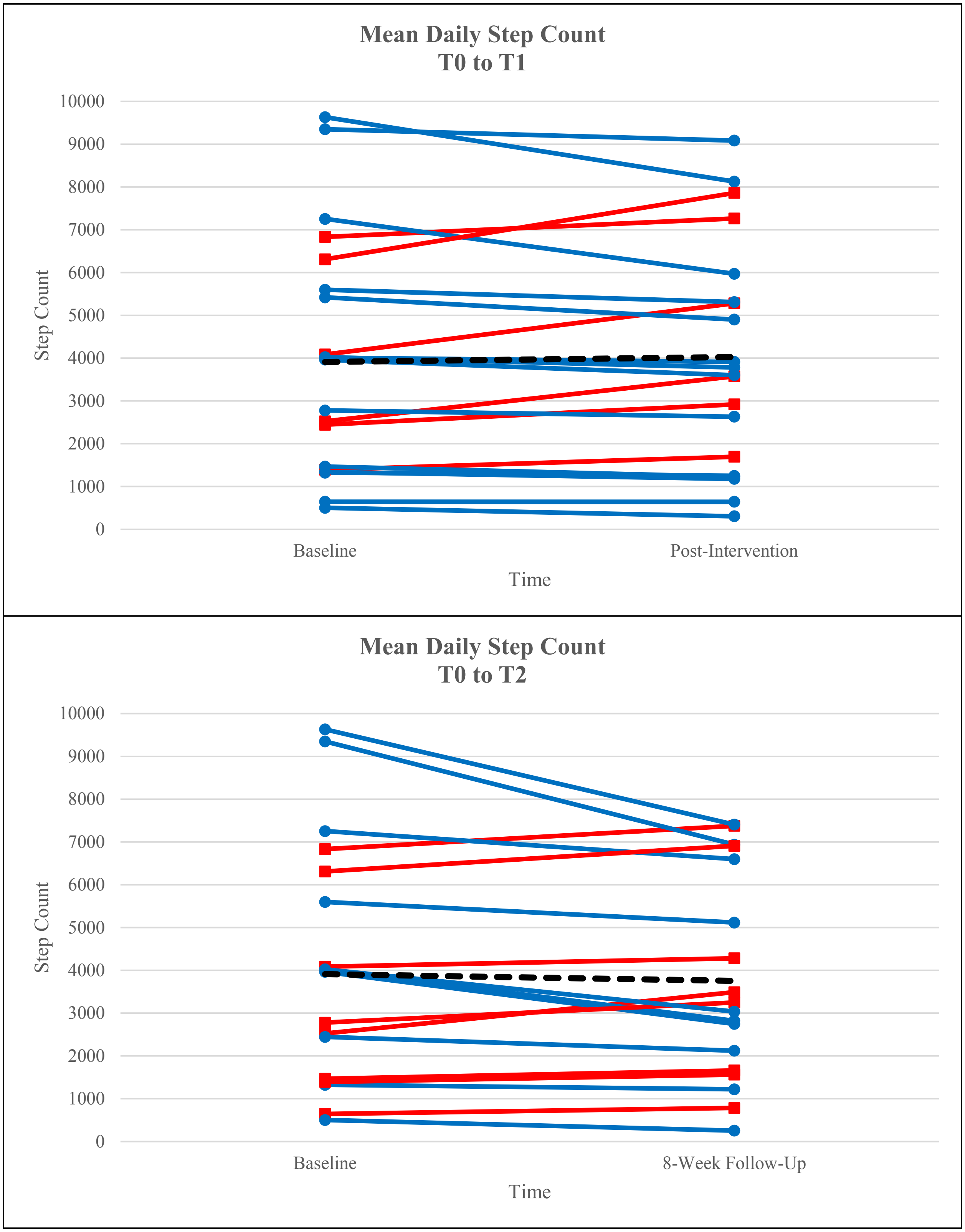

Figure 10 ABLE study: Change over time on mean daily step count

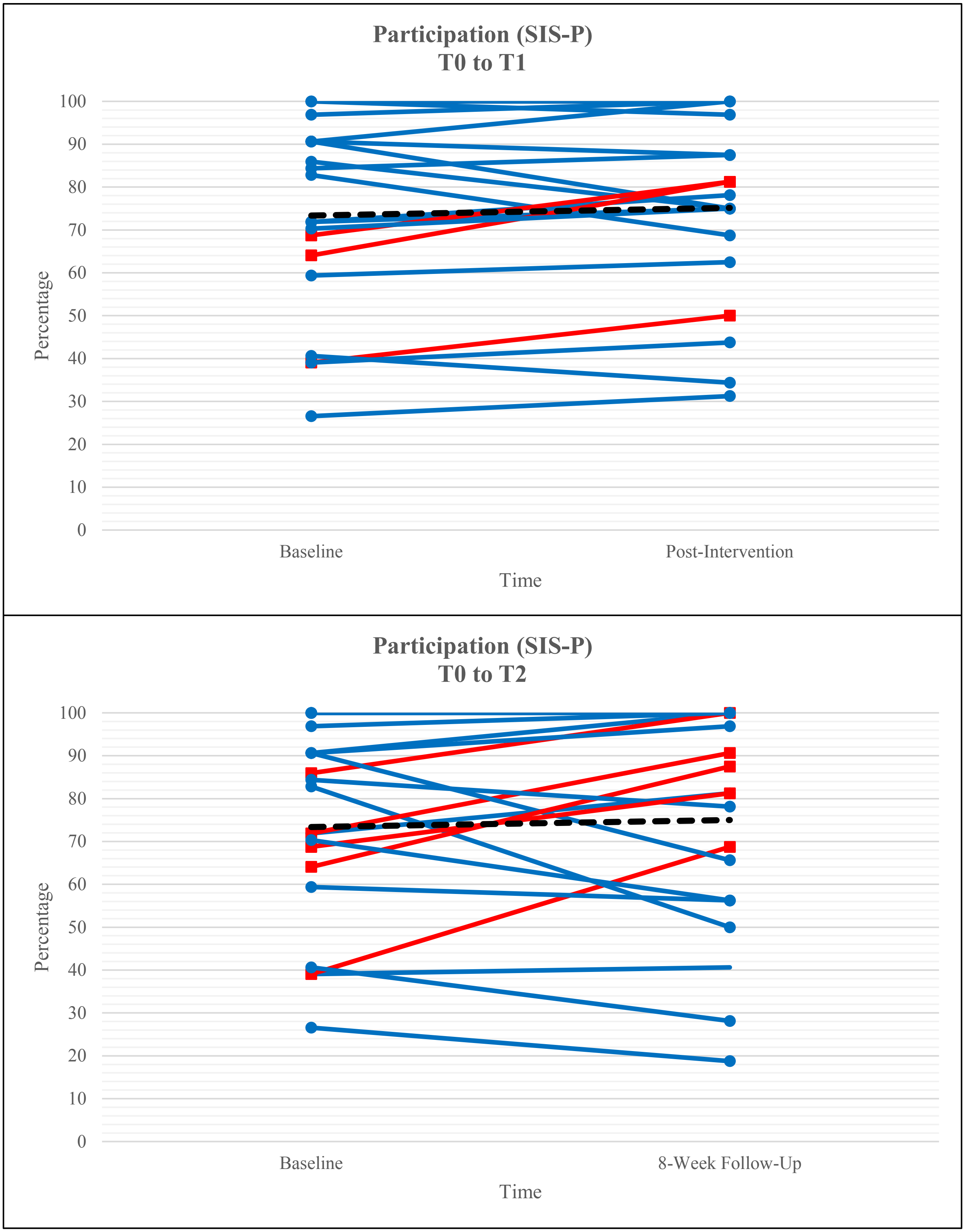

Figure 11 ABLE study: Change in participation over time

Appendix D Publications, Presentations, and Awards

The studies included in this dissertation were disseminated through publication and presentation. Publications and presentations are listed below. Awards are indicated in italics.

D.1 Publications

1) Kringle EA, Barone Gibbs B, Campbell G, Terhorst L, McCue M, Kersey J, Skidmore ER. Do interventions influence daily living physical activity and sedentary behavior after stroke? A scoping review. [under review].

2) Kringle EA, Campbell G, McCue M, Barone Gibbs B, Terhorst L, Skidmore ER. Development of a sedentary behavior intervention for stroke: A descriptive case series. [under review].

3) Kringle EA, Terhorst L, McCue M, Barone Gibbs B, Campbell G, Skidmore ER. Preliminary effects of the ABLE intervention on sedentary behavior and community participation after stroke. [under development].

D.2 Presentations

1) Kringle EA, Skidmore ER. ABLE after stroke: A feasibility study. Oral presentation at Rehabilitation Institute Research Day, Pittsburgh, PA, June 13, 2018.

**This presentation received the Best Research Award in the Pre-Doctoral Category.*

2) Kringle EA, Campbell G, McCue M, Barone Gibbs B, Terhorst L, Skidmore ER. Activating Behavior for Lasting Engagement (ABLE) To Reduce Sedentary Behavior in Chronic Stroke: A Feasibility Study. Poster presentation at the American Occupational Therapy Association Annual Conference, New Orleans, LA, April 5, 2019.

**This poster received a Young Scientist Theater Poster Award at the American Occupational Therapy Association Annual Conference, April 5, 2019.*

Bibliography

Aadahl, M., & JØrgensen, T. (2003). Validation of a new self-report instrument for measuring physical activity. *Medicine and Science in Sports and Exercise, 35*(7), 1196-1202.

Adamson, B. C., Ensari, I., & Motl, R. W. (2015). Effect of exercise on depressive symptoms in adults with neurologic disorders: A systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation, 96*(7), 1329-1338.

Alfonsson, S., Parling, T., & Ghaderi, A. (2015). Group behavioral activation for patients with severe obesity and binge eating disorder: A randomized controlled trial. *Behavior Modification, 39*(2), 270-294.

American Heart Association. (2017). Heart disease and stroke statistics—2017 update: A report from the American Heart Association. *Circulation, 135*(10), e146.

Anticevic, A., Cole, M. W., Murray, J. D., Corlett, P. R., Wang, X.-J., & Krystal, J. H. (2012). The role of default network deactivation in cognition and disease. *Trends in Cognitive Sciences, 16*(12), 584-592.

Askim, T., Langhammer, B., Ihle-Hansen, H., Gunnes, M., Lydersen, S., Indredavik, B., . . . Hansen, A. (2018). Efficacy and safety of individualized coaching after stroke: The LAST Study (Life After STroke) A pragmatic randomized controlled trial. *Stroke, 49*(2), 426-432.

Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine, 26*(4), 217-238.

Atler, K., Malcolm, M., & Greife, C. (2015). A follow-up study on the relationship among participation, activity and motor function in survivors of stroke following constraint-induced therapy. *Disability and Rehabilitation, 37*(2), 121-128.

Attkisson, C. C., & Greenfield, T. K. (2004). The UCSF Client Satisfaction Scales: I. The Client Satisfaction Questionnaire-8. In M. E. Maruish (Ed.), *The use of psychological testing for treatment planning and outcomes assessment: Instruments for adults* (pp. 799-811). Mahwah, NJ,: Lawrence Erlbaum Associates Publishers.

Balboa-Castillo, T., León-Muñoz, L. M., Graciani, A., Rodríguez-Artalejo, F., & Guallar-Castillón, P. (2011). Longitudinal association of physical activity and sedentary behavior during leisure time with health-related quality of life in community-dwelling older adults. *Health and Quality of Life Outcomes, 9*(1), 47.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior, 31*(2), 143-164.

Barone Gibbs, B., & Kline, C. (2018). When does sedentary behavior become sleep? A proposed framework for classifying 24-hour movement behavior during sleep-wake transitions. *International Journal of Behavioral Nutrition and Physical Activity, 15*, 81.

Bastien, M., Korner-Bitensky, N., Lalonde, S., LeBrun, N., & Matte, D. (1998). A health and leisure program for community-dwelling individuals with stroke: A pilot study. *Canadian Journal of Rehabilitation, 12*(1), 7-14.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., Martin, B. W., & Group, L. P. A. S. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *The Lancet, 380*(9838), 258-271.

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., . . . Czajkowski, S. (2004). Enhancing treatment fidelity in health behavior change studies: Best practices and recommendations from the nih behavior change consortium. *Health Psychology, 23*(5), 443-451.

Benatti, F. B., & Ried-Larsen, M. (2015). The effects of breaking up prolonged sitting time: A review of experimental studies. *Medicine and Science in Sports and Exercise, 47*(10), 2053-2061.

Billinger, S. A., Arena, R., Bernhardt, J., Eng, J. J., Franklin, B. A., Johnson, C. M., . . . Roth, E. J. (2014). Physical activity and exercise recommendations for stroke survivors: A statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke, 45*(8), 2532-2553.

Borod, J. C., Goodglass, H., & Kaplan, E. (1980). Normative data on the Boston Diagnostic Aphasia Examination, Parietal Lobe Battery, and the Boston Naming Test. *Journal of Clinical and Experimental Neuropsychology, 2*(3), 209-215.

Boysen, G., Krarup, L.-H., Zeng, X., Oskedra, A., Kõrv, J., Andersen, G., . . . Hansen, L. (2009). Ex-Stroke pilot trial of the effect of repeated instructions to improve physical activity after ischaemic stroke: A multinational randomised controlled clinical trial. *BMJ, 339*, b2810.

Brach, J., Almeida, G., Perera, S., Hergenroeder, A., Kotlarczyk, M., & Barone Gibbs, B. (2018). The role of the environment in sedentary behavior in community-dwelling older adults. *Journal of Housing for the Elderly*, 1-10.

Bradbury, C. L., Christensen, B. K., Lau, M. A., Ruttan, L. A., Arundine, A. L., & Green, R. E. (2008). The efficacy of cognitive behavior therapy in the treatment of emotional distress after acquired brain injury. *Archives of Physical Medicine and Rehabilitation, 89*(12), S61-S68.

Buman, M. P., Winkler, E. A., Kurka, J. M., Hekler, E. B., Baldwin, C. M., Owen, N., . . . Gardiner, P. A. (2013). Reallocating time to sleep, sedentary behaviors, or active behaviors: Associations with cardiovascular disease risk biomarkers, nhanes 2005–2006. *American Journal of Epidemiology, 179*(3), 323-334.

Cameron, J. I., & Gignac, M. A. (2008). “Timing it right”: A conceptual framework for addressing the support needs of family caregivers to stroke survivors from the hospital to the home. *Patient Education and Counseling, 70*(3), 305-314.

Cella, D., Lai, J.-S., Jensen, S. E., Christodoulou, C., Junghaenel, D. U., Reeve, B. B., & Stone, A. A. (2016). PROMIS Fatigue item bank had clinical validity across diverse chronic conditions. *Journal of Clinical Epidemiology, 73*, 128-134.

Chastin, S. F., Egerton, T., Leask, C., & Stamatakis, E. (2015a). Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity, 23*(9), 1800-1810.

Chastin, S. F., Palarea-Albaladejo, J., Dontje, M. L., & Skelton, D. A. (2015b). Combined effects of time spent in physical activity, sedentary behaviors and sleep on obesity and cardio-metabolic health markers: A novel compositional data analysis approach. *PLOS One, 10*(10), e0139984.

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Communications in Statistics—Simulation and Computation®, 39*(4), 860-864.

Clanchy, K. M., Tweedy, S. M., & Trost, S. G. (2016). Evaluation of a physical activity intervention for adults with brain impairment: A controlled clinical trial. *Neurorehabilitation and Neural Repair, 30*(9), 854-865.

Cleland, V., Hughes, C., Thornton, L., Squibb, K., Venn, A., & Ball, K. (2015). Environmental barriers and enablers to physical activity participation among rural adults: A qualitative study. *Health Promotion Journal of Australia, 26*(2), 99-104.

The Cochrane Collaboration. (2011). *Cochrane handbook for systematic reviews of interventions*. Higgins, JPT & Green S (Eds.). Retrieved from http://handbook-5-1.cochrane.org/.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Craig, C. L., Marshall, A. L., Sjorstrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., . . . Sallis, J. F. (2003). International Physical Activity Questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise, 35*(8), 1381-1395.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: The new Medical Research Council guidance. *BMJ, 337*, a1655.

Cuijpers, P., Van Straten, A., & Warmerdam, L. (2007). Behavioral activation treatments of depression: A meta-analysis. *Clinical Psychology Review, 27*(3), 318-326.

Cumming, T. B., Tyedin, K., Churilov, L., Morris, M. E., & Bernhardt, J. (2012). The effect of physical activity on cognitive function after stroke: A systematic review. *International Psychogeriatrics, 24*(4), 557-567.

Dacosta-Aguayo, R., Grana, M., Iturria-Medina, Y., Fernández-Andújar, M., López-Cancio, E., Caceres, C., . . . Toran, P. (2015). Impairment of functional integration of the default mode network correlates with cognitive outcome at three months after stroke. *Human Brain Mapping, 36*(2), 577-590.

Damush, T. M., Plue, L., Bakas, T., Schmid, A., & Williams, L. S. (2007). Barriers and facilitators to exercise among stroke survivors. *Rehabilitation Nursing, 32*(6), 253-262.

Danks, K. A., Roos, M. A., McCoy, D., & Reisman, D. S. (2014). A step activity monitoring program improves real world walking activity post stroke. *Disability and Rehabilitation, 36*(26), 2233-2236.

de Rezende, L. F. M., Lopes, M. R., Rey-López, J. P., Matsudo, V. K. R., & do Carmo Luiz, O. (2014). Sedentary behavior and health outcomes: An overview of systematic reviews. *PLOS One, 9*(8), e105620.

Dean, C. M., Rissel, C., Sherrington, C., Sharkey, M., Cumming, R. G., Lord, S. R., . . . O'Rourke, S. (2012). Exercise to enhance mobility and prevent falls after stroke: The community stroke club randomized trial. *Neurorehabilitation and Neural Repair, 26*(9), 1046-1057.

Dean, S. G., Poltawski, L., Forster, A., Taylor, R. S., Spencer, A., James, M., . . . Shepherd, A. I. (2018). Community-based rehabilitation training after stroke: Results of a pilot randomised controlled trial (ReTrain) investigating acceptability and feasibility. *BMJ Open, 8*(2), e018409.

Desrosiers, J., & Bourbonnais, D. (2005). Participation after stroke compared to normal aging. *Journal of Rehabilitation Medicine, 37*, 353-357.

Desrosiers, J., Demers, L., Robichaud, L., Vincent, C., Belleville, S., & Ska, B. (2008). Short-term changes in and predictors of participation of older adults after stroke following acute care or rehabilitation. *Neurorehabilitation and Neural Repair, 22*(3), 288-297.

Desrosiers, J., Noreau, L., Rochette, A., Bourbonnais, D., Bravo, G., & Bourget, A. (2006). Predictors of long-term participation after stroke. *Disability and Rehabilitation, 28*(4), 221-230.

Ding, X., Li, C.-Y., Wang, Q.-S., Du, F.-Z., Ke, Z.-W., Peng, F., . . . Chen, L. (2014). Patterns in default-mode network connectivity for determining outcomes in cognitive function in acute stroke patients. *Neuroscience, 277*, 637-646.

Doering, B., & Exner, C. (2011). Combining neuropsychological and cognitive–behavioral approaches for treating psychological sequelae of acquired brain injury. *Current Opinion in Psychiatry, 24*(2), 156-161.

Douiri, A., Rudd, A. G., & Wolfe, C. D. (2013). Prevalence of poststroke cognitive impairment: South London Stroke Register 1995–2010. *Stroke, 44*(1), 138-145.

Dowd, K. P., Harrington, D. M., Bourke, A. K., Nelson, J., & Donnelly, A. E. (2012). The measurement of sedentary patterns and behaviors using the ActivPAL™ professional physical activity monitor. *Physiological Measurement, 33*(11), 1887.

Duncan, P., Lai, S., Bode, R., Perera, S., DeRosa, J., & GAIN Americas Investigators. (2003). Stroke Impact Scale-16: A brief assessment of physical function. *Neurology, 60*(2), 291-296.

Duncan, P. W., Sullivan, K. J., Behrman, A. L., Azen, S. P., Wu, S. S., Nadeau, S. E., . . . Cen, S. (2011). Body-weight–supported treadmill rehabilitation after stroke. *New England Journal of Medicine, 364*(21), 2026-2036.

Dunstan, D. W., Kingwell, B. A., Larsen, R., Healy, G. N., Cerin, E., Hamilton, M. T., . . . Salmon, J. (2012). Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care, 35*(5), 976-983.

Edwardson, C. L., Winkler, E. A., Bodicoat, D. H., Yates, T., Davies, M. J., Dunstan, D. W., & Healy, G. N. (2017). Considerations when using the ActivPAL monitor in field-based research with adult populations. *Journal of Sport and Health Science, 6*(2), 162-178.

English, C., Healy, G. N., Coates, A., Lewis, L., Olds, T., & Bernhardt, J. (2016a). Sitting and activity time in people with stroke. *Physical Therapy, 96*(2), 193-201.

English, C., Healy, G. N., Olds, T., Parfitt, G., Borkoles, E., Coates, A., . . . Bernhardt, J. (2016b). Reducing sitting time after stroke: A Phase II safety and feasibility randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 97*(2), 273-280.

English, C., Manns, P. J., Tucak, C., & Bernhardt, J. (2014). Physical activity and sedentary behaviors in people with stroke living in the community: A systematic review. *Physical Therapy, 94*(2), 185-196.

Ezeugwu, V. E., & Manns, P. J. (2018). The feasibility and longitudinal effects of a home-based sedentary behavior change intervention after stroke. *Archives of Physical Medicine and Rehabilitation, 99*(12), 2540-2547.

Faulkner, J., McGonigal, G., Woolley, B., Stoner, L., Wong, L., & Lambrick, D. (2015). A randomized controlled trial to assess the psychosocial effects of early exercise engagement in patients diagnosed with transient ischaemic attack and mild, non-disabling stroke. *Clinical Rehabilitation, 29*(8), 783-794.

Ford, E. S., & Caspersen, C. J. (2012). Sedentary behaviour and cardiovascular disease: A review of prospective studies. *International Journal of Epidemiology, 41*(5), 1338-1353.

Fulk, G. D., Ludwig, M., Dunning, K., Golden, S., Boyne, P., & West, T. (2010). How much change in the Stroke Impact Scale-16 is important to people who have experienced a stroke? *Topics in Stroke Rehabilitation, 17*(6), 477-483.

Gagnier, J. J., Kienle, G., Altman, D. G., Moher, D., Sox, H., & Riley, D. (2013). The CARE guidelines: Consensus-based clinical case reporting guideline development. *Journal of Medical Case Reports, 7*(1), 223.

Gebruers, N., Vanroy, C., Truijen, S., Engelborghs, S., & De Deyn, P. P. (2010). Monitoring of physical activity after stroke: A systematic review of accelerometry-based measures. *Archives of Physical Medicine and Rehabilitation, 91*(2), 288-297.

Gilbody, S., Richards, D., Brealey, S., & Hewitt, C. (2007). Screening for depression in medical settings with the Patient Health Questionnaire (PHQ): A diagnostic meta-analysis. *Journal of General Internal Medicine, 22*(11), 1596-1602.

Givon, N., Zeilig, G., Weingarden, H., & Rand, D. (2016). Video-games used in a group setting is feasible and effective to improve indicators of physical activity in individuals with chronic stroke: A randomized controlled trial. *Clinical Rehabilitation, 30*(4), 383-392.

Greco, C. M., Glick, R. M., Morone, N. E., & Schneider, M. J. (2013). Addressing the "it is just placebo" pitfall in CAM: Methodology of a project to develop patient-reported measures of nonspecific factors in healing. *Evidence-Based Complementary and Alternative Medicine, 2013(*613797).

Greco, C. M., Yu, L., Johnston, K. L., Dodds, N. E., Morone, N. E., Glick, R. M., . . . Lawrence, S. (2016). Measuring nonspecific factors in treatment: Item banks that assess the healthcare experience and attitudes from the patient's perspective. *Quality of Life Research, 25*(7), 1625-1634.

Hamer, M., Stamatakis, E., & Steptoe, A. (2014). Effects of substituting sedentary time with physical activity on metabolic risk. *Medicine and Science in Sports and Exercise, 46*(10), 1946-1950.

Hamilton, M. T., Healy, G. N., Dunstan, D. W., Zderic, T. W., & Owen, N. (2008). Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior. *Current Cardiovascular Risk Reports, 2*(4), 292.

Hammel, J., Magasi, S., Heinemann, A., Gray, D. B., Stark, S., Kisala, P., . . . Hahn, E. A. (2015). Environmental barriers and supports to everyday participation: A qualitative insider perspective from people with disabilities. *Archives of Physical Medicine and Rehabilitation, 96*(4), 578-588.

Hammel, J., Magasi, S., Heinemann, A., Whiteneck, G., Bogner, J., & Rodriguez, E. (2008). What does participation mean? An insider perspective from people with disabilities. *Disability and Rehabilitation, 30*(19), 1445-1460.

Hankey, G. J., & Warlow, C. P. (1999). Treatment and secondary prevention of stroke: Evidence, costs, and effects on individuals and populations. *The Lancet, 354*(9188), 1457-1463.

Harris, J. E., Eng, J. J., Miller, W. C., & Dawson, A. S. (2016). The role of caregiver involvement in upper-limb treatment in individuals with subacute stroke. *Physical Therapy, 90*(9), 1302-1310.

Hartman-Maeir, A., Soroker, N., Ring, H., Avni, N., & Katz, N. (2007). Activities, participation and satisfaction one-year post stroke. *Disability and Rehabilitation, 29*(7), 559-566.

Haslam, C., Holme, A., Haslam, S. A., Iyer, A., Jetten, J., & Williams, W. H. (2008). Maintaining group memberships: Social identity continuity predicts well-being after stroke. *Neuropsychological Rehabilitation, 18*(5-6), 671-691.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008a). Breaks in sedentary time: Beneficial associations with metabolic risk. *Diabetes Care, 31*(4), 661-666.

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., & Owen, N. (2008b). Objectively measured sedentary time, physical activity, and metabolic risk: The Australian Diabetes, Obesity and Lifestyle Study (AUSDIAB). *Diabetes Care, 31*(2), 369-371.

Healy, G. N., Winkler, E. A., Brakenridge, C. L., Reeves, M. M., & Eakin, E. G. (2015). Accelerometer-derived sedentary and physical activity time in overweight/obese adults with type 2 diabetes: Cross-sectional associations with cardiometabolic biomarkers. *PLOS One, 10*(3), e0119140.

Heaton, R. K., Akshoomoff, N., Tulsky, D., Mungas, D., Weintraub, S., Dikmen, S., . . . Slotkin, J. (2014). Reliability and validity of composite scores from the NIH Toolbox Cognition Battery in adults. *Journal of the International Neuropsychological Society, 20*(6), 588-598.

Heeren, A., van Ooijen, M. W., Geurts, A. C., Day, B. L., Janssen, T. W., Beek, P. J., . . . Weerdesteyn, V. (2013). Step by step: A proof of concept study of c-mill gait adaptability training in the chronic phase after stroke. *Journal of Rehabilitation Medicine, 45*(7), 616-622.

Heinemann, A. W., Lai, J.-S., Magasi, S., Hammel, J., Corrigan, J. D., Bogner, J. A., & Whiteneck, G. G. (2011). Measuring participation enfranchisement. *Archives of Physical Medicine and Rehabilitation, 92*(4), 564-571.

Heinemann, A. W., Magasi, S., Bode, R. K., Hammel, J., Whiteneck, G. G., Bogner, J., & Corrigan, J. D. (2013). Measuring enfranchisement: Importance of and control over participation by people with disabilities. *Archives of Physical Medicine and Rehabilitation, 94*(11), 2157-2165.

Hildebrand, M. W., Host, H. H., Binder, E. F., Carpenter, B., Freedland, K. E., Morrow-Howell, N., . . . Lenze, E. J. (2012). Measuring treatment fidelity in a rehabilitation intervention study. *American Journal of Physical Medicine & Rehabilitation, 91*(8), 715-724.

Hutchison, A. J., Breckon, J. D., & Johnston, L. H. (2009). Physical activity behavior change interventions based on the transtheoretical model: A systematic review. *Health Education & Behavior, 36*(5), 829-845.

Hyndman, D., Ashburn, A., & Stack, E. (2002). Fall events among people with stroke living in the community: Circumstances of falls and characteristics of fallers. *Archives of Physical Medicine and Rehabilitation, 83*(2), 165-170.

Jaeger, R. G., & Halliday, T. R. (1998). On confirmatory versus exploratory research. *Herpetologica*, S64-S66.

Jones, T. M., Dear, B. F., Hush, J. M., Titov, N., & Dean, C. M. (2016). MyMoves program: Feasibility and acceptability study of a remotely delivered self-management program for increasing physical activity among adults with acquired brain injury living in the community. *Physical Therapy, 96*(12), 1982-1993.

Jørgensen, L., Engstad, T., & Jacobsen, B. K. (2002). Higher incidence of falls in long-term stroke survivors than in population controls: Depressive symptoms predict falls after stroke. *Stroke, 33*(2), 542-547.

Kane, R. A., & Cutler, L. J. (2015). Re-imagining long-term services and supports: Towards livable environments, service capacity, and enhanced community integration, choice, and quality of life for seniors. *The Gerontologist, 55*(2), 286-295.

Kanter, J. W., Manos, R. C., Bowe, W. M., Baruch, D. E., Busch, A. M., & Rusch, L. C. (2010). What is behavioral activation? A review of the empirical literature. *Clinical Psychology Review, 30*(6), 608-620.

Katz, N., Karpin, H., Lak, A., Furman, T., & Hartman-Maeir, A. (2003). Participation in occupational performance: Reliability and validity of the activity card sort. *OTJR: Occupation, Participation and Health, 23*(1), 10-17.

Kendall, B. J., & Gothe, N. P. (2016). Effect of aerobic exercise interventions on mobility among stroke patients: A systematic review. *American Journal of Physical Medicine & Rehabilitation, 95*(3), 214-224.

Kendzor, D. E., Shuval, K., Gabriel, K. P., Businelle, M. S., Ma, P., High, R. R., . . . Demark-Wahnefried, W. (2016). Impact of a mobile phone intervention to reduce sedentary behavior in a community sample of adults: A quasi-experimental evaluation. *Journal of Medical Internet Research, 18*(1), e19.

King, A. C., Castro, C., Wilcox, S., Eyler, A. A., Sallis, J. F., & Brownson, R. C. (2000). Personal and environmental factors associated with physical inactivity among different racial–ethnic groups of us middle-aged and older-aged women. *Health Psychology, 19*(4), 354-364.

Kirk, H., Kersten, P., Crawford, P., Keens, A., Ashburn, A., & Conway, J. (2014). The cardiac model of rehabilitation for reducing cardiovascular risk factors post transient ischaemic attack and stroke: A randomized controlled trial. *Clinical Rehabilitation, 28*(4), 339-349.

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine, 16*(9), 606-613.

Langhorne, P., Coupar, F., & Pollock, A. (2009). Motor recovery after stroke: A systematic review. *The Lancet Neurology, 8*(8), 741-754.

Lee, D., Fischer, H., Zera, S., Robertson, R., & Hammel, J. (2017). Examining a participation-focused stroke self-management intervention in a day rehabilitation setting: A quasi-experimental pilot study. *Topics in Stroke Rehabilitation, 24*(8), 601-607.

Lerdal, A., Bakken, L. N., Kouwenhoven, S. E., Pedersen, G., Kirkevold, M., Finset, A., & Kim, H. S. (2009). Poststroke fatigue—A review. *Journal of Pain and Symptom Management, 38*(6), 928-949.

Logan, P., Gladman, J., Avery, A., Walker, M., Dyas, J., & Groom, L. (2004). Randomised controlled trial of an occupational therapy intervention to increase outdoor mobility after stroke. *BMJ, 329*(7479), 1372.

Losada, A., Márquez-González, M., & Romero-Moreno, R. (2011). Mechanisms of action of a psychological intervention for dementia caregivers: Effects of behavioral activation and modification of dysfunctional thoughts. *International Journal of Geriatric Psychiatry, 26*(11), 1119-1127.

Mackintosh, S. F., Goldie, P., & Hill, K. (2005). Falls incidence and factors associated with falling in older, community-dwelling, chronic stroke survivors (> 1 year after stroke) and matched controls. *Aging Clinical and Experimental Research, 17*(2), 74-81.

Mackintosh, S. F., Hill, K. D., Dodd, K. J., Goldie, P. A., & Culham, E. G. (2006). Balance score and a history of falls in hospital predict recurrent falls in the 6 months following stroke rehabilitation. *Archives of Physical Medicine and Rehabilitation, 87*(12), 1583-1589.

Manns, P. J., Dunstan, D. W., Owen, N., & Healy, G. N. (2012). Addressing the nonexercise part of the activity continuum: A more realistic and achievable approach to activity programming for adults with mobility disability? *Physical Therapy, 92*(4), 614-625.

Marshall, S. J., Jones, D. A., Ainsworth, B. E., Reis, J. P., Levy, S. S., & Macera, C. A. (2007). Race/ethnicity, social class, and leisure-time physical inactivity. *Medicine and Science in Sports and Exercise, 39*(1), 44-51.

Mayo, N. E., Anderson, S., Barclay, R., Cameron, J. I., Desrosiers, J., Eng, J. J., . . . Moriello, C. (2015). Getting on with the rest of your life following stroke: A randomized trial of a complex intervention aimed at enhancing life participation post stroke. *Clinical Rehabilitation, 29*(12), 1198-1211.

Mayo, N. E., Wood-Dauphinee, S., Coˆte, R., Durcan, L., & Carlton, J. (2002). Activity, participation, and quality of life 6 months poststroke. *Archives of Physical Medicine and Rehabilitation, 83*(8), 1035-1042.

Mazzucchelli, T., Kane, R., & Rees, C. (2009). Behavioral activation treatments for depression in adults: A meta-analysis and review. *Clinical Psychology: Science and Practice, 16*(4), 383-411.

Mazzucchelli, T. G., Kane, R. T., & Rees, C. S. (2010). Behavioral activation interventions for well-being: A meta-analysis. *The Journal of Positive Psychology, 5*(2), 105-121.

McEwen, S., Polatajko, H., Baum, C., Rios, J., Cirone, D., Doherty, M., & Wolf, T. (2015). Combined cognitive-strategy and task-specific training improve transfer to untrained activities in subacute stroke: An exploratory randomized controlled trial. *Neurorehabilitation and Neural Repair, 29*(6), 526-536.

McNamara, R. J., McKeough, Z. J., McKenzie, D. K., & Alison, J. A. (2014). Physical comorbidities affect physical activity in chronic obstructive pulmonary disease: A prospective cohort study. *Respirology, 19*(6), 866-872.

Mekary, R. A., Willett, W. C., Hu, F. B., & Ding, E. L. (2009). Isotemporal substitution paradigm for physical activity epidemiology and weight change. *American Journal of Epidemiology, 170*(4), 519-527.

Michael, K., Goldberg, A. P., Treuth, M. S., Beans, J., Normandt, P., & Macko, R. F. (2009). Progressive adaptive physical activity in stroke improves balance, gait, and fitness: Preliminary results. *Topics in Stroke Rehabilitation, 16*(2), 133-139.

Michael, K. M., Allen, J. K., & Macko, R. F. (2005). Reduced ambulatory activity after stroke: The role of balance, gait, and cardiovascular fitness. *Archives of Physical Medicine and Rehabilitation, 86*(8), 1552-1556.

Michie, S., Fixsen, D., Grimshaw, J. M., & Eccles, M. P. (2009). Specifying and reporting complex behaviour change interventions: The need for a scientific method. *BioMed Central, 4*(40), 1-6.

Moore, C. G., Carter, R. E., Nietert, P. J., & Stewart, P. W. (2011). Recommendations for planning pilot studies in clinical and translational research. *Clinical and Translational Science, 4*(5), 332-337.

Moore, R. C., Chattillion, E. A., Ceglowski, J., Ho, J., von Känel, R., Mills, P. J., . . . Mausbach, B. T. (2013a). A randomized clinical trial of Behavioral Activation (BA) therapy for improving psychological and physical health in dementia caregivers: Results of the Pleasant Events Program (PEP). *Behaviour Research and Therapy, 51*(10), 623-632.

Moore, S. A., Hallsworth, K., Plötz, T., Ford, G. A., Rochester, L., & Trenell, M. I. (2013b). Physical activity, sedentary behaviour and metabolic control following stroke: A cross-sectional and longitudinal study. *PLOS One, 8*(1), e55263.

Moore, S. A., Hrisos, N., Flynn, D., Errington, L., Price, C., & Avery, L. (2018). How should long-term free-living physical activity be targeted after stroke? A systematic review and narrative synthesis. *International Journal of Behavioral Nutrition and Physical Activity, 15*(1), 100.

Morris, J. H., MacGillivray, S., & Mcfarlane, S. (2014). Interventions to promote long-term participation in physical activity after stroke: A systematic review of the literature. *Archives of Physical Medicine and Rehabilitation, 95*(5), 956-967.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods, 11*(2), 364-386.

Morton, S., Fitzsimons, C., Hall, J., Clarke, D., Forster, A., English, C., . . . Mead, G. (2018). Sedentary behavior after stroke: A new target for therapeutic intervention. *International Journal of Stroke, 14*(1), 9-11.

Mudge, S., Barber, P. A., & Stott, N. S. (2009). Circuit-based rehabilitation improves gait endurance but not usual walking activity in chronic stroke: A randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 90*(12), 1989-1996.

Noar, S. M., & Zimmerman, R. S. (2005). Health behavior theory and cumulative knowledge regarding health behaviors: Are we moving in the right direction? *Health Education Research, 20*(3), 275-290.

Nomura, E. M., Gratton, C., Visser, R. M., Kayser, A., Perez, F., & D'Esposito, M. (2010). Double dissociation of two cognitive control networks in patients with focal brain lesions. *Proceedings of the National Academy of Sciences, 107*(26), 12017-12022.

O'Donoghue, G., Perchoux, C., Mensah, K., Lakerveld, J., Van Der Ploeg, H., Bernaards, C., . . . Nazare, J.-A. (2016). A systematic review of correlates of sedentary behaviour in adults aged 18–65 years: A socio-ecological approach. *BMC Public Health, 16*(1), 163.

Olney, S. J., Nymark, J., Brouwer, B., Culham, E., Day, A., Heard, J., . . . Parvataneni, K. (2006). A randomized controlled trial of supervised versus unsupervised exercise programs for ambulatory stroke survivors. *Stroke, 37*(2), 476-481.

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: The population-health science of sedentary behavior. *Exercise and Sport Sciences Reviews, 38*(3), 105-113.

Owen, N., Salmon, J., Koohsari, M. J., Turrell, G., & Giles-Corti, B. (2014). Sedentary behaviour and health: Mapping environmental and social contexts to underpin chronic disease prevention. *British Journal of Sports Medicine, 48*(3), 174-177.

Owen, N., Sugiyama, T., Eakin, E. E., Gardiner, P. A., Tremblay, M. S., & Sallis, J. F. (2011). Adults' sedentary behavior: Determinants and interventions. *American Journal of Preventive Medicine, 41*(2), 189-196.

Pang, M. Y., Eng, J. J., Dawson, A. S., McKay, H. A., & Harris, J. E. (2005). A community-based fitness and mobility exercise program for older adults with chronic stroke: A randomized, controlled trial. *Journal of the American Geriatrics Society, 53*(10), 1667-1674.

Pang, M. Y., & Lau, R. W. (2010). The effects of treadmill exercise training on hip bone density and tibial bone geometry in stroke survivors: A pilot study. *Neurorehabilitation and Neural Repair, 24*(4), 368-376.

Patient-Centered Outcomes Research Institute. (2018). *PCORI Methodology Standards.* Retrieved from https://www.pcori.org/research-results/about-our-research/research-methodology/pcori-methodology-standards#Complex.

Paul, L., Wyke, S., Brewster, S., Sattar, N., Gill, J. M., Alexander, G., . . . Dybus, A. (2016). Increasing physical activity in stroke survivors using Starfish, an interactive mobile phone application: A pilot study. *Topics in Stroke Rehabilitation, 23*(3), 170-177.

Pitta, F., Troosters, T., Spruit, M. A., Probst, V. S., Decramer, M., & Gosselink, R. (2005). Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine, 171*(9), 972-977.

Preston, E., Dean, C. M., Ada, L., Stanton, R., Brauer, S., Kuys, S., & Waddington, G. (2017). Promoting physical activity after stroke via self-management: A feasibility study. *Topics in Stroke Rehabilitation, 24*(5), 353-360.

Prince, S., Saunders, T., Gresty, K., & Reid, R. (2014). A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: A systematic review and meta-analysis of controlled trials. *Obesity Reviews, 15*(11), 905-919.

Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion, 12*(1), 38-48.

Rimmer, J. H., Wang, E., & Smith, D. (2008). Barriers associated with exercise and community access for individuals with stroke. *Journal of Rehabilitation Research & Development, 45*(2), 315-321.

Robinson, R. G., & Jorge, R. E. (2015). Post-stroke depression: A review. *American Journal of Psychiatry, 173*(3), 221-231.

Rosa, E. M., & Tudge, J. (2013). Urie Bronfenbrenner's theory of human development: Its evolution from ecology to bioecology. *Journal of Family Theory & Review, 5*(4), 243-258.

Rosenberg, D. E., Norman, G. J., Wagner, N., Patrick, K., Calfas, K. J., & Sallis, J. F. (2010). Reliability and validity of the Sedentary Behavior Questionnaire (SBQ) for adults. *Journal of Physical Activity and Health, 7*(6), 697-705.

Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health Education Monographs, 2*(4), 328-335.

Salter, K., Jutai, J., Teasell, R., Foley, N., Bitensky, J., & Bayley, M. (2005). Issues for selection of outcome measures in stroke rehabilitation: ICF participation. *Disability and Rehabilitation, 27*(9), 507-528.

Salter, K. L., Foley, N. C., Jutai, J. W., & Teasell, R. W. (2007). Assessment of participation outcomes in randomized controlled trials of stroke rehabilitation interventions. *International Journal of Rehabilitation Research, 30*(4), 339-342.

Sangha, O., Stucki, G., Liang, M. H., Fossel, A. H., & Katz, J. N. (2003). The Self-Administered Comorbidity Questionnaire: A new method to assess comorbidity for clinical and health services research. *Arthritis Care & Research, 49*(2), 156-163.

Sattoe, J. N., Hilberink, S. R., van Staa, A., & Bal, R. (2014). Lagging behind or not? Four distinctive social participation patterns among young adults with chronic conditions. *Journal of Adolescent Health, 54*(4), 397-403.

Severinsen, K., Jakobsen, J. K., Pedersen, A. R., Overgaard, K., & Andersen, H. (2014). Effects of resistance training and aerobic training on ambulation in chronic stroke. *American Journal of Physical Medicine & Rehabilitation, 93*(1), 29-42.

Sharp, S. A., & Brouwer, B. J. (1997). Isokinetic strength training of the hemiparetic knee: Effects on function and spasticity. *Archives of Physical Medicine and Rehabilitation, 78*(11), 1231-1236.

Shaughnessy, M., Michael, K., & Resnick, B. (2012). Impact of treadmill exercise on efficacy expectations, physical activity, and stroke recovery. *The Journal of Neuroscience Nursing, 44*(1), 27-.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology, 4*, 1-32.

Shrestha, N., Grgic, J., Wiesner, G., Parker, A., Podnar, H., Bennie, J. A., . . . Pedisic, Z. (2018). Effectiveness of interventions for reducing non-occupational sedentary behaviour in adults and older adults: A systematic review and meta-analysis. *British Journal of Sports Medicine, 0*, 1-9.

Simpson, D. B., Breslin, M., Cumming, T., de Zoete, S., Gall, S. L., Schmidt, M., . . . Callisaya, M. L. (2018). Go home, sit less: The impact of home versus hospital rehabilitation environment on activity levels of stroke survivors. *Archives of Physical Medicine and Rehabilitation, 99*(11), 2216-2221.

Singer, J. D. (1998). Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. *Journal of Educational and Behavioral Statistics, 23*(4), 323-355.

Sit, J. W., Yip, V. Y., Ko, S. K., Gun, A. P., & Lee, J. S. (2007). A quasi-experimental study on a community-based stroke prevention programme for clients with minor stroke. *Journal of Clinical Nursing, 16*(2), 272-281.

Spitzer, R. L., Williams, J. B., Kroenke, K., Linzer, M., Verloin deGruy, F., Hahn, S. R., . . . Johnson, J. G. (1994). Utility of a new procedure for diagnosing mental disorders in primary care: The PRIME-MD 1000 study. *JAMA, 272*(22), 1749-1756.

Stamatakis, E., Rogers, K., Ding, D., Berrigan, D., Chau, J., Hamer, M., & Bauman, A. (2015). All-cause mortality effects of replacing sedentary time with physical activity and sleeping using an isotemporal substitution model: A prospective study of 201,129 mid-aged and older adults. *International Journal of Behavioral Nutrition and Physical Activity, 12*(1), 121.

Stone, A., Shiffman, S., Atienza, A., & Nebeling, L. (2007). *The science of real-time data capture: Self-reports in health research*: New York, NY: Oxford University Press.

Sullivan, J. E., Espe, L. E., Kelly, A. M., Veilbig, L. E., & Kwasny, M. J. (2014). Feasibility and outcomes of a community-based, pedometer-monitored walking program in chronic stroke: A pilot study. *Topics in Stroke Rehabilitation, 21*(2), 101-110.

ter Hoeve, N., Sunamura, M., van Geffen, M. E., Fanchamps, M. H., Horemans, H. L., Bussmann, J. B., . . . van den Berg-Emons, R. J. (2017). Changes in physical activity and sedentary behavior during cardiac rehabilitation. *Archives of Physical Medicine and Rehabilitation, 98*(12), 2378-2384.

Thorp, A. A., Owen, N., Neuhaus, M., & Dunstan, D. W. (2011). Sedentary behaviors and subsequent health outcomes in adults: A systematic review of longitudinal studies, 1996–2011. *American Journal of Preventive Medicine, 41*(2), 207-215.

Tieges, Z., Mead, G., Allerhand, M., Duncan, F., Van Wijck, F., Fitzsimons, C., . . . Chastin, S. (2015). Sedentary behavior in the first year after stroke: A longitudinal cohort study with objective measures. *Archives of Physical Medicine and Rehabilitation, 96*(1), 15-23.

Touillet, A., Guesdon, H., Bosser, G., Beis, J.-M., & Paysant, J. (2010). Assessment of compliance with prescribed activity by hemiplegic stroke patients after an exercise programme and physical activity education. *Annals of Physical and Rehabilitation Medicine, 53*(4), 250-265.

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., . . . Chinapaw, M. J. (2017). Sedentary Behavior Research Network (SBRN)–terminology consensus project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 75.

Tudor-Locke, C., Craig, C. L., Thyfault, J. P., & Spence, J. C. (2012). A step-defined sedentary lifestyle index:< 5000 steps/day. *Applied Physiology, Nutrition, and Metabolism, 38*(2), 100-114.

Vahlberg, B., Cederholm, T., Lindmark, B., Zetterberg, L., & Hellström, K. (2017). Short-term and long-term effects of a progressive resistance and balance exercise program in individuals with chronic stroke: A randomized controlled trial. *Disability and Rehabilitation, 39*(16), 1615-1622.

van Nassau, F., Mackenbach, J. D., Compernolle, S., De Bourdeaudhuij, I., Lakerveld, J., & van der Ploeg, H. P. (2017). Individual and environmental correlates of objectively measured sedentary time in Dutch and Belgian adults. *PLOS One, 12*(10), e0186538.

Vancampfort, D., Stubbs, B., Lara, E., Vandenbulcke, M., Swinnen, N., & Koyanagi, A. (2018). Correlates of sedentary behavior in middle-aged and old age people with mild cognitive impairment: A multinational study. *International Psychogeriatrics*, 1-11.

Viscogliosi, C., Desrosiers, J., Belleville, S., Caron, C. D., Ska, B., & Group, B. (2011). Differences in participation according to specific cognitive deficits following a stroke. *Applied Neuropsychology, 18*(2), 117-126.

Washburn, R. A., Smith, K. W., Jette, A. M., & Janney, C. A. (1993). The Physical Activity Scale for the Elderly (PASE): Development and evaluation. *Journal of Clinical Epidemiology, 46*(2), 153-162.

Washburn, R. A., Zhu, W., McAuley, E., Frogley, M., & Figoni, S. F. (2002). The Physical Activity Scale for Individuals with Physical Disabilities: Development and evaluation. *Archives of Physical Medicine and Rehabilitation, 83*(2), 193-200.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Bauer, P. J., . . . Wallner-Allen, K. (2013). Cognition assessment using the NIH Toolbox. *Neurology, 80*(11 Supplement 3), S54-S64.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Slotkin, J., . . . Fox, N. (2014). The Cognition Battery of the NIH Toolbox for assessment of neurological and behavioral function: Validation in an adult sample. *Journal of the International Neuropsychological Society, 20*(6), 567-578.

Williamson, A., & Hoggart, B. (2005). Pain: A review of three commonly used pain rating scales. *Journal of Clinical Nursing, 14*(7), 798-804.

Winkler, E. A., Bodicoat, D. H., Healy, G. N., Bakrania, K., Yates, T., Owen, N., . . . Edwardson, C. L. (2016). Identifying adults' valid waking wear time by automated estimation in ActivPAL data collected with a 24 h wear protocol. *Physiological Measurement, 37*(10), 1653.

Wolf, T. J., Baum, C. M., Lee, D., & Hammel, J. (2016). The development of the Improving Participation After Stroke Self-management program (IPASS): An exploratory randomized clinical study. *Topics in Stroke Rehabilitation, 23*(4), 284-292.

World Health Organization. (2001). *International Classification of Functioning, Disability and Health: ICF*. Geneva: World Health Organization.

Zanto, T. P., & Gazzaley, A. (2013). Fronto-parietal network: Flexible hub of cognitive control. *Trends in Cognitive Sciences, 17*(12), 602-603.