

Towards sustainable movement behaviour change in people with stroke



Development of the RISE Intervention



RISE

Wendy Hendrickx

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Utrecht University, Utrecht, The Netherlands

ISBN: 978-90-393-7632-4

Design cover: Gemma de Waard

Provided by thesis specialist Ridderprint, ridderprint.nl

Printing: Ridderprint

Layout and design: Jolanda Hiddink, persoonlijkproefschrift.nl

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The research presented in this thesis was conducted at:

1. Research Group Empowering Healthy Behaviour, Department of Health Innovations and Technology, Fontys University of Applied Sciences, Eindhoven, The Netherlands;
2. Department of Rehabilitation, Physiotherapy Science & Sport, UMC Utrecht Brain Center, University Medical Center Utrecht, Utrecht University, The Netherlands;
3. Center for Physical Therapy Research and Innovation in Primary Care, Julius Health Care Centers, Utrecht, The Netherlands.

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Development of the RISE intervention

Op weg naar duurzame verandering van beweeggedrag bij mensen met een beroerte

Ontwikkeling van de RISE interventie
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de
Universiteit Utrecht
op gezag van de
rector magnificus, prof. dr. H.R.B.M. Kummeling,
ingevolge het besluit van het college voor promoties
in het openbaar te verdedigen op

dinsdag 12 maart 2024 des middags te 12.15 uur

door

Wendy Hendrickx

geboren op 14 januari 1982
te Oosterhout

Promotoren:

Prof. dr. C. Veenhof

Prof. dr. C. English

Copromotoren:

Dr. M.F. Pisters

Dr. R. Wondergem

Beoordelingscommissie:

Prof. dr. R. Crutzen

Prof. dr. O.H. Franco Duran

Prof. dr. L.J. Kappelle

Prof. dr. F.H. Rutten (voorzitter)

Prof. dr. F. van Wijck

The Taskforce of Applied Research SIA (RAAK.PUB05.021), part of the Dutch Research Council (NWO), funded this work.

The printing of this thesis was financially supported by Fontys Allied Health Professions, the Scientific College Physical Therapy (WCF) of the Royal Dutch Society for Physical Therapy (KNGF).

Financial support by the Dutch Heart Foundation for the publication of this thesis is gratefully acknowledged.

“Learning never exhausts the mind”

Leonardo Davinci

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CHAPTER 1

General introduction

Stroke

A stroke is defined as an 'infarction or haemorrhage in the brain, spinal cord, or retina because of thrombosis of a cerebral venous structure'.¹ In other words, a stroke is caused by an interruption of blood flow to the brain, resulting in a lack of oxygen and nutrition to (part of) the brain and thereby causing damage to the brain.² Stroke is still the second leading cause of death and the third leading cause of disability in the world.³ The incidence of stroke worldwide is increasing, and the estimated global cost of stroke is currently over US\$891 billion.³ Stroke is also highly prevalent in the Netherlands. In 2021, approximately 40,000 people in the Netherlands had a stroke.⁴ Although approximately 9,000 people died as a result of a stroke in 2021,⁴ stroke is not always lethal. In the Netherlands, approximately 372,000 people are living with the consequences of having had a stroke.⁴ The cost of stroke-related health care in the Netherlands is estimated at 1.4 billion per year.⁵

With the improvement of acute care and treatment options such as thrombolysis and thrombectomy, the survival rates after stroke have improved, and stroke sequelae are often less severe.^{3,6} Approximately two out of three people who have had an ischaemic stroke and one in three of the people who had a haemorrhagic stroke are able to live at home three months after hospital submission with relatively limited physical and cognitive disabilities.⁴ Traditional care after stroke aims mostly to improve people's abilities and independence in daily living. The focus is upon rehabilitation of physical and cognitive functions and participation, such as the ability to walk, carry on a conversation or return to work. Despite recommendations in recent guidelines,⁶ there is limited attention given to secondary prevention.

Secondary prevention after stroke

People who have suffered a stroke are at high risk of recurrent stroke,⁷⁻⁹ even when people have received optimal evidence-based care.¹⁰ Up to 40% of people who have suffered a stroke have a recurrent stroke in the first ten years post-onset.⁷ The 5-year survival rate after stroke was found to be 49.4% in people who had ischaemic stroke and 37.8% in people who had haemorrhagic stroke, compared to 64.6% in the general population.¹¹ Therefore, secondary prevention of stroke is important.^{3,6,12} The top 10 risk factors for stroke include elevated systolic blood pressure, high body mass index, high fasting glucose, air pollution and several lifestyle factors. Recommendations after stroke include identifying risk factors such as elevated blood pressure and high fasting glucose and prescribing appropriate medication were applicable.^{3,6} Lifestyle factors include, among others, poor diet, smoking and poor movement behaviour.^{3,6} Since these are modifiable risk factors, they are also highly relevant in secondary prevention. Lifestyle factors, including healthy diet and healthy movement behaviour, are even included in the top 10 take home messages of the 2021 Guidelines for the Prevention of Stroke of the American Heart Association/American

Stroke Association as important for the prevention of secondary stroke.⁶ This guideline not only includes the recommendation to engage in sufficient levels of physical activity, but reducing sedentary behaviour is also advised. Despite this growing emphasis on the importance of lifestyle in secondary prevention, in daily health care, the emphasis is still on medication management.

Movement behaviour

As mentioned, unhealthy movement behaviour is one of the top 10 risk factors after stroke. Sedentary behaviour is a component of movement behaviour and is defined as 'any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task while in a sitting, reclining, or lying posture'.¹³⁻¹⁵ The other part of movement behaviour is physical activity, and combined with sleeping behaviour, these three behaviours make up the 24-hour cycle (see Figure 1).¹³ Physical activity is divided into light, moderate and vigorous physical activity based on the energy expenditure levels while conducting physical activity, based on the metabolic equivalents (METs). The reference is the basic metabolic rate, 1.0 MET.¹⁶ Light physical activity represents activities involving an energy expenditure of 1.5-3.0 METs, moderate to vigorous 3.0-6.0 METs and vigorous over 6 METs.¹⁶

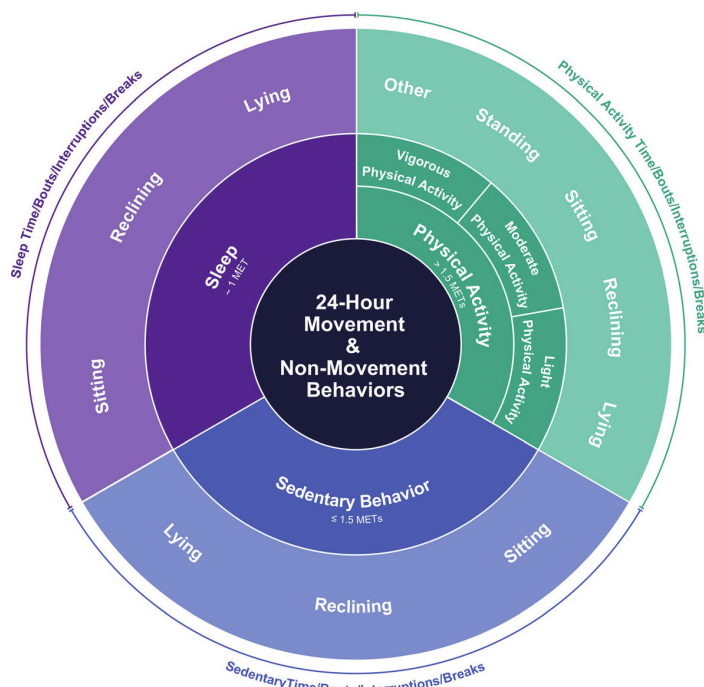


Figure 1. Illustration of the 24-hour conium of movement and non-movement behaviour, including distinctions in both the metabolic equivalents (METs) and the possible postural positions.¹³ Note: the distribution is symbolic and not representative of the actual distribution of the different categories.

Both low levels of physical activity and high amounts of sedentary behaviour are associated with an increased risk of cardiovascular diseases and cardiovascular and all-cause mortality.^{17–21} Large observational studies revealed increased health risks when sedentary time was high and moderate-to-vigorous physical activity (MVPA) levels were low.²¹ Light Physical Activity (LPA) was found to be protective when levels were sufficiently high.²¹ It was also reported that the health risks of sedentary behaviour increase when sedentary time is accumulated in prolonged bouts.^{22–25} This indicates that all these aspects of movement behaviour are relevant. Also, the risks and benefits related to these different aspects of movement behaviour are not independent, and recent studies emphasize the need to towards personalised recommendations for both physical activity and sedentary behaviour combined.^{20,26}

Health risks of sedentary behaviour

From several studies on the relationship between sedentary time and prolonged sedentary time and health risks, a dose–response relationship between higher amounts of sedentary time and higher levels of health risks is seen.^{20,21,27–30} Several studies have shown that increases of 30–60 minutes in sedentary time are related to increased hazard ratios for all-cause mortality (including stroke) and cardiovascular mortality.^{21,29} These study findings indicate that a reduction in total sedentary time of 30–60 minutes seems to be clinically meaningful. When looking at the association between sedentary time and cardiovascular risk scores (using the Framingham risk score), one study even showed an increase in the risk score even with only a 10-minute increase in sedentary time.³¹ Also, Bell et al.'s study findings indicated the long-term effectiveness of sedentary behaviour reduction interventions on CVD risk, although further research is needed in this area.²⁸

Benefits are also found from interrupting sedentary time in people with stroke. The Breaking Up Sitting Time after Stroke study found that when sedentary time is interrupted by short bouts of standing exercises or walking, this reduces systolic blood pressure in people with stroke, even if participants were on antihypertensive medication.³² This finding is highly relevant because high (systolic) blood pressure is one of the strongest modifiable risk factors for first and recurrent stroke.^{3,33}

Movement behaviour after stroke

Looking at the high risk of recurrent stroke and the increased risks associated with high amounts of sedentary behaviour and low levels of physical activity, it might be prudent to address these risk factors as part of secondary prevention in people who have had a stroke. To estimate the possible effect of these types of interventions, first, identifying peoples' movement behaviour patterns was needed. Several studies have found that people with stroke are highly sedentary in comparison to their healthy peers.^{34–38} Also lower levels of physical activity were found.^{34–38} The RISE-cohort study identified movement behaviour patterns of people with first ever stroke in the Netherlands after returning home from the hospital. The results showed that 33 percent of the population was highly sedentary (78% of their waking hours), rarely interrupted their sedentary time and spent minimal time engaged in MVPA (see Figure 2-5).³⁴ Individuals with this movement pattern were labelled 'sedentary prolongers'. Additionally, 46 percent had a movement behaviour pattern that included two out of three risk factors, i.e., high sedentary time and minimal time spent in MVPA (see Figure 2-4), and they were labelled 'sedentary movers'.³⁴ The final 22 percent, labelled 'sedentary exercisers', also had high amounts of sedentary time, although they do engage in sufficient amounts of MVPA (see Figure 2-4).³⁴ These results indicated that over three quarters (79%) of people with stroke have a movement pattern that may put them at high risk of recurrent stroke and other cardiovascular events. These findings match the 2021

Guideline for the Prevention of Stroke of the American Heart Association/American Stroke Association as being important for prevention of second stroke, with the recommendation to reduce and interrupt sedentary behaviour and increase the levels of physical activity after stroke.⁶ With the identification of these behaviour patterns, we can specifically target those people who are in need of improving their movement behaviour pattern most and design interventions specifically for this part of the population to enhance the possibility of creating sustainable movement behaviour change.

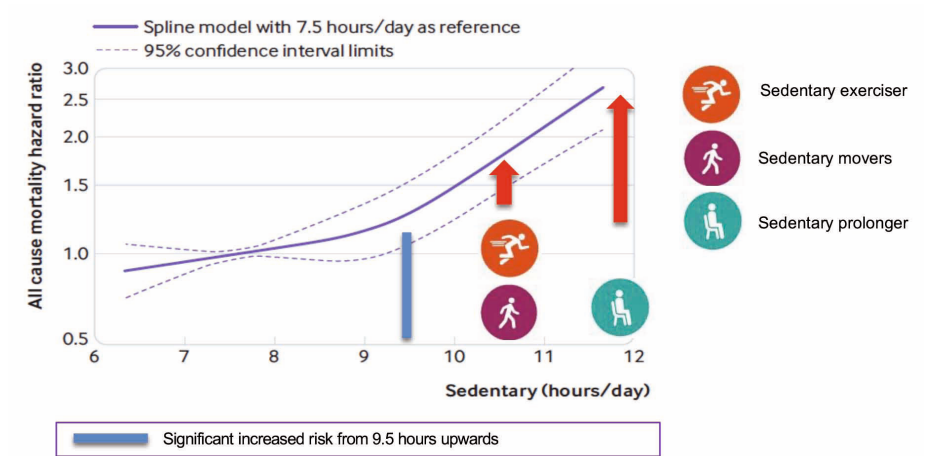


Figure 2. The association between sedentary behaviour and all-cause mortality, reprinted from Ekelund et al.,²¹ including a representation of the time spent sedentary for each movement pattern identified by Wondergem et al.³⁴

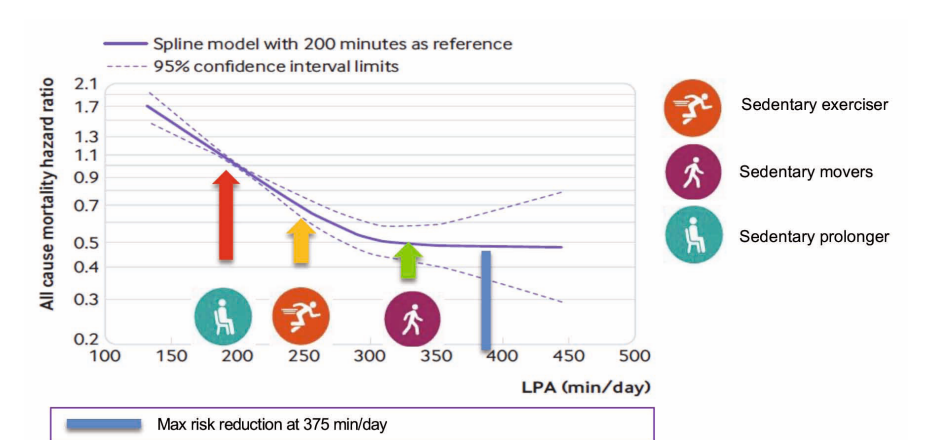


Figure 3. The association between light physical activity (LPA) and all-cause mortality, reprinted from Ekelund et al.,²¹ including a representation of the time in LPA for each movement pattern identified by Wondergem et al.³⁴

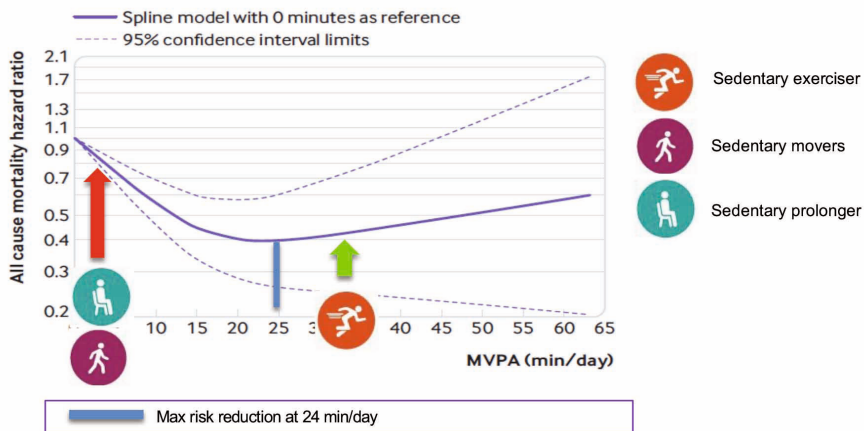


Figure 4. The association between moderate-to-vigorous physical activity (MVPA) and all-cause mortality, reprinted from Ekelund et al.,²¹ including a representation of the time in MVPA for each movement pattern identified by Wondergem et al.³⁴

Improving movement behaviour after stroke

In addition to the international guidelines, in the Netherlands, secondary prevention of stroke is conducted for the most part via general practitioner practices in primary care, following the newly updated NHG standard.³⁹ This new (updated August 2022) standard includes similar advice as the international guidelines regarding physical activity and sedentary behaviour.³⁹ Nevertheless, secondary prevention after stroke is limited to short half yearly check-ups, and all factors related to secondary prevention need to be addressed. By default, the focus for the most part is on medication management. In regard to movement behaviour, sufficient levels of MPVA are briefly mentioned as important, although no personalised recommendations are made. Also, risk identification in regard to movement behaviour is lacking, and the prescription of interventions to support movement behaviour change is rare. Referral to a physiotherapist is mostly related to physical limitations. This despite the fact that within physiotherapy guidelines, there is also growing attention to secondary prevention in regard to the levels of physical activity.⁴⁰ This provides the opportunity to start targeting movement behaviour improvements in people with stroke, which has not been accomplished before both in the Netherlands and internationally.^{41–43} In current (physiotherapy) interventions, there is still a tendency to focus on physical capabilities and (supervised) training instead of addressing movement behaviour, including sedentary behaviour.⁴⁰ Unfortunately, interventions aiming to improve physical activity do not automatically lead to a reduction in sedentary behaviour.⁴⁴ Therefore, there is a need for interventions that identify people with stroke at risks in regard to movement behaviour, including sedentary behaviour, and support and empower

people towards sustainable changes in their movement behaviour by reducing and interrupting their sedentary time and replacing sedentary time with physical activity.

To enable sustainable movement behaviour change, effective interventions are needed, which are currently lacking, especially in regard to sedentary behaviour and movement behaviour as a whole.⁴⁵ International experts believe that interventions to reduce sedentary behaviour in people who have had a stroke should aim at behavioural aspects and self-management specifically to support people with stroke reduce their sedentary time.⁴⁵

Information regarding factors associated with sedentary behaviour in people with stroke is limited. There is one qualitative study in which people with stroke stated that factors like self-efficacy, confidence, motivation and the social environment influence their time spent sedentary.⁴⁶ In addition, a cohort study showed that low self-efficacy was associated with high-risk movement behaviour patterns.³⁴ This suggests that behavioural aspects indeed play an important role and need to be the focus of interventions, although more information is needed to draw definitive conclusions. Other previous studies that have looked at movement behaviour in people with stroke showed associations between self-reported physical function after stroke and total sedentary time; for other physical factors, the results were inconsistent.^{35,36} Behaviour change theory clearly states that to enable effective intervention development, a thorough understanding of the behaviour and all its underlying barriers and facilitators is needed to enable the design of effective interventions.^{47,48} Before relevant behaviour change techniques to be included in interventions can be identified, a thorough understanding of which aspects of all three domains, Capabilities, Opportunities and Motivations, should be addressed is needed,^{47,48} and it might indicate that more than the current provision of basic health information is warranted.

Possibilities of technology

Persuasive eCoaching is the use of technology during coaching to motivate and stimulate people to change attitudes, behaviour and rituals.⁴⁹ Monitoring of movement behaviour and eCoaching might support movement behaviour change.^{46,49–51} Monitoring will allow the identification of individual movement behaviour patterns and give direction to what should be changed. This is especially important in sedentary behaviour because this part of movement behaviour is often spread out throughout the day. Currently, there are several monitors available for research that give a valid and reliable identification of sedentary behaviour, although they are not fit to provide real-time feedback of movement behaviour patterns across the day.^{26,52–55} There are several commercial trackers on the market that do include feedback, for instance, via a smartphone application; unfortunately, they are not able to validly and reliably determine sedentary behaviour. This is only possible with

an inclinometer that is worn on the (anterior) thigh.^{26,52–55} This calls for the integration of a valid and reliable monitor with a real-time digital feedback system that can be used in primary health care settings to support people with stroke to reduce and interrupt their sedentary time.

The integration of eHealth, such as eCoaching and face-to-face contact with a health professional, is called blended care. This combination seems promising for sustainable behaviour change.^{50,51} It allows for the integration of a reliable identification and feedback system as part of the intervention. Additionally, eCoaching can be used to support people in changing their behaviour between face-to-face coaching sessions. Several behaviour change techniques can be incorporated more extensively by this combination of modalities of delivery.^{47,48} Combining these new promising developments with a deeper understanding of movement behaviour, especially sedentary behaviour, might lead to an effective intervention to support movement behaviour change after stroke. This may reduce the risk of recurrent stroke and other health risks associated with high amounts of sedentary behaviour and low levels of physical activity after stroke.

Objectives and outline of this thesis

The overall aim of this thesis is to identify what is needed to support people with stroke who are highly sedentary and inactive to sustainably change their movement behaviour pattern. This will enable the development of an intervention that aims at improving movement behaviour by reducing and interrupting sedentary behaviour and the determination of the preliminary effectiveness and feasibility of the intervention.

Chapter 2 provides insights into factors associated with a high amount of sedentary behaviour in people with stroke. In **Chapter 3**, we explored sedentary behaviour accumulation patterns. These two data pooling studies provided information for intervention development. In **Chapter 4**, we present the results of a systematic literature review of general lifestyle interventions aiming to improve the levels of physical activity after stroke or TIA to see if anything could be learned from these types of interventions in regard to improving movement behaviour. **Chapter 5** includes the perspective of people with stroke who are highly sedentary and inactive regarding their needs to improve their movement behaviour to enable the development of an intervention that meets their needs. The development process of the RISE intervention to support people with stroke to improve their movement behaviour by reducing and interrupting sedentary behaviour is described in **Chapter 6**. In **Chapter 7**, we present the results regarding the preliminary effectiveness and feasibility of the RISE intervention. In this multiple-baseline design study, we determined the preliminary effectiveness to reduce sedentary time and increase the interruption of sedentary time as well as the feasibility of the intervention. Additionally,

the added value of including participatory support within the RISE intervention was determined. In **Chapter 8**, a general discussion of this dissertation is provided, the steps taken to develop and the results of the RISE intervention. The implications of the findings are described, including methodological considerations and recommendations for future research, education and clinical practice. This dissertation ends with a summary in English and Dutch in **Chapter 9**.

References:

1. Sacco RL, Kasner SE, Broderick JP, et al. An Updated Definition of Stroke for the 21st Century. *Stroke*. 2013;44(7):2064-2089. doi:10.1161/STR.0b013e318296aeca
2. World Health Organization. Stroke, Cerebrovascular accident. http://www.who.int/topics/cerebrovascular_accident/en/.
3. Feigin VL, Brainin M, Norrving B, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2022. *Int J Stroke*. 2022;17(1):18-29. doi:10.1177/17474930211065917
4. Cijfers hart- en vaatziekten 2022 | Hartstichting. <https://www.hartstichting.nl/hart-en-vaatziekten/cijfers-hart-en-vaatziekten>. Accessed January 13, 2023.
5. RIVM. Volksgezondheidszorg info, Beroerte. <https://www.volksgezondheidszorg.info/onderwerp/beroerte>.
6. Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association. *Stroke*. 2021;52(7). doi:10.1161/STR.0000000000000375
7. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
8. Pennlert J, Eriksson M, Carlberg B, Wiklund P-G. Long-term risk and predictors of recurrent stroke beyond the acute phase. *Stroke*. 2014;45(6):1839-1841. doi:10.1161/STROKEAHA.114.005060
9. GBD 2016 Stroke Collaborators. Global, regional, and national burden of stroke, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18(5):439-458. doi:10.1016/S1474-4422(19)30034-1
10. Amarenco P, Lavallée PC, Monteiro Tavares L, et al. Five-Year Risk of Stroke after TIA or Minor Ischemic Stroke. *N Engl J Med*. 2018;378(23):2182-2190. doi:10.1056/NEJMoa1802712
11. Sennfält S, Norrving B, Petersson J, Ullberg T. Long-Term Survival and Function After Stroke. *Stroke*. 2019;50(1):53-61. doi:10.1161/STROKEAHA.118.022913
12. WHO | Global atlas on cardiovascular disease prevention and control. WHO. 2015.
13. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi:10.1186/s12966-017-0525-8
14. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev*. 2008;36(4):173-178. doi:10.1097/JES.0b013e3181877d1a
15. Sedentary Behaviour Research Network. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". *Appl Physiol Nutr Metab*. 2012;37(3):540-542. doi:10.1139/h2012-024
16. AINSWORTH BE, HASKELL WL, HERRMANN SD, et al. 2011 Compendium of Physical Activities: A Second Update of Codes and MET Values. *Med Sci Sport Exerc*. 2011;43(8):1575-1581. doi:10.1249/MSS.0b013e31821ece12

17. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338-1353. doi:10.1093/ije/dys078
18. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-132. doi:10.7326/M14-1651
19. Bauman AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep*. 2013;7(4):293-298. doi:10.1007/s12170-013-0316-y
20. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
21. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*. 2019;366:l4570. doi:10.1136/bmj.l4570
22. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-666. doi:10.2337/dc07-2046
23. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
24. Benatti FB, Ried-Larsen M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Med Sci Sports Exerc*. 2015;47(10):2053-2061. doi:10.1249/MSS.0000000000000654
25. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity (Silver Spring)*. 2015;23(9):1800-1810. doi:10.1002/oby.21180
26. Chastin SFM, McGregor DE, Biddle SJH, et al. Striking the Right Balance: Evidence to Inform Combined Physical Activity and Sedentary Behavior Recommendations. *J Phys Act Health*. 2021;18(6):631-637. doi:10.1123/jpah.2020-0635
27. Duran AT, Romero E, Diaz KM. Is Sedentary Behavior a Novel Risk Factor for Cardiovascular Disease? *Curr Cardiol Rep*. 2022;24(4):393-403. doi:10.1007/s11886-022-01657-w
28. Bell AC, Richards J, Zakrzewski-Fruer JK, Smith LR, Bailey DP. Sedentary Behaviour—A Target for the Prevention and Management of Cardiovascular Disease. *Int J Environ Res Public Health*. 2022;20(1):532. doi:10.3390/ijerph20010532
29. Patterson R, McNamara E, Tainio M, et al. Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis. *Eur J Epidemiol*. 2018;33(9). doi:10.1007/S10654-018-0380-1
30. Hooker SP, Diaz KM, Blair SN, et al. Association of Accelerometer-Measured Sedentary Time and Physical Activity With Risk of Stroke Among US Adults. *JAMA Netw open*. 2022;5(6):e2215385. doi:10.1001/jamanetworkopen.2022.15385

31. Länsitie M, Kangas M, Jokelainen J, et al. Cardiovascular disease risk and all-cause mortality associated with accelerometer-measured physical activity and sedentary time – a prospective population-based study in older adults. *BMC Geriatr.* 2022;22(1):729. doi:10.1186/s12877-022-03414-8
32. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: Breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke.* 2018;13(9):932-940. doi:10.1177/1747493018798535
33. Sacco RL, Benjamin EJ, Broderick JP, et al. American Heart Association Prevention Conference. IV. Prevention and Rehabilitation of Stroke. Risk factors. *Stroke.* 1997;28(7):1507-1517. <http://www.ncbi.nlm.nih.gov/pubmed/9227708>. Accessed July 18, 2018.
34. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behavior Patterns in People With First-Ever Stroke. *Stroke.* 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
35. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. *Phys Ther.* 2016;96(2):193-201. doi:10.2522/ptj.20140522
36. Tieges Z, Mead G, Allerhand M, et al. Sedentary behavior in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil.* 2015;96(1):15-23. doi:10.1016/j.apmr.2014.08.015
37. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil.* 2016;38(4):362-367. doi:10.3109/09638288.2015.1041615
38. Fini NA, Holland AE, Keating J, Simek J, Bernhardt J. How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis. *Phys Ther.* 2017;97(7):707-717. doi:10.1093/ptj/pzx038
39. Dolmans L, Hegeman L, Tjon-A-Tsien M, et al. *NHG-Standaard Beroerte (M103)*. <https://richtlijnen.nhg.org/standaarden/beroerte>.
40. Koninkrijk Nederlands Genootschap voor Fysiotherapie. KNGF-richtlijn Beroerte. 2017. www.kngfrichtlijnen.nl.
41. de Weerd L, Groenhof F, Kollen BJ, van der Meer K. Survival of stroke patients after introduction of the “Dutch Transmural Protocol TIA/CVA”. *BMC Fam Pract.* 2013;14:74. doi:10.1186/1471-2296-14-74
42. Pedersen R, Petursson H, Hetlevik I. Stroke follow-up in primary care: a prospective cohort study on guideline adherence. *BMC Fam Pract.* 2018;19(1). doi:10.1186/S12875-018-0872-9
43. Olaiya MT, Cadilhac DA, Kim J, et al. Long-term unmet needs and associated factors in stroke or TIA survivors: An observational study. *Neurology.* 2017;89(1):68-75. doi:10.1212/WNL.0000000000004063
44. Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJH. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol Rev.* 2016;10(1):89-112. doi:10.1080/17437199.2015.1082146
45. Saunders DH, Mead GE, Fitzsimons C, et al. Interventions for reducing sedentary behaviour in people with stroke. *Cochrane Database Syst Rev.* 2018;2018(4). doi:10.1002/14651858.CD012996

46. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil.* 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764
47. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions.* Silverback Publishing Great Britain; 2014.
48. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011;6(1):42. doi:10.1186/1748-5908-6-42
49. Lentferink AJ, Oldenhuis HK, de Groot M, Polstra L, Velthuijsen H, van Gemert-Pijnen JE. Key Components in eHealth Interventions Combining Self-Tracking and Persuasive eCoaching to Promote a Healthier Lifestyle: A Scoping Review. *J Med Internet Res.* 2017;19(8):e277. doi:10.2196/jmir.7288
50. Stephenson A, McDonough SM, Murphy MH, Nugent CD, Mair JL. Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act.* 2017;14(1):105. doi:10.1186/s12966-017-0561-4
51. Fjeldsoe B, Neuhaus M, Winkler E, Eakin E. Systematic review of maintenance of behavior change following physical activity and dietary interventions. *Heal Psychol.* 2011;30(1):99-109. doi:10.1037/a0021974
52. Fanchamps MHJ, Horemans HLD, Ribbers GM, Stam HJ, Bussmann JBJ. The Accuracy of the Detection of Body Postures and Movements Using a Physical Activity Monitor in People after a Stroke. *Sensors (Basel).* 2018;18(7). doi:10.3390/s18072167
53. Taraldsen K, Askim T, Sletvold O, et al. Evaluation of a body-worn sensor system to measure physical activity in older people with impaired function. *Phys Ther.* 2011;91(2):277-285. doi:10.2522/ptj.20100159
54. Godfrey A, Culhane KM, Lyons GM. Comparison of the performance of the activPAL Professional physical activity logger to a discrete accelerometer-based activity monitor. *Med Eng Phys.* 2007;29(8):930-934. doi:10.1016/j.medengphy.2006.10.001
55. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc.* 2012;44(11):2243-2252. doi:10.1249/MSS.0b013e318260c477



CHAPTER 2

Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies.

Wendy Hendrickx
Carlos Riveros
Torunn Askim
Johannes B.J. Bussmann
Michele L. Callisaya
Sebastien F.M. Chastin
Catherine M. Dean
Victor E. Ezeugwu
Taryn M. Jones
Suzanne S. Kuys
Niruthikha Mahendran
Trish J. Manns
Gillian Mead
Sarah A. Moore
Lorna Paul
Martijn F. Pisters
David H. Saunders
Dawn B. Simpson
Zoë Tieges
Olaf Verschuren
Coralie English

Abstract

Background

High levels of sedentary time increases the risk of cardiovascular disease, including recurrent stroke.

Objective

This study aimed to identify factors associated with high sedentary time in community dwelling people with stroke.

Methods

For this data pooling study, authors of published and ongoing trials that collected sedentary time data, using the activPAL monitor, in community dwelling people with stroke were invited to contribute their raw data. The data was reprocessed, algorithms were created to identify sleep-wake time and determine the percentage of waking hours spent sedentary. We explored demographic and stroke related factors associated with total sedentary time and time in uninterrupted sedentary bouts using unique, both univariable and multivariable, regression analyses.

Results

The 274 included participants were from Australia, Canada and the United Kingdom, and spent, on average, 69% (SD 12.4) of their waking hours sedentary. Of the demographic and stroke related factors, slower walking speeds were significantly and independently associated with a higher percentage of waking hours spent sedentary ($p=0.001$) and uninterrupted sedentary bouts of >30 and >60 minutes ($p=0.001$ and $p=0.004$, respectively). Regression models explained 11-19% of the variance in total sedentary time and time in prolonged sedentary bouts.

Conclusion

We found that variability in sedentary time of people with stroke was largely unaccounted for by demographic and stroke-related variables. Behavioural and environmental factors are likely to play an important role in sedentary behaviour after stroke. Further work is required to develop and test effective interventions to address sedentary behaviour after stroke.

Introduction

Stroke is the second most common cause of death and the third leading cause of disability worldwide,^{1,2} with the burden expected to increase during the next 20 years.¹ Almost 40% of people with stroke have a recurrent stroke within 10 years,³ making secondary prevention vital.^{3,4} High amounts of sedentary time have been found to increase the risk of cardiovascular disease,⁵⁻¹¹ particularly when sedentary time is accumulated in prolonged bouts.¹²⁻¹⁵ Sedentary behaviour, is defined as “any waking behaviour characterized by an energy expenditure ≤ 1.5 Metabolic Equivalent of Task (METs) while in a sitting, reclining or lying posture”.^{16,17} Studies in healthy people, as well as people with diabetes and obesity, have shown that reducing the total amount of sedentary time and/or breaking up long periods of uninterrupted sedentary time, reduces metabolic risk factors associated with cardiovascular disease.^{6,9,10,12-15} Recent studies have shown that people living in the community after stroke spend more time each day sedentary, and more time in uninterrupted bouts of sedentary time compared to age-matched healthy peers.¹⁸⁻²⁰ Reducing sedentary time and breaking up long sedentary bouts with short bursts of activity may be a promising intervention to reduce the risk of recurrent stroke and other cardiovascular disease in people with stroke.

To develop effective interventions, it is important to understand the factors associated with sedentary time in people with stroke. Previous studies have found associations between self-reported physical function after stroke and total sedentary time, but inconsistent results with regards to the relationship of age, stroke severity and walking speed with sedentary time.^{20,21} These results are from secondary analyses of single-site observational studies, not powered to address associations, and inconsistent in the methods used to determine waking hours; thus making direct comparisons between studies difficult.^{20,21} Individual participant data pooling, with consistent processing of wake time data, allows novel exploratory analyses of larger datasets with greater power.

By pooling all available individual participant data internationally, this study aimed to comprehensively explore the factors associated with sedentary time in community dwelling people with stroke. Specifically, our research questions were: 1) What factors are associated with total sedentary time during waking hours after stroke? 2) What factors are associated with time spent in prolonged sedentary bouts during waking hours?

Methods

Study design

This was an exploratory data pooling study, in which existing individual participant data were used for secondary analyses. By searches of databases, trial registries and word of mouth, potentially eligible datasets were identified, and authors were invited to contribute their individual participant data and raw activity monitor data. The study was approved by the Human Research Ethics Committee of The University of Newcastle (H-2016-0427).

Study selection

Datasets from studies were included if they met the following criteria;

1. Included adults with stroke who were living in the community,
2. Measured sedentary behaviour using the activPAL monitor (PAL Technologies Ltd, Glasgow, United Kingdom),
3. The ethical approval and informed consent for the data collection permitted use of the data for secondary analyses,
4. The available data was not influenced by any form of intervention.

Authors of original studies provided de-identified datasets. Factors included in the datasets were mapped by one author (WH) in consultation with the co-authors. A list of factors of interest was created *a priori* (see Box 1), based on previous research in determinants of sedentary time and consideration of other relevant stroke-related factors.²⁰⁻²⁸ For each dataset, we determined which factors were measured and what measurement instrument was used. Where different measurement instruments were used for the same factor, we sought valid methods to categorize or dichotomize data to facilitate data pooling (see Supplementary Materials 1, Box 1 for the conversion methods). Where the original studies included repeated measures, we included data from one time-point only, and used the time-point with the least missing data or at baseline in the case of intervention trials.

Box 1. Factors of interest determined *a priori*

Demographics
Age
Sex
Employment status
Socio-economic status
Education attainment
Living status
Personal factors
Body Mass Index
Smoking
Levels of moderate to vigorous physical activity
Comorbidities
Environmental aspects
Season of accelerometer data collection
Stroke related factors
Type of stroke
Time since stroke
Stroke severity
Impairments
Upper and lower extremity impairment
Vision impairment
Walking ability
Walking speed
Walking capacity (distance)
Use of walking aids
Physical ability
Self-reported physical function
Independence in activities of daily living
Cognition and mood
Cognitive ability
Fatigue
Anxiety
Depression

Activity monitor data

We chose to only include data on sedentary time that was measured using the activPAL monitor (PAL Technologies Ltd, Glasgow, United Kingdom) because it is highly reliable (Intraclass correlation coefficient 0.79-0.99) and valid (98-100% accuracy) for measuring sedentary time and posture transitions during daily life in people with stroke.²⁹⁻³¹ The ActivPAL uses an inclinometer worn on the anterior side of the thigh to determine if someone is either sedentary (sitting, lying or reclining), standing or walking making it a highly valid and accurate monitor to determine sedentary time.²⁹⁻³¹ A conversion to METs is also possible.²⁹⁻³¹ Event files from all participants were combined into one dataset. To identify waking hours, a custom algorithm was developed based on previously published codes.³² The algorithm aggregated sleep time based on the largest bout of sitting/lying time within a 24-hour period and then aggregated adjacent bouts of sitting/lying time where these bouts were interrupted by short bursts of activity, i.e. to account for getting up to the toilet overnight (see Appendix 1 for more details). Our previous work has found that any three days of monitoring, regardless of weekend or weekday, is sufficient to accurately represent habitual physical activity over seven days.³³ We therefore included participants with at least three days of valid (>8 hours day) waking wear time.³³ We excluded days in which more than 18 hours of wake time were identified.

Data processing and analyses

From the activPAL data during waking hours, the percentage of total sedentary time and the percentage of waking hours spent in prolonged bouts of sedentary time was determined. Two variables were created for prolonged bouts: percentage of sedentary time in bouts >30 min and percentage of sedentary time in bouts >60 min.^{9,10,12,18} Linear regressions (adjusting for age, gender and study) were conducted to determine the association of individual factors with percentage of total sedentary time, percentage of sedentary time in bouts >30 min and percentage of sedentary time in bouts >60 min. All factors and residuals (from regression analyses) were checked for normality and where needed the appropriate transformations were computed. Factors that were found significantly associated in univariable regressions ($p < 0.05$) were included in the multivariable regressions. We first determined the coverage of factors across studies and then conducted the multivariable regressions with the best coverage of factors across studies and the highest sample sizes. To avoid collinearity, if correlations between independent factors were higher than $r = 0.850$ one factor was removed from the analyses.^{34,35} Both forward and backward stepwise linear regressions were run. Based on the 1:10 rule by Peduzzi et al,³⁶ a sample of at least $n = 250$ was needed to be able to include all the factors we identified *a priori* (Box 1). All analyses were conducted with R statistical software, version 3.3.3 and IBM SPSS statistics version 22.

Results

Participant characteristics

Ten datasets were identified that met the inclusion criteria and we were able to obtain individual participant data from 9 (90%), including n=350 individual participants (Table 1). In all, n=274 (78%) individual participants contributed at least three days of valid activPAL data. There were no differences in demographics between the original (n=350) and final (n=274) sample (Table 2). On average, participants spent 69 (Standard Deviation 12)% of waking hours sedentary, 40 (SD 16)% of waking hours in sedentary bouts >30 minutes and 23 (SD 15)% of waking hours in sedentary bouts >60 minutes. Only age and gender were reported in all studies; other variables were reported in between 3 (33%) and 8 (89%) of included studies (Supplementary Materials 1, Table 1).

Table 1. Characteristics of studies that provided data

Author	Country	n	Design	Time since stroke	Walking ability
Dean*	Australia	4	Intervention	< 2 years	Able to walk 10 m independently, no aids
English 2016 ²¹	Australia	48	Observational	> 6 months	Able to walk independently indoors, no aids
Ezeugwu*	Canada	30	Intervention	2-4 months	Able to walk ≥ 5 m independently, no aids
Jones 2016 ⁵⁰	Australia	21	Intervention	No criteria specified; recruitment from general population	Able to walk ≥ 50 m, no aids
Kuys*	Australia	29	Intervention	< 2 months	Able to walk 10 m independently
Mahendran 2016 ⁵¹	Australia	36	Observational	< 4 months	
Paul*	United Kingdom	56	Intervention	Discharged from active rehabilitation	Able to walk independently
Simpson*	Australia	30	Observational	No criteria specified; Participants were recruited from rehabilitation ward	No criteria specified
Tieges 2015 ²⁰	United Kingdom	96	Observational	No criteria specified; Participants with a recent acute hemorrhagic or ischemic stroke were recruited	No criteria specified

*Data from ongoing trials

Table 2. Participant demographics

Characteristic	All available data	Pooled data
Sample size, n		
Total	350	274
mean (SD) across studies	39 (25)	30 (15)
Sex, number male (%)	213 (61)	167 (61)
Age, (yr) mean (SD)	66 (14)	66 (13)
Time since stroke (<i>month</i>) mean (SD)	17 (28)	18 (29)

Factors associated with total sedentary time

The results of the univariable regression (adjusting for age, gender and study) for percentage of total sedentary time are shown in Table 3. Body mass index ($p=0.048$), stroke severity ($p=0.035$), walking speed ($p<0.001$), walking capacity ($p<0.001$), walking aid use ($p<0.001$), degree of independence in activities of daily living ($p=0.014$), and anxiety ($p=0.028$) were all significantly associated with percentage of total sedentary time. As walking speed and walking capacity were highly correlated ($r=0.897$), and more data were available across the datasets for walking speed, only walking speed was included in the multivariable regression analyses. Only walking speed remained significant in the multivariable regression model ($p=0.001$, see Table 4), which explained 14% of the variance in percentage of total sedentary time.

Factors associated with time spent in prolonged sedentary bouts

The results of the univariable regression (adjusting for age, gender and study) for percentage of sedentary time in bouts $>30\text{ min}$ and percentage of sedentary time in bouts $>60\text{ min}$ are shown in Table 3. Body mass index ($p=0.024$ and $p=0.038$), stroke severity ($p=0.019$ and $p=0.016$), walking speed (both $p<0.001$), walking capacity (both $p<0.001$), walking aid use ($p<0.001$ and $p=0.009$), and independence in activities of daily living ($p=0.003$ and $p=0.005$) were significantly associated with percentage of sedentary time in bouts $>30\text{ min}$ and percentage of sedentary time in bouts $>60\text{ min}$. Fatigue was significantly associated only with percentage of sedentary time in bouts $>60\text{ min}$ ($p=0.044$).

Walking capacity was removed from the multivariable regression because of the high correlation with walking speed. In the multivariable regressions (Table 4), only walking speed was significantly associated with percentage of sedentary time in bouts $>30\text{ min}$ ($p=0.001$) and percentage of sedentary time in bouts $>60\text{ min}$ ($p=0.004$). For percentage of sedentary time in bouts $>30\text{ min}$, body mass index ($p=0.049$) was also found to be significantly associated. The models explained 19% of the variance in percentage of sedentary time in bouts $>30\text{ min}$ and 11% of the variance in percentage of sedentary time in bouts $>60\text{ min}$.

There was a wide range in time since stroke in our dataset (1 to 237 months) and these data were highly skewed. To check whether this confounded results, we categorized the time since stroke into three epochs (1 to 3 months, 3 to 6 months and >6 months) and re-ran the regression models for percentage of total sedentary time using this ordinal variable. This did not change the results.

Table 3. Univariate regressions

Factor	Number participants, n (number studies)	Missing data within studies, n (%)	Time spent sedentary			Time spent in sedentary bouts >30 min			Time spent in sedentary bouts >60 min		
			p value	Adjusted R ²		p value	Adjusted R ²		p value	Adjusted R ²	
Demographics											
Educational level	52 (3)	0 (0%)	0.564	-0.052		0.709	<0.001		0.845	0.071	
Living arrangements	144 (6)	0 (0%)	0.107	0.005		0.524	0.017		0.872	0.028	
Personal factors											
BMI	205 (7)	27 (13%)	0.048	0.023		0.024	0.037		0.038	0.031	
Smoker	171 (4)	6 (4%)	0.317	0.006		0.971	0.007		0.859	0.018	
Comorbidities	147 (4)	0 (0%)	0.359	0.005		0.295	0.016		0.423	0.023	
Stroke related factors											
Type of stroke	198 (6)	6 (3%)	-0.067	0.024		0.214	0.033		0.290	0.022	
Time since stroke	268 (8)	3 (1%)	0.893	0.010		0.468	0.013		0.254	0.011	
Stroke severity	118 (3)	2 (2%)	0.035	0.030		0.019	0.046		0.016	0.045	
Walking ability											
Walking speed	195 (6)	6 (3%)	< 0.001	0.156		< 0.001	0.167		< 0.001	0.112	
Walking capacity (distance)	149 (5)	46 (31%)	< 0.001	0.158		< 0.001	0.187		< 0.001	0.158	
Walking aid	216 (7)	4 (2%)	< 0.001	0.064		< 0.001	0.066		0.009	0.039	
Physical ability											
Degree of ADL independence	197 (6)	4 (2%)	0.014	0.045		0.003	0.065		0.005	0.053	
Cognition and mood											
Cognitive function	145 (5)	37 (26%)	0.864	0.004		0.445	0.019		0.150	0.028	
Fatigue	192 (6)	36 (19%)	0.084	0.027		0.101	0.026		0.044	0.020	
Mood disorder	194 (6)	8 (4%)	0.235	0.019		0.179	0.016		0.315	0.006	
Anxiety	153 (4)	3 (2%)	0.028	0.031		0.079	0.020		0.164	0.003	
Depression	175 (5)	8 (5%)	0.055	0.027		0.118	0.016		0.095	0.008	

All regressions corrected for age, gender and study. Bolded values indicate statistical significance.
BMI = body mass index, ADL = activities of daily living

Table 4. Multivariable regression

Dependent variable		Number participants, n (number studies)	Missing data within studies, n (%)	p value	Unstandardized β (95% CI)*	Standardized β *
Time spent sedentary	BMI	182 (7)	69 (27%)	0.071	0.206	
	Stroke severity	118 (7)	133 (53%)	0.231	0.139	
	Walking speed	195 (7)	56 (22%)	0.001	-0.115 (-0.182 to -0.048)	-0.390
	Walking aid	197 (7)	54 (22%)	0.451	-0.094	
	Degree of ADL independence	197 (7)	54 (21%)	0.532	0.78	
Time spent in sedentary bouts >30 min	Anxiety	153 (7)	98 (39%)	0.512	-0.77	
	BMI	182 (7)	69 (27%)	0.049	0.007 (0 to -0.014)	0.222
	Stroke severity	118 (7)	133 (53%)	0.182	0.151	
	Walking speed	195 (7)	56 (22%)	<0.001	-0.153 (-0.235 to -0.070)	-0.410
	Walking aid	197 (7)	54 (22%)	0.413	-0.100	
Time spent in sedentary bouts >60 min	Degree of ADL independence	197 (7)	54 (21%)	0.351	0.113	
	BMI	182 (7)	69 (27%)	0.110	0.186	
	Stroke severity	118 (7)	133 (53%)	0.132	0.177	
	Walking speed	195 (7)	56 (22%)	0.004	-0.131 (-0.217 to -0.045)	-0.351
	Walking aid	197 (7)	54 (22%)	0.670	-0.054	
Fatigue	Degree of ADL independence	197 (7)	54 (21%)	0.333	0.122	
	Fatigue	192 (7)	59 (24%)	0.441	-0.091	

All regression were corrected for age, gender and study. All regression analyses included data from: English, Ezeugwu, Kuys, Mahendran, Paul, Simpson and Tieges. Bolded values indicate statistical significance.

*Since forward and backward methods were used for the regressions, not all data is available for the non-significant variables

Discussion

We pooled data from 274 individuals from three countries and found that people with stroke spent on average 69% of waking hours sedentary. Slower walking speed was the only factor independently associated with more total sedentary time, and more time spent in prolonged bouts of sedentary behaviour. However, our models accounted for only a small proportion of the variance in sedentary behaviour, suggesting that other factors not measured in the participants included in this study are also important.

Our findings in relation to walking speed are consistent with a previous study which found both slower walking speed, and other measures of poorer physical function (in this case the Stroke Impact Scale) were associated with greater sedentary time²¹ However, walking speed may also be a proxy measure for general health and co-morbidities³⁷⁻³⁹ In older people, walking speed is an important predictor of a number of adverse outcomes such as falls, activities of daily living difficulties, disability, institutionalization, comorbidities and mortality³⁷⁻⁴¹ Further research is needed to determine whether there is a direct causal pathway between slow walking speed and high sedentary time, or if it is a proxy measure of general health. It is possible that interventions aimed at improving the walking abilities of people with stroke might help reduce the total sedentary time and the time spent sedentary in prolonged bouts. However, this premise requires testing in clinical trials.

We found few other factors were independently associated with high sedentary behaviour. This is in contrast to previous studies. In older adults *without* stroke, age, gender, education level, living arrangements, body mass index, smoking status, and independence in activities of daily living, were all found to be associated with sedentary behaviour.^{22,25-27} In previous studies of people *with* stroke both age and stroke severity were associated with sedentary behaviour.^{20,21} In people with multiple sclerosis, both disease severity and physical ability are reported to be associated with high sedentary time.⁴² Taken together, this suggests that the factors associated with high sedentary time may differ between population groups. This is important to consider when developing interventions to reduce sedentary behaviour.

In our analyses, the regression models accounted for only a small proportion of the variance in sedentary behaviour. It is likely that environmental and behavioural factors may also influence sedentary time in people with stroke, and this should be taken into consideration when designing interventions to reduce sedentary behaviour in this population. Such interventions will need to be carefully developed and include strategies to address both the factors influencing sedentary behaviour, and the barriers and motivations to increase light, moderate and vigorous physical activity. Systematic reviews of clinical trials in other

populations (healthy and older adults, those with diabetes or obesity) have highlighted the importance of developing interventions specifically targeted to reduce sedentary time, as such programs are more effective for reducing sedentary time compared with interventions that aim to increase physical activity alone.^{45,46} An international consensus framework for sedentary behaviour research across all population groups,²³ as well as qualitative research involving people with stroke,⁴⁷ highlight the importance of the environment, psychology (including motivation), education and behaviour as determinants of sedentary time. Development of effective interventions to address high levels of sedentary time in people with stroke will need to take all these factors into consideration.

Strengths and limitations

We pooled all available individual participant activity monitor data, and completed a novel exploratory analyses on a large dataset, with sufficient statistical power. We choose this novel data pooling methodology (instead of for instance a meta-analyses) to be able to conduct independent secondary analyses using raw data. This also allowed the inclusion of data from ongoing and unpublished studies. We did not complete systematic literature searches, meaning that it is possible that some potentially relevant datasets were missed. The extensive international collaboration that was the foundation of this study allows confidence that we captured the vast majority of trials that have included activPAL data. The large dataset provides confidence in the results. We re-processed all raw activity monitor files using a custom-built algorithm to consistently and systematically identify sleep-wake time without manual error.³² We decided to use only data in which the activPAL was used to measure sedentary time. This decision was based on the fact that different activity monitors use different methods to determine sedentary time and movement, and therefore combining raw data from different monitors would introduce bias.^{48,49} Two studies have shown the incompatibility of data from different monitors.^{48,49} Only including activPAL data provides confidence in the validity of data between datasets. We acknowledge that this reduced the number of datasets we were able to include. Since the activPAL is highly reliable in the determination of sedentary behaviour it is a commonly used monitor and therefore enabled the inclusion of most of the data that is available.

While we pooled all the available individual participant data, not all factors of interest we identified *a priori* were available. Furthermore, even where the same construct (for example, depression, anxiety, physical ability) was measured, the variability in the outcome measures used necessitated categorizing or dichotomizing data. To facilitate comparability of research findings and future data pooling studies, greater consistency in outcome measurement tools used is required.^{43,44} The international Stroke Recovery and Rehabilitation Round Table group recently conducted a consensus project and have

published recommendations for a core dataset for all stroke recovery and rehabilitation trials.⁴³

Though the cut-offs of 30 and 60 minutes, used as an outcome variable for prolonged sedentary time, in their origin are arbitrary they have been used in previous studies on the risk of sedentary behaviour.¹²⁻¹⁵ These studies have shown that the risk of cardiovascular disease increases even more when sedentary time is accumulated in these prolonged bouts.¹²⁻¹⁵ Therefore these cut-offs provide a standard metric for prolonged sedentary time.

This study included only people with stroke living in the community, and for the most part only those able to walk independently, therefore results have limited generalisability beyond this group.

Conclusion

We found that variability in sedentary time of people with stroke was largely unaccounted for by demographic and stroke-related variables. Behavioural and environmental factors are likely to play an important role in sedentary behaviour after stroke. Further work is required to develop and test effective interventions to address sedentary behaviour after stroke.

References

1. Donnan GA, Fisher M, Macleod M, Davis SM. Stroke. *Lancet*. 2008; 371:1612–23.
2. Feigin VL, Forouzanfar MH, Krishnamurthi R, et al. Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. *Lancet*. 2014;383:245–254.
3. Johnston SC, Rothwell PM, Nguyen-Huynh MN, et al. Validation and refinement of scores to predict very early stroke risk after transient ischaemic attack. *Lancet*. 2007;369(9558):283–92.
4. Mohan KM, Wolfe CD, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489–94. doi: 10.1161/STROKEAHA.110.602615.
5. Ploeg, van der HP, Chey T, Korda RJ, et al. Sitting time and all-cause mortality risk in 222,497 Australian adults. *Arch Intern Med*. 2012;172:494–500.
6. Neville O, Healy GN, Matthews CE, and Dunstan DW. Too Much Sitting: The Population-Health Science of Sedentary Behaviour. *Exerc Sport Sci Rev*. 2010; 38(3): 105–113. doi:10.1097/JES.0b013e3181e373a2.
7. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338–53. doi: 10.1093/ije/dys078.
8. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123–32. doi: 10.7326/M14-1651.
9. Bauman, AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep*. 2013;7:293–298 DOI 10.1007/s12170-013-0316-y.
10. Dunstan, DW, Howard B, Healy GN, Owen N. Too much sitting – A health hazard. *Diabetes Res Clin Pract*. 2012;97(3):368–76. doi: 10.1016/j.diabres.2012.05.020.
11. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab*. 2010;35(6):725–40. doi: 10.1139/H10-079.
12. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661–6. doi: 10.2337/dc07-2046.
13. Benatti FB, Ried-Larsen M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Med Sci Sports Exerc*. 2015;47(10):2053–61. doi: 10.1249/MSS.0000000000000654.
14. Chastin SF, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behaviour and cardiometabolic health. *Obesity (Silver Spring)*. 2015;23(9):1800–10. doi: 10.1002/oby.21180.
15. Healy GN, Matthews CE, Dunstan DW, et al. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003–06. *Eur Heart J*. 2011;32:590–597.
16. Pate RR, O'Neill JR, Lobelo F. The evolving definition of “sedentary”. *Exerc Sport Sci Rev*. 2008;36(4):173–8. doi: 10.1097/JES.0b013e3181877d1a.

17. Tremblay MS, Aubert S, et al; SBRN Terminology Consensus Project Participants. Sedentary Behaviour Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi: 10.1186/s12966-017-0525-8.
18. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. *Phys Ther*. 2016;96(2):193-201. doi: 10.2522/ptj.20140522.
19. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil*. 2016;38(4):362-7. doi: 10.3109/09638288.2015.1041615.
20. Tiegies Z, Mead G, Allerhand M, et al. Sedentary behaviour in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil*. 2015;96(1):15-23. doi: 10.1016/j.apmr.2014.08.015.
21. English C, Healy GN, Coates A, Lewis LK, Olds T, Bernhardt J. Sitting time and physical activity after stroke: physical ability is only part of the story. *Top Stroke Rehabil*. 2016;23(1):36-42. doi: 10.1179/1945511915Y.0000000009.
22. Chastin SF, Buck C, Freiburger et al; DEDIPAC consortium and on behalf of the DEDIPAC consortium. Systematic literature review of determinants of sedentary behaviour in older adults: a DEDIPAC study. *International Journal of Behavioural Nutrition and Physical Activity* . 2015;12:127 DOI 10.1186/s12966-015-0292-3.
23. Chastin SF, De Craemer M, Lien N, et al; DEDIPAC consortium, expert working group and consensus panel. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. *Int J Behav Nutr Phys Act*. 2016;13:83. doi: 10.1186/s12966-016-0409-3.
24. Bampton EA, Johnson ST, Vallance JK. Profiles of resistance training behaviour and sedentary time among older adults: Associations with health-related quality of life and psychosocial health. *Prev Med Rep*. 2015;2:773-6. doi: 10.1016/j.pmedr.2015.08.017.
25. Chen T, Narazaki K, Haeuchi Y, Chen S, Honda T, Kumagai S. Associations of Sedentary Time and Breaks in Sedentary Time With Disability in Instrumental Activities of Daily Living in Community-Dwelling Older Adults. *J Phys Act Health*. 2016;13(3):303-9. doi: 10.1123/jpah.2015-0090.
26. Diaz KM, Howard VJ, Hutto B, et al. Patterns of Sedentary Behaviour in US Middle-Age and Older Adults: The REGARDS Study. *Med Sci Sports Exerc*. 2016 Mar;48(3):430-8. doi: 10.1249/MSS.0000000000000792.
27. Heseltine R, Skelton DA, Kendrick D, et al. "Keeping Moving": factors associated with sedentary behaviour among older people recruited to an exercise promotion trial in general practice. *BMC Fam Pract*. 2015;16:67. doi: 10.1186/s12875-015-0284-z.
28. Sardinha LB, Santos DA, Silva AM, Baptista F, Owen N. Breaking-up sedentary time is associated with physical function in older adults. *J Gerontol A Biol Sci Med Sci*. 2015;70(1):119-24. doi: 10.1093/gerona/glu193. Epub 2014 Oct 16.
29. Taraldsen K, Askim T, Sletvold O, et al. Evaluation of a body-worn sensor system to measure physical activity in older people with impaired function. *Phys Ther*. 2011;91:277-285.
30. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc* 2012;44:2243-52.

31. Godfrey A, Culhane KM, Lyons GM. Comparison of the performance of the activPAL Professional physical activity logger to a discrete accelerometer-based activity monitor. *Med Eng Phys.* 2007;29:930-4.
32. Winkler EAH, Bodicoat DH, Healy GN, et al. "Identifying Adults' Valid Waking Wear Time by Automated Estimation in ActivPAL Data Collected with a 24 H Wear Protocol." *Physiological Measurement.* 2016;37 (10): 1653. 2016; doi:10.1088/0967-3334/37/10/1653.
33. Tinlin L, Fini N, Bernhardt J, et al. Best practice guidelines for the measurement of physical activity levels in stroke survivors. *Int J Rehabil Res.* 2018 Mar;41(1):14-19. doi: 10.1097/MRR.0000000000000253.
34. Vocht, de A. *Basishandboek SPSS 22 IBM SPSS statistics 22.* Bijleveld April 2014:192-193; 9789055482412.
35. Fields, Andy *Discovering statistics using SPSS.* SAGE Publications Ltd, 2009:223-224; 9781847879066.
36. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49(12):1373-9.
37. Viccaro LJ, Perera S, Studenski SA. Is timed up and go better than gait speed in predicting health, function, and falls in older adults? *J Am Geriatr Soc.* 2011;59(5):887-92. doi: 10.1111/j.1532-5415.2011.03336.x.
38. Callisaya ML, Blizzard L, Schmidt MD, et al. Gait, gait variability and the risk of multiple incident falls in older people: a population-based study. *Age Ageing.* 2011 Jul;40(4):481-7. doi: 10.1093/ageing/afr055.
39. Tabue-Teguo M, Le Goff M, Avila-Funes JA, et al. Walking and psychomotor speed in the elderly: concordance, correlates and prediction of death. *J Nutr Health Aging.* 2015;19(4):468-73. doi: 10.1007/s12603-014-0560-y.
40. Donoghue OA, Savva GM, Cronin H, Kenny RA, Horgan NF. Using timed up and go and usual gait speed to predict incident disability in daily activities among community-dwelling adults aged 65 and older. *Arch Phys Med Rehabil.* 2014;95(10):1954-61. doi: 10.1016/j.apmr.2014.06.008.
41. Abellan van Kan G, Rolland Y, Andrieu S, et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. *J Nutr Health Aging.* 2009 ;13(10):881-9.
42. Veldhuijzen van Zanten JJ, Pilutti LA, Duda JL, Motl RW. Sedentary behaviour in people with multiple sclerosis: Is it time to stand up against MS? *Mult Scler.* 2016;22(10):1250-6. doi: 10.1177/1352458516644340.
43. Kwakkel G, Lannin NA, Borschmann K, et al. Standardized measurement of sensorimotor recovery in stroke trials: Consensus-based core recommendations from the Stroke Recovery and Rehabilitation Roundtable. *Int J Stroke.* 2017;12(5):451-461. doi: 10.1177/174749301711813.
44. Ali M, English C, Bernhardt J, Sunnerhagen KS, Brady M. VISTA-Rehab Collaboration. More outcomes than trials: a call for consistent data collection across stroke rehabilitation trials. *Int J Stroke.* 2013;8(1):18-24. doi: 10.1111/j.1747-4949.2012.00973.x.

45. Prince SA, Saunders TJ, Gresty K, Reid RD. 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. *Obes Rev.* 2014;15(11):905-19. doi: 10.1111/obr.12215.
46. Martin A, Fitzsimons C, Jepson R, et al. Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis. EuroFIT consortium. *Br J Sports Med.* 2015;49(16):1056-63. doi: 10.1136/bjsports-2014-094524.
47. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil.* 2017;39(25):2551-2558. doi: 10.1080/09638288.2016.1239764.
48. Fanchamps MHJ, van den Berg-Emons HJG, Stam HJ, Bussmann JBJ. Sedentary behaviour: Different types of operationalization influence outcome measures. *Gait Posture.* 2017;54:188-193. doi: 10.1016/j.gaitpost.2017.02.025.
49. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behaviour. *Med Sci Sports Exerc.* 2011;43(8):1561-7. doi: 10.1249/MSS.0b013e31820ce174.
50. Jones TM, Dear BF, Hush JM, Titov N, Dean CM. 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. *Phys Ther.* 2016;96(12):1982-1993.
51. Mahendran N, Kuys SS, Brauer SG. Recovery of ambulation activity across the first six months post-stroke. *Gait Posture.* 2016;49:271-6. doi: 10.1016/j.gaitpost.2016.06.038.

Appendix 1. Sleep / Non-wear time identification algorithm

Objective

Identify the single daily longest period of sleep / non-wear activity in order to delineate what is considered as wake period.

Methods

The simple prescription given by Elisabeth Winkler et al. (Winkler et al. (2016)) was used as a starting point.

Recorded data consists of activPAL timestamped events, typified as *sitting/lying*, *standing* and *walking*. Events represent the longest continuous uninterrupted activity of each class. There is one event per step.

It was observed during initial implementation of Winkler's prescription that sleep period patterns for this cohort exhibit a more interrupted pattern, requiring a more flexible approach to correctly identify periods. The algorithm was modified as shown below.

Pseudocode:

Definitions

- **SL:** sleep period. A sleep period consists of a "chain" of "nearby" events, primarily of class *lying*, that accounts for the longest aggregated resting period in a 24hr interval. The meaning of "chain" and "nearby" is made precise through the pseudocode. A sleep period is defined by its start and end times, which must be start and end times of *lying*-class events, and all events encompassed in between. duration(SL) is the total accumulated time in *lying* events in **SL**.
- **e1, e2** represent generic *lying* events. A *lying* event carries an "aggregation opportunity window" of length of 12 minutes + 10% of event duration, capped at 45 minutes. Longer events have longer opportunity windows to be aggregated into the sleep event chain. The opportunity window of a *lying* event is denoted below as opp.window(e).
- **Ev** is the list of all events in a 24hr interval for an individual, from noon to noon next day.
- **LEv** is the list of *lying* events longer than 30 minutes in **Ev**, to be considered for aggregation in the sleep period ("long lying events")
- **Tlev** is the total time accumulated in long lying events in the day. Used in considering an alternative *chain* of *lying* events for the sleep period.

Algorithm

Note: how to read pseudocode. A simplified pseudocode of the algorithm is shown below. while and for each imply a loop, if imply testing a condition; the level of indentation indicates the actions included in the repeating part of the loop or the true outcome of the test. For clarity, abnormal termination conditions are excluded from the algorithm below.

```

Input: Ev
Output: SL

LEv = get lying events longer than 30 minutes from Ev
Tlev = sum of event duration for events in LEv
e1 = find longest event in LEv

A:
initialise sleep chain SL with e1
mark e1 as used
while there are unused events in LEv and SL modified since last pass
  for each unused event e2 in LEv, in descending duration order
    if opp.window(e2) overlaps SL
      add e2 to SL
      mark e2 as used
    endif
  endfor
endwhile

if duration(SL) < 0.4 Tlev and there are unused events in LEv
  e1 = find longest unused event from LEv
  mark all events in LEv as unused
  mark e1 as used
  restart from A:
endif

```

Running environment

```

## R version 3.3.3 (2017-03-06)
## Platform: x86_64-redhat-linux-gnu (64-bit)
## Running under: Fedora 25 (Workstation Edition)
##
## locale:
##  [1] LC_CTYPE=en_AU.UTF-8      LC_NUMERIC=C
##  [3] LC_TIME=en_AU.UTF-8      LC_COLLATE=en_AU.UTF-8
##  [5] LC_MONETARY=en_AU.UTF-8  LC_MESSAGES=en_AU.UTF-8
##  [7] LC_PAPER=en_AU.UTF-8     LC_NAME=C
##  [9] LC_ADDRESS=C             LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_AU.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods   base
##
## other attached packages:
## [1] lubridate_1.6.0 chron_2.3-50
##
## loaded via a namespace (and not attached):
## [1] backports_1.0.5 magrittr_1.5   rprojroot_1.2  tools_3.3.3
## [5] htmltools_0.3.5 yaml_2.1.14    Rcpp_0.12.10   stringi_1.1.5
## [9] rmarkdown_1.5  knitr_1.15.1  stringr_1.2.0  digest_0.6.12
## [13] evaluate_0.10

```

References

1. Grolemund, Garrett, and Hadley Wickham. 2011. "Dates and Times Made Easy with lubridate." *Journal of Statistical Software* 40 (3): 1–25. <http://www.jstatsoft.org/v40/i03/>.
2. James, David, and Kurt Hornik. 2017. *Chron: Chronological Objects Which Can Handle Dates and Times*. <https://CRAN.R-project.org/package=chron>.
3. R Core Team. 2017. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>.
4. Winkler, Elisabeth A. H., Danielle H. Bodicoat, Genevieve N. Healy, Kishan Bakrania, Thomas Yates, Neville Owen, David W. Dunstan, and Charlotte L. Edwardson. 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. doi:10.1088/0967-3334/37/10/1653.

Supplementary Material 1

Box 1. Conversion method per variable

Demographics
Age
In years
Sex
Male/female
Education attainment
3 categories: no high school, high school, college degree
Living status
Dichotomized to living alone/living with someone
Personal factors
Body Mass Index
If BMI was not reported it was calculated from height and weight data were available
Smoking
Dichotomized to yes/no, previous smokers were classified as non-smokers.
Comorbidities
Categorized in 3 categories; 0, 1 or ≥ 2 comorbidities
Stroke related factors
Type of stroke
Infarct/hemorrhage/both
Time since stroke
If not recorded this was calculated based on date of stroke and date of assessment; all data were converted to months.
Stroke severity
NIHSS

Walking ability

Walking speed

Five and ten meter walk test converted to meters per second

Walking capacity (distance)

Six minute walk test, meters

Use of walking aids

Yes/No

Physical ability

Independence in activities of daily living

FIM, NEADL, MRS, EQoL or via study specific questions. Dichotomized to independent/not independent in ADLs¹**Cognition and mood**

Cognitive ability

MMSE or the MoCA. Scores dichotomized to either cognitive impaired or not cognitive impaired based on published cut-off scores¹. Cognitive impaired was scored if MMSE ≤ 23 or MoCA ≤ 25 ¹

Fatigue

CIS-f the FSS or FAS. Dichotomized to either fatigued or not, based on published cut-off scores.

Published cut-off scores were not available for FAS so we used cut-off scores developed via expert consensus. Fatigue was scored if CIS-f ≥ 27 ², FSS ≥ 24 ¹ or FAS ≥ 4

Mood disorder

K10³ and HADS and DHS. Dichotomized to mood disorder yes/no using published cut-off scores.Mood disorder was scored if K10 ≥ 20 , HADS ≥ 8 and DHS ≥ 42 ^{1,3}

Anxiety

HADS A, dichotomized to anxious/not anxious based on published cut-off scores. Anxiety was scored if HADS A ≥ 8 ¹

Depression

HADS D and DHS. Dichotomized to depressed or not based on published cut-off scores. Depression was scored if HADS D ≥ 8 or DHS ≥ 42 ¹

MMSE=Mini Mental State examination, MoCA=Montreal Cognitive Assessment, FIM=Functional Independence measure, ADL=Activities of Daily Living, NEADL=Nottingham Extended Activities of Daily Living, MRS=Modified Ranking Scale, EQoL=Euro Quality of Life, NIHSS= National Institutes of Health Stroke Scale, CIS-f= Checklist for individual strength, FSS=Fatigue Severity Scale, FAS=Fatigue Assessment Scale, K10=Kessler Psychological Distress Scale, HADS=Hospital Anxiety And Depression Scale, DHS=Depression Happiness Scale.

References:

1. <http://www.rehabmeasures.org>.
2. Vercoulen JHMM, Swanink CMA, Galama JMD, Fennis JFM, van der Meer JWM, Bleijenberg G. Dimensional assessment in chronic fatigue syndrome. *J Psychosom Res* 1994;38:383-392.
3. Andrews, G., Slade, T. Interpreting scores on the Kessler Psychological Distress Scale (k10). *Australian and New Zealand Journal of Public Health*, 25, 494-497 (2001).

Table 1. Overview of variables available within the studies

Study no:	1	2	3	4	5	6	7	8	9			
Variable:										Number of studies	Sample size	Missing within studies
Age	x	x	x	x	x	x	x	x	x	9	274	0
Gender	x	x	x	x	x	x	x	x	x	9	274	0
Educational level	x		x	x						3	52	0
Living arrangements	x	x	x	x		x		x		6	144	0
BMI	x	x	x	x	x		x		x	7	205	27 (13%)
Smoker		x	x					x	x	4	171	6 (4%)
Comorbidities	x	x	x	x						4	147	0
Type of stroke		x	x		x	x		x	x	6	198	6 (3%)
Time since stroke		x	x	x	x	x	x	x	x	8	268	3 (1%)
Stroke severity		x						x	x	3	118	2 (2%)
Walking speed		x	x		x	x	x	x		6	195	6 (3%)
Walking capacity (distance)					x	x	x	x	x	5	149	46 (31%)
Walking aid		x	x	x	x	x	x	x		7	216	4 (2%)
Degree of ADL independence		x	x		x	x		x	x	6	197	4 (2%)
cognitive function		x	x			x		x	x	5	145	37 (26%)
Fatigue		x			x	x	x	x	x	6	192	36 (19%)
Mood disorder				x	x	x	x	x	x	6	194	8 (4%)
Anxiety					x		x	x	x	4	153	3 (2%)
Depression					x	x	x	x	x	5	175	8 (5%)

Study no: 1:Dean, 2:English, 3:Ezeugwu, 4:Jones, 5:Kuys, 6:Mahendran, 7:Paul, 8: Simpson 9:Tieges



CHAPTER 3

An exploration of sedentary behaviour
patterns in community dwelling people
with stroke: a cluster-based analysis.

Wendy Hendrickx
Carlos Riveros
Torunn Askim
Johannes B.J. Bussmann
Michele L. Callisaya
Sebastien F.M. Chastin
Catherine M. Dean
Victor E. Ezeugwu
Taryn M. Jones
Suzanne S. Kuys
Niruthikha Mahendran
Trish J. Manns
Gillian Mead
Sarah A. Moore
Lorna Paul
Martijn F. Pisters
David H. Saunders
Dawn B. Simpson
Zoë Tieges
Olaf Verschuren
Coralie English

ABSTRACT

Background and Purpose: Long periods of daily sedentary time, particularly accumulated in long uninterrupted bouts, are a risk factor for cardiovascular disease. People with stroke are at high risk of recurrent events and prolonged sedentary time may increase this risk. We aimed to explore how people with stroke distribute their periods of sedentary behaviour, which factors influence this distribution, and whether sedentary behaviour clusters can be distinguished?

Methods: Secondary analysis of original accelerometry data from adults with stroke living in the community. We conducted data-driven clustering analyses to identify unique accumulation patterns of sedentary time across participants, followed by multinomial logistical regression to determine the association between the clusters, and the total amount of sedentary time, age, gender, body mass index (BMI), walking speed and wake time.

Results: Participants in the highest quartile of total sedentary time accumulated a significantly higher proportion of their sedentary time in prolonged bouts ($p < 0.001$). Six unique accumulation patterns were identified; all of which were characterized by high sedentary time. Total sedentary time, age, gender, BMI and walking speed were significantly associated with the probability of a person being in a specific accumulation pattern cluster, $p < 0.001$ – $p = 0.002$.

Discussion and Conclusions: Although unique accumulation patterns were identified, there is not just one accumulation pattern for high sedentary time. This suggests that interventions to reduce sedentary time must be individually tailored.

Introduction

High amounts of sedentary time, defined as any waking behaviour characterized by an energy expenditure ≤ 1.5 Metabolic Equivalent of Task while in a sitting, reclining or lying posture,¹⁻³ is a well-known health risk. Both the total time spent sedentary each day and the pattern of accumulation of sedentary time; specifically the time spent in long bouts of uninterrupted sedentary time, are associated with increased cardiovascular disease risk.⁴⁻¹⁰ Two recent large meta-analyses have found an exponentially increased risk of both cardiovascular disease and all-cause mortality in healthy adults when daily sedentary time exceeds 8-9 hours a day, particularly in people with low levels of physical activity.^{11,12} This risk is increased even more when sedentary time is accumulated in prolonged bouts.⁴⁻¹⁰ People with stroke fit this high-risk profile with daily sedentary time exceeding 9 hours/day,¹³⁻¹⁶ accumulated in long bouts¹³⁻¹⁵ and with minimal time spent physically active.¹³⁻¹⁷ The risk of recurrent stroke is up to 40% in the first ten years post onset.¹⁸ Reducing sedentary time is a potential new intervention to reduce recurrent stroke risk.¹⁹ Long bouts of uninterrupted sitting negatively affect blood pressure and glycaemic control^{4-10,20}, both of which are important risk factors for recurrent stroke.^{21,22} However, preliminary data from one study suggests that interrupting prolonged sedentary bouts with frequent, short breaks of light intensity physical activity reduces blood pressure in people with stroke.²³

Understanding how individuals with stroke accumulate sedentary time is a fundamental step in designing effective interventions to reduce sedentary time. At the time this analysis was planned there was only one published study examining accumulation patterns of sedentary time in people with stroke.¹⁴ The results suggested that people with stroke accumulated most of their sedentary time during the afternoon and evening,¹⁴ but the study did not explore the amount, duration and distribution of sedentary bouts across the day, or individual differences in accumulation patterns. Therefore, the objective of this study was to explore whether there are differences in the patterns in which people with stroke accumulate sedentary time during waking hours. The specific research questions were;

1. Do people with stroke with the highest quartile of total sedentary time accumulate more of their sedentary time in long bouts, compared with people in the lowest quartile?
2. Are there distinctly different patterns of accumulating sedentary time in people with stroke?
3. Do these unique accumulation patterns differ by total sedentary time?
4. Do these unique accumulation patterns differ by demographic or stroke-related variables?

Method

Design

Secondary analysis of original accelerometer data from 9 primary studies involving n=274 participants, from 3 different countries. These were either observational or intervention studies; from the latter we only baseline data was used. Additional information on the included studies and full methods for pooling and harmonization of data are described elsewhere.²⁴ This study was approved by the Human Research Ethics Committee of The University of Newcastle (H-2016-0427).

Participants and data processing

The inclusion criteria for the studies were: 1) adults with stroke who were living in the community, 2) sedentary time was measured using the activPAL monitor (PAL Technologies Ltd, Glasgow, United Kingdom), 3) the ethical approval and informed consent for the data collection permitted inclusion of the data in this study. We included data from the ActivPAL (PAL Technologies Ltd, Glasgow, United Kingdom, from now on referred to as Accelerometer-based Activity Monitor, AAM), a 24 hours/day thigh worn accelerometer which is reliable (0.79-0.99 Interclass correlation coefficient) and valid (accuracy is 98-100%) to determine sedentary behaviour.²⁵⁻²⁷ Lead authors of the primary studies provided the original de-identified participant data, including AAM CSV files, demographic and stroke related variables. All data were combined into one data set for analyses.

To harmonize the AAM data we first determined waking hours using a custom algorithm we developed based on previously published and validated methods.²⁸ The full methods are published elsewhere.²⁴ We then excluded participants who had less than 3 days of at least 8 hours/day (waking hours) of AAM data, as this has been determined as the minimum data required for accurate measurement of habitual movement behaviour.²⁹ In the cases where different outcome measures were used for a stroke related or demographic variable, we used validated methods to dichotomize or categorize data – for example into ‘independent in Activities of Daily Living (ADL)’ or not. More details on the processing and harmonization of AAM data and outcome variables can be found elsewhere.²⁴

Analyses

First, we identified how much of the total wake time spent sedentary was accumulated in prolonged bouts. To adjust for different amounts of waking hours we used the percentage of waking hours spent sedentary and spent in prolonged sedentary bouts of over 30 or 60 minutes.^{8,10,30,31} Participants with the highest and lowest amounts of sedentary time were identified based on quartiles of total sedentary time data. We used independent t-tests (or Mann-Whitney U tests where data were not normally distributed), to examine differences

in the proportion of sedentary time accumulated in >30 and >60-minute bouts between participants in the highest and lowest quartiles of sedentary time. Alpha was set at 0.05, with Bonferoni correction for multiple testing at 0.025.

To determine unique patterns of accumulating sedentary time using the AAM data, we used a 'symbolic time series representation' method.^{32,33} The AAM records movement data as events of type: 0 = lying / sitting (sedentary activity), 1 = standing, and 2 = walking. Event (movement) data were summarized into fixed duration intervals with each interval represented by a letter (t: sedentary, s: standing, w: walking) according to the event type with the most accumulated time in the interval. For example, an interval of 60 seconds with 30 seconds of sedentary time, 15 seconds of standing and 15 seconds of walking would be classified as 't'(sedentary). A letter can represent any predetermined time interval > 15 seconds. Consecutive intervals were then combined to form a linear sequence of letters or a 'word' which represents the pattern of movement during that time period (*P*). The periods thus consist of multiples of intervals of at least 15 seconds. For example, a movement period (*P*) of 15 minutes with 1-minute intervals (*I*) (*P*15/*I*) would consist of 15 separate letters. For instance; 1 minute of standing, 2 minutes sedentary, 3 minutes walking, another 1 minute sedentary, then 8 minutes standing, would be represented by: 'sttwwwtssssssss'. Movement patterns were formed by a sliding window of a fixed number of intervals (letters) see Figure 1. This method involves moving one interval (letter) at a time across the entire wake time, and then aggregating movement patterns. This method was chosen so as not to predetermine the pattern due to the chosen interval.^{32,33}

sttwwwtssssssss ssssswwwtttttt w

s ttwwwtssssssss ssssswwwttttttw

Figure 1. Symbolic time series representation with sliding window

Our aim was to determine the optimal movement period (*P*) and interval (*I*) that created the most clearly defined clusters. To do this we ran iterative analyses with varying interval (letter) durations of 5, 10, 30, and 60 seconds, and period durations of 6, 12 and 30 intervals. This provided descriptions of movement patterns in period durations ranging from 30 seconds to half an hour. The final interval and period combination was chosen as the one that led to the most clearly defined clusters, and the lowest residuals in the co-variable modelling analyses (described below).

Determining and defining clusters

Based on the movement accumulation patterns of each participant (as described above), clusters were identified based on Euclidean distance metrics on the normalized activity pattern count, using hierarchical clustering with dynamic cuts. A standard dendrogram was generated, and then cut to obtain the clusters with the Hybrid Dynamic Tree Cut method of Langfelder, Zahng and Horvath.³⁴ We then used multinomial logistic regression with *cluster* as the outcome to determine which variables were associated with the probability of an individual participant belonging to a particular cluster. We included all independent variables available across datasets that had no missing values in them; these were age, gender, BMI and walking speed. To determine the period (*P*) and interval (*I*) combination that was most meaningful, the residual deviance of all the models was determined, the lowest showing the best fit. All analyses were conducted with R statistical software, version 3.3.3 and IBM SPSS statistics version 22.

Results

Data from 274 people with stroke were included in the analyses. The mean age was 66 (SD 13) years, 167 (61%) were male and mean time since stroke was 18 (SD 29) months (see Table 1).

Table 1. Participant characteristics

Characteristic	n participants (n studies)	Mean (SD) or n (%)
Age (yr),	274 (9)	66 (13)
Gender, number female	274 (9)	107 (39)
Time since stroke (mth)	268 (8)	18 (29)
BMI (kg/m ²),	205 (7)	27 (5.5)
Walking speed (m/s),	195 (6)	0.9 (0.4)
Living alone, number yes	144 (6)	38 (26%)
Independent in ADL, number yes	197 (6)	153 (88%)

Abbreviations: BMI, body mass index; ADL, Activities of Daily Living

Across the whole data set participants spent on average 69 (SD12)% of waking hours sedentary; 56 (SD15)% of sedentary time during waking hours was accumulated in bouts >30 minutes and 32 (SD 17)% in bouts >60 minutes (Table 2). Participants in the highest quartile of total sedentary time (>79% waking hours) accumulated a significantly higher proportion of their sedentary time in >60 and >30 min bouts compared to the participants in the lowest quartile of total sedentary time (<61% waking hours, mean difference >60 min bouts 27% [95% CI 23 to 32], mean difference >30 min bouts 26% [95% CI 22 to 30]), (Table 2).

Table 2. Differences in bout duration, expressed as percentage of waking hours. Values are means (SD) for groups and mean (95% confidence interval) for differences between groups.

Bouts	Whole sample (n=274)	Groups		Difference between groups
		Highest quartile sitting time (n=68)	Lowest quartile sitting time (n=68)	
>30 min	56% (15)	69% (11)	44% (13)	26% (22 to 30)
>60 min	31% (17)	47% (16)	20% (12)	27% (23 to 32)

P<0.001 for all between group differences

Six unique clusters of accumulation pattern were identified across the whole dataset by the dendrogram (Figure 2) and the dotplot (Figure 3). The window period duration of 12 letters and sampling interval of 30 seconds (6 minutes total duration) created the most meaningful clusters with the lowest residuals (residual deviance 168.2). For ease of description we have labelled and named the clusters according to the relative amount of sedentary time and bout durations (either prolonged bout duration or breaking bout duration) (Table 3).

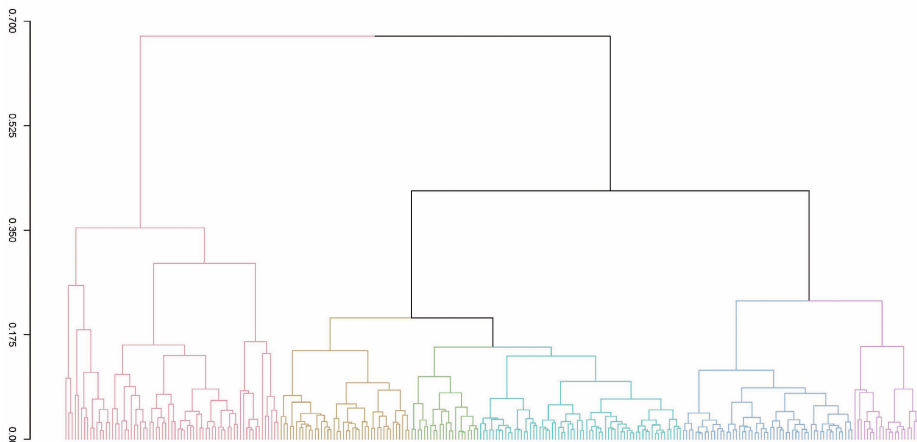


Figure 2. Dendrogram hierarchical clustering

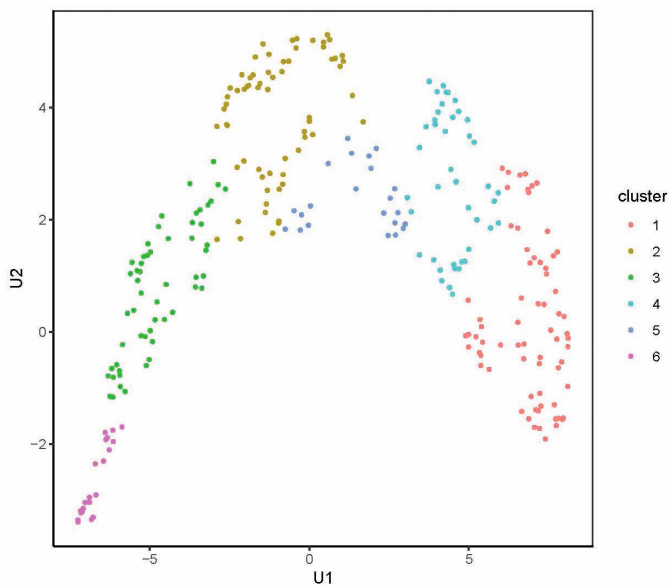


Figure 3. Dotplot clusters hierarchical clustering g

Table 3. Characteristics of clusters

	High sedentary prolongers (n=21)	High sedentary breakers (1) (n=55)	High sedentary breakers (2) (n=65)	Medium sedentary breakers (1) (n=22)	Medium sedentary breakers (2) (n=42)	Low sedentary breakers (n=69)
Gender, number female (%)	10 (48) ^{a,-}	18 (33) ^{a,*}	25 (38) ^{b,*}	8 (36) ^{a,-}	15 (36) ^{a,+}	31 (45)
Age (yr), mean (SD)	69 (11) ^{a,+}	67 (14) ^{a,+}	65 (13) ^{a,+}	69 (14) ^{a,+}	69 (14) ^{a,+}	64 (13)
BMI (kg/m ²) mean (SD)	30.1 (5.3) ^{a,+}	27.3 (6.5) ^{a,-}	28.1 (5.1) ^{b,-}	29.3 (6.9) ^{a,+}	25.4 (3.6) ^{a,*}	26.2 (5.0)
Walking speed (m/s) mean (SD)	0.6 (0.4) ^{b,-}	0.8 (0.3) ^{a,+}	0.9 (0.4) ^{a,+}	0.9 (0.4) ^{b,-}	1.1 (0.4) ^{b,+}	1.1 (0.5)
Wake time (hr) mean (SD)	14 (2) ^{a,+}	13 (1) ^{a,-}	14 (2)	14 (1)	14 (2)	15 (1)
Total sitting time (% waking hr) mean (SD)	86 (3) ^{a,+}	81 (3) ^{a,+}	74 (4) ^{b,+}	68 (4) ^{a,+}	64 (5) ^{a,+}	53 (8)
Sedentary bout duration (min) mean (SD) ^b	37 (5)	19 (8)	16 (11)	16 (6)	13 (6)	10 (5)
Total standing time (% waking hr) mean (SD) ^b	11(4)	14 (3)	19 (3)	26 (3)	26 (6)	35 (8)

^a Significant association with the probability to belong to this cluster in comparison to the reference cluster 'Low sedentary breakers', multinomial logistic regression, $p < 0.05$.

^{+/,-} Shows the direction of the probability change, i.e. the direction of the regression coefficient.

^b Not included in the multinomial logistic regression.

High sedentary prolongers on average had the highest proportion of waking hours spent sedentary (86%) and longest bout duration (37 min). We labelled 2 clusters as *high sedentary breakers* as they both had high proportions of waking hours spent sedentary (81% and 74% of waking hours spent sedentary) and frequent bouts of activity (average sedentary bout duration 19- and 16-min, respectively). We labelled 2 clusters as *medium sedentary breakers*, as they both had lower proportions of waking hours spent sedentary (68% and 64%) and frequent bouts of activity (average sedentary bout duration 16- and 13-min, respectively). Finally, we labelled one cluster *low sedentary breakers* as it had the lowest proportion of waking hours spent sedentary (53%) and shortest average sedentary bout duration (10 min) indicating low amounts of prolonged sedentary bouts. In other words, the *high sedentary prolongers* accumulated the highest amount of sedentary time, mostly in long, uninterrupted bouts duration. The *high sedentary breakers* also accumulated high amounts of sedentary time, but in shorter bouts. The average walking speed was slowest in the *high sedentary prolongers* cluster.

The multinomial logistic regression estimates the probability for an individual to belong to each of the 6 clusters characterized above, given the values of the predictor variables. Total sedentary time was significantly associated with the probability of an individual being in a specific cluster ($p < 0.001$). Age, gender, body mass index (BMI) and walking speed were significantly associated with the probability of a person being in a specific cluster ($p < 0.001 - 0.002$) but wake time duration was not ($p < 0.001 - 0.961$).

Compared with the *low sedentary breakers* reference cluster, higher sedentary time was associated with a higher probability of participants being in either the *high sedentary prolongers* or the *high sedentary breakers* clusters. Participants with lower walking speed were more likely to be in the *high sedentary prolongers* or the *medium sedentary breakers* clusters, and those of younger age were more likely to be in the *low sedentary breakers* cluster (Table 3).

Discussion

The results of this study show that people with stroke with the highest amount of total sedentary time accumulate most of their sitting time in prolonged bouts. We identified 6 distinct patterns of accumulation of sedentary time which differed by total daily sedentary time, average bout duration and participants' walking speed. We found a wide variability in total sedentary time and average bout duration across the clusters and there was not one unique cluster for people with high sedentary time.

Our finding that people with stroke with the highest amount of total sedentary time accumulate this time in prolonged bouts suggest that '*high sedentary prolongers*' may have the most to gain from interventions to reduce sedentary time. Two large meta-analyses have shown exponential increases in both cardiovascular and all-cause mortality related to daily sedentary time of 9 hours or more.^{11,12} These risk curves suggest that even small reductions in daily sedentary time could lead to substantial reduction in disease risk – but this remains to be tested in clinical trials. There is also evidence that interrupting sitting time with frequent, short bouts of physical activity can have immediate beneficial physiological effects such as reductions in blood pressure and improvements in glucose control in a range of populations,³⁵ including stroke.²³ However, whether or not people with stroke are able to increase their frequent bouts of physical activity in order to break up sedentary time in the long-term, and whether this has an effect on reducing stroke risk has not yet been tested.

While we found 6 distinct clusters of patterns of accumulation of sedentary time, they varied less than we expected in total sedentary time. Three clusters (*high sedentary time prolongers* and *high sedentary time breakers* [1] and [2]) included an average of 74 to 86% of waking hours spent sedentary. This means that though there are similarities in the unique movement patterns of people with higher or lower amounts of sedentary time there is not one distinct pattern for each of them. We found that older age, higher BMI and slower walking speed were related to a higher probability of being in a cluster defined by high total sedentary time and long sedentary bout duration. This is largely in agreement with our previous work²⁴ and that of others.^{15,36} While this might indicate that these people are more likely to spend long periods of the day in uninterrupted sitting time, it is unlikely that we could be able to predict high sitting time using these variables. Instead, clinicians should first assess an individual's daily sedentary time, preferably using objective accelerometer-based measures, then provide individualized interventions to reduce sedentary time.

To date, only 2 trials have been published that have tested interventions to encourage people with stroke to reduce or break up their daily sitting time. One small randomised trial showed that people with stroke reduced their daily sitting time (measured by accelerometry) in response to a coaching intervention, but not significantly more than the attention-matched control group.³⁷ Another small, non-controlled trial also found reductions in sedentary time in response to a coaching intervention.³⁸ Both of these trials were designed to test safety and feasibility and were not powered to test efficacy. Further work is needed to carefully design and test interventions to reduce sedentary time in people with stroke, since they are more sedentary than their healthy peers.^{13,16} Our results suggest that these interventions should target the *high sedentary prolongers*

and *high sedentary breakers* groups in particular (these groups constituted 51% of our sample). Interventions should focus on both reducing sedentary time and interrupting long sedentary bouts. Furthermore, while our results provide some information about characteristics of these groups, the similarities between groups are more striking than the differences. For example, obese (average BMI 30.1 kg/m²) stroke survivors with very slow walking speed (average 0.6 m/s) are more likely to be *high sedentary prolongers*. However, those who are near-normal BMI or overweight (average BMI 25.4 to 29.3 kg/m²) with near-normal walking speeds (0.8 to 1.1 m/s) may also be spending large amounts of their day sedentary (64-81% waking hours). The take-home message from these results is that all people after stroke should have their sedentary and activity time objectively measured to determine their level of risk. Our group is using results from this and other^{15,24} studies we have completed to design an intervention to reduce sedentary time after stroke.

Limitations

Our sample consisted primarily of older adults more than 6 months post-stroke who were independent in activities of daily living and walked with near-normal speed (average walking speed 0.9 (0.4) m/s). Around 26% of included participants lived alone. We only included participants for whom we had at least 3 days of valid activity monitor data, so we can be confident our data are representative of usual activity levels in this group. This method of using a pooled dataset allowed us to use a data-driven method of clustering analyses to determine unique patterns of the accumulation of sedentary time. It is important to note that this was exploratory analyses from 9 original primary studies. Our sample size was large (n=274) and came from 3 different countries, increasing the generalisability of our findings. However, we did not have any participant data from low to middle income countries. The three countries where the studies were conducted were Australia, the United Kingdom and Canada. While there may be some differences across countries in terms of environmental and cultural drivers of physical activity, we do not expect these to be of significant influence on the results. We checked this in our previous analyses (by using 'study' as an independent variable).²⁴ The data-driven method of determining clusters of sedentary time patterns minimizes the influence of researcher bias, but means that the clusters found were difficult to clearly define.

Conclusion

In conclusion this study shows that people with high total sedentary time also accumulate this time in prolonged, uninterrupted bouts. Although unique accumulation pattern clusters were identified, high sedentary time was a feature for many of them. Individual assessment and tailoring of interventions to reduce sedentary time is required.

References

1. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behaviour Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act.* 2017;14(1):75. doi:10.1186/s12966-017-0525-8
2. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev.* 2008;36(4):173-178. doi:10.1097/JES.0b013e3181877d1a
3. Sedentary Behaviour Research Network. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". *Appl Physiol Nutr Metab.* 2012;37(3):540-542. doi:10.1139/h2012-024
4. van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med.* 2012;172(6):494-500. doi:10.1001/archinternmed.2011.2174
5. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behaviour. *Exerc Sport Sci Rev.* 2010;38(3):105-113. doi:10.1097/JES.0b013e3181e373a2
6. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol.* 2012;41(5):1338-1353. doi:10.1093/ije/dys078
7. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med.* 2015;162(2):123-132. doi:10.7326/M14-1651
8. Dunstan DW, Howard B, Healy GN, Owen N. Too much sitting--a health hazard. *Diabetes Res Clin Pract.* 2012;97(3):368-376. doi:10.1016/j.diabres.2012.05.020
9. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab.* 2010;35(6):725-740. doi:10.1139/H10-079
10. Bauman AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep.* 2013;7(4):293-298. doi:10.1007/s12170-013-0316-y
11. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet.* 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
12. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ.* 2019;366:l4570. doi:10.1136/bmj.l4570
13. English C, Healy GN, Coates A, Lewis LK, Olds T, Bernhardt J. Sitting time and physical activity after stroke: physical ability is only part of the story. *Top Stroke Rehabil.* 2016;23(1):36-42. doi:10.1179/1945511915Y.0000000009
14. Tieges Z, Mead G, Allerhand M, et al. Sedentary behaviour in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil.* 2015;96(1):15-23. doi:10.1016/j.apmr.2014.08.015

15. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behaviour Patterns in People With First-Ever Stroke. *Stroke*. 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
16. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil*. 2016;38(4):362-367. doi:10.3109/09638288.2015.1041615
17. Fini NA, Holland AE, Keating J, Simek J, Bernhardt J. How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis. *Phys Ther*. 2017;97(7):707-717. doi:10.1093/ptj/pzx038
18. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
19. Morton S, Fitzsimons C, Hall J, et al. Sedentary behaviour after stroke: A new target for therapeutic intervention. *Int J Stroke*. 2019;14(1):9-11. doi:10.1177/1747493018784505
20. Lee PH, Wong FKY. The association between time spent in sedentary behaviours and blood pressure: a systematic review and meta-analysis. *Sports Med*. 2015;45(6):867-880. doi:10.1007/s40279-015-0322-y
21. Sacco RL, Benjamin EJ, Broderick JP, et al. American Heart Association Prevention Conference. IV. Prevention and Rehabilitation of Stroke. Risk factors. *Stroke*. 1997;28(7):1507-1517. <http://www.ncbi.nlm.nih.gov/pubmed/9227708>. Accessed July 18, 2018.
22. Fonville S, Zandbergen AAM, Koudstaal PJ, Den Hertog HM. Prediabetes in patients with stroke or transient ischemic attack: Prevalence, risk and clinical management. *Cerebrovasc Dis*. 2014;37(6):393-400. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L53227258>.
23. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: Breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke*. 2018;13(9):932-940. doi:10.1177/1747493018798535
24. Hendrickx W, Riveros C, Askim T, et al. Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies. *Top Stroke Rehabil*. 2019;26(5):327-334. doi:10.1080/10749357.2019.1601419
25. Taraldsen K, Askim T, Sletvold O, et al. Evaluation of a body-worn sensor system to measure physical activity in older people with impaired function. *Phys Ther*. 2011;91(2):277-285. doi:10.2522/ptj.20100159
26. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc*. 2012;44(11):2243-2252. doi:10.1249/MSS.0b013e318260c477
27. Godfrey A, Culhane KM, Lyons GM. Comparison of the performance of the activPAL Professional physical activity logger to a discrete accelerometer-based activity monitor. *Med Eng Phys*. 2007;29(8):930-934. doi:10.1016/j.medengphy.2006.10.001
28. Winkler EAH, Bodicoat DH, Healy GN, et al. Identifying adults' valid waking wear time by automated estimation in activPAL data collected with a 24 h wear protocol. *Physiol Meas*. 2016;37(10):1653-1668. doi:10.1088/0967-3334/37/10/1653

29. Tinlin L, Fini N, Bernhardt J, Lewis LK, Olds T, English C. Best practice guidelines for the measurement of physical activity levels in stroke survivors. *Int J Rehabil Res.* 2017;41(1):1. doi:10.1097/MRR.0000000000000253
30. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J.* 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
31. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. *Phys Ther.* 2016;96(2):193-201. doi:10.2522/ptj.20140522
32. Senin P, Malinchik S. SAX-VSM: Interpretable Time Series Classification Using SAX and Vector Space Model. In: *2013 IEEE 13th International Conference on Data Mining.* IEEE; 2013:1175-1180. doi:10.1109/ICDM.2013.52
33. Song W, Wang Z, Zhang F, Ye Y, Fan M. Empirical study of symbolic aggregate approximation for time series classification. *Intell Data Anal.* 2017;21(1):135-150. doi:10.3233/IDA-150351
34. Langfelder P, Zhang B, Horvath S. Defining clusters from a hierarchical cluster tree: the Dynamic Tree Cut package for R. *Bioinformatics.* 2008;24(5):719-720. doi:10.1093/bioinformatics/btm563
35. Mackie P, Weerasekara I, Crowfoot G, et al. What is the effect of interrupting prolonged sitting with frequent bouts of physical activity or standing on first or recurrent stroke risk factors? A scoping review. *PLoS One.* 2019;14(6):e0217981. doi:10.1371/journal.pone.0217981
36. Fini NA, Bernhardt J, Holland AE. Low gait speed is associated with low physical activity and high sedentary time following stroke. *Disabil Rehabil.* November 2019:1-8. doi:10.1080/09638288.2019.1691273
37. English C, Healy GN, Olds T, et al. Reducing Sitting Time After Stroke: A Phase II Safety and Feasibility Randomized Controlled Trial. *Arch Phys Med Rehabil.* 2016;97(2):273-280. doi:10.1016/j.apmr.2015.10.094
38. Ezeugwu VE, Manns PJ. The Feasibility and Longitudinal Effects of a Home-Based Sedentary Behaviour Change Intervention After Stroke. *Arch Phys Med Rehabil.* 2018;99(12):2540-2547. doi:10.1016/j.apmr.2018.06.014



CHAPTER 4

General lifestyle interventions on their own seem insufficient to improve the level of physical activity after stroke or TIA: a systematic review.

Wendy Hendrickx
Lara Vlietstra
Karin Valkenet
Roderick Wondergem
Cindy Veenhof
Coralie English
Martijn F. Pisters

Abstract

Background: Insufficient amounts of physical activity is a risk factor for (recurrent) stroke. People with a stroke or transient ischemic attack (TIA) have a high risk of recurrent stroke and have lower levels of physical activity than their healthy peers. Though several reviews have looked at the effects of lifestyle interventions on a number of risk factors of recurrent stroke, the effectiveness of these interventions to increase the amounts of physical activity performed by people with stroke or TIA are still unclear. Therefore, the research question of this study was: what is the effect of lifestyle interventions on the level of physical activity performed by people with stroke or TIA?

Method: A systematic review was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. Pubmed, Embase and Cumulative Index for Nursing and Allied Health Literature (CINAHL), were searched up to August 2018. Randomised controlled trials that compared lifestyle interventions, aimed to increase the amount of physical activity completed by participants with a stroke or TIA, with controls were included. The Physiotherapy Evidence Database (PEDro) score was used to assess the quality of the articles, and the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) method for the best evidence synthesis.

Results: Eleven trials (n=2403) met the inclusion criteria. The quality of the trials was mostly high, with 8 (73%) of trials scoring ≥ 6 on the PEDro scale. The overall best evidence syntheses showed moderate quality evidence that lifestyle interventions do not lead to significant improvements in the physical activity level of people with stroke or TIA. There is low quality evidence that lifestyle interventions that specifically target physical activity are effective at improving the levels of physical activity of people with stroke or TIA.

Conclusion: Based on the results of this review, general lifestyle interventions on their own seem insufficient in improving physical activity levels after stroke or TIA. Lifestyle interventions that specifically encourage increasing physical activity may be more effective. Further properly powered trials using objective physical activity measures are needed to determine the effectiveness of such interventions.

Registration: PROSPERO, CRD42018094437.

Background

Cardiovascular disease is the leading cause of death and disability globally.¹ Cerebrovascular diseases, including stroke and transient ischemic attack (TIA), account for 34% of cardiovascular disease in males and 37% in females.¹ This equates to approximately 15 million people worldwide having a stroke or TIA each year.¹ Due to improvements in acute stroke treatment, survival rates are improving in several parts of the world.¹ However, people who have had a stroke or TIA are at high risk (40% in 10 years) of having a recurrent stroke.^{2,3} Therefore, secondary prevention is vital.

Insufficient levels of physical activity is one of the strongest modifiable risk factors of stroke and recurrent stroke.^{1,4,5} The World Health Organisation, the American Heart Association and the American Stroke Association recommend 150 minutes per week of moderate-intensity aerobic activity or 75 minutes per week of vigorous aerobic activity, or a combination of both, preferably spread throughout the week and preferably performed in bouts of at least 10 minutes duration.⁶⁻⁸ However, recent studies have shown that the levels of physical activity performed by people with a stroke or TIA do not meet these recommendations and are low compared to the physical activity levels of healthy peers.⁹⁻¹¹ Thus, it appears that people with stroke and TIA require additional interventions to support them to improve their level of physical activity.

Several multimodal lifestyle interventions have been developed, incorporating educational, motivational and other psychosocial components with the aim to support behaviour change to reduce risk factors of recurrent stroke, including improving physical activity levels for people after stroke or TIA. Since improving physical activity is recommended in Stroke Clinical Guidelines internationally,¹²⁻¹⁵ it is important to know if these lifestyle interventions are effective in order to guide clinical practice. Three earlier similar reviews have been conducted. The first review only included trials published up to 2009,¹⁶ and found insufficient evidence to determine the effects of lifestyle interventions on the levels of physical activity. The second review was also inconclusive,¹⁷ both recommend further high quality research.^{16,17} The most recent review,¹⁸ including trials published up to May 2015, concluded that a meta-analysis on physical activity was not possible due to diversity in the outcome measures used.¹⁸ A best evidence synthesis including comparison of the intervention effect to controls and weighing the quality of the included trials was not conducted nor was an effect estimate of the interventions provided.¹⁸ It remains unclear if lifestyle interventions are effective in improving the levels of physical activity performed by people with stroke or TIA. Furthermore, the need to include strategies that specifically focus on the levels of physical activity, e.g. supervised exercise, is unclear. A review specifically examining the effects of lifestyle interventions on physical activity after

stroke is needed to support physiotherapists' clinical practice. Therefore, the research question for this systematic review was: What is the effect of lifestyle interventions on the level of physical activity performed by people with stroke or TIA?

Methods

This systematic review was conducted in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,¹⁹ and is registered with the International Prospective Register of Systematic Reviews (PROSPERO; CRD42018094437).

Eligibility criteria

Trials were eligible for inclusion if:

1. the participants were adults with clinically confirmed stroke or TIA;
2. the intervention was a lifestyle or behavioural intervention, defined as an intervention that incorporated educational, motivational and other psychosocial components with the aim to support behaviour change to reduce risk factors of recurrent stroke;
3. the study design was a randomised clinical trial (RCT) where the lifestyle intervention was compared with 'no intervention', 'placebo' and/or 'usual care';
4. at least one outcome measure of physical activity (any form of light physical activity and/or moderate to vigorous physical activity) was reported;
5. the full text article was available in English or Dutch.

Trials defined in the manuscript as a pilot or feasibility trial were excluded because of likely insufficient power to show effect.

Search

Three electronic databases, Pubmed, Embase and CINAHL, were searched up to August 2018. The search strategy was constructed in Pubmed and adapted for CINAHL and Embase, see Supplementary Materials 1, Search Strategy for the search strategy. We also scanned reference lists of relevant previous reviews identified in the initial orientation search and in the systematic search, for any additional relevant citations.^{16–18}

Study selection

All trials identified in the search were first screened by title and abstract, then full-texts reviewed to determine eligibility. The study selection was independently conducted by the 2 authors (WH and LV). Disagreements were resolved by discussion. If no consensus could be reached, a third author (MFP) was consulted.

Data extraction

Data extraction included descriptive data, demographics of study populations, sample sizes, the content of the intervention and the control, duration of the intervention, outcome measures on physical activity, time points of measurement and the study results. Data were extracted by one author (WH) and checked by a second author (LV) with disagreements resolved by discussion. If no consensus could be reached a third author (MFP) was consulted.

Quality Appraisal

The PEDro scale for RCTs and controlled clinical trials was used to determine the methodological quality of the included trials.²⁰ The PEDro scale consists of 11 'yes' or 'no' statements with regards to domains like randomisation, blinding, attrition and reporting of results (see Supplementary Materials 2, Table S1, PEDro scale). Points are only awarded when a criterion is clearly satisfied.²⁰ The highest possible score is 10 points (item 1 is not scored).²⁰ Trials with a total score of 6 or higher are considered to be of high quality.²¹ The quality appraisal was independently completed by 2 authors (WH and LV). The results were compared to see if there were any differences. If so, these were discussed. If no consensus could be reached a third author (MFP) was consulted.

Best evidence synthesis

A meta-analysis was the preferred synthesis method. However, due to heterogeneity of outcome measures in the different trials, this was not possible. Instead, a best evidence synthesis was conducted, based on the available results from the included trials. We used the best evidence synthesis method from the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) Working Group.²²⁻²⁵ This method combines the consistency of the findings with the quality of the included trials. The domains for high quality evidence are:²²⁻²⁵

1. At least 75% of the RCTs with no limitations of study design have consistent findings,
2. Direct data, (this refers generalisability, the extent to which the people, interventions and outcomes in the trials are comparable to those defined in the inclusion criteria of the review)
3. Precise data, (this refers to a sufficient number of participants and events and the width of the confidence intervals)
4. No known or suspected publication biases.

For each domain for 'high quality evidence', that is not met, the level of evidence is downgraded:²²⁻²⁵

- High quality evidence: At least 75% of the RCTs with no limitations of study design have consistent findings, direct and precise data and no known or suspected publication biases;
- Moderate quality evidence: 1 of the above domains is not met;
- Low quality evidence: 2 of the above domains are not met;
- Very low quality evidence: 3 of the above domains are not met.

Effect size of the intervention and subgroup analyses

To determine the effect size of the interventions, the standardized mean difference (SMD), including the 95% confidence intervals, was calculated where possible for the between group differences at follow-up.²⁶ A SMD of ≥ 0.2 was considered a small effect, ≥ 0.5 a moderate effect, and ≥ 0.8 a large effect of exercise therapy as stated by Cohen et al.²⁷ Subgroup analyses were performed based on the content of the intervention, i.e. the inclusion of specific strategies targeting improving the level of physical activity in people with stroke or TIA.

Results

Flow of trials through the review

A total of 8245 articles were identified in the literature search. When duplicates were removed, 7986 articles remained. After screening the titles and abstracts, 35 articles progressed to full text review, of which 11 trials were included (Figure 1, 'PRISMA Flow diagram').

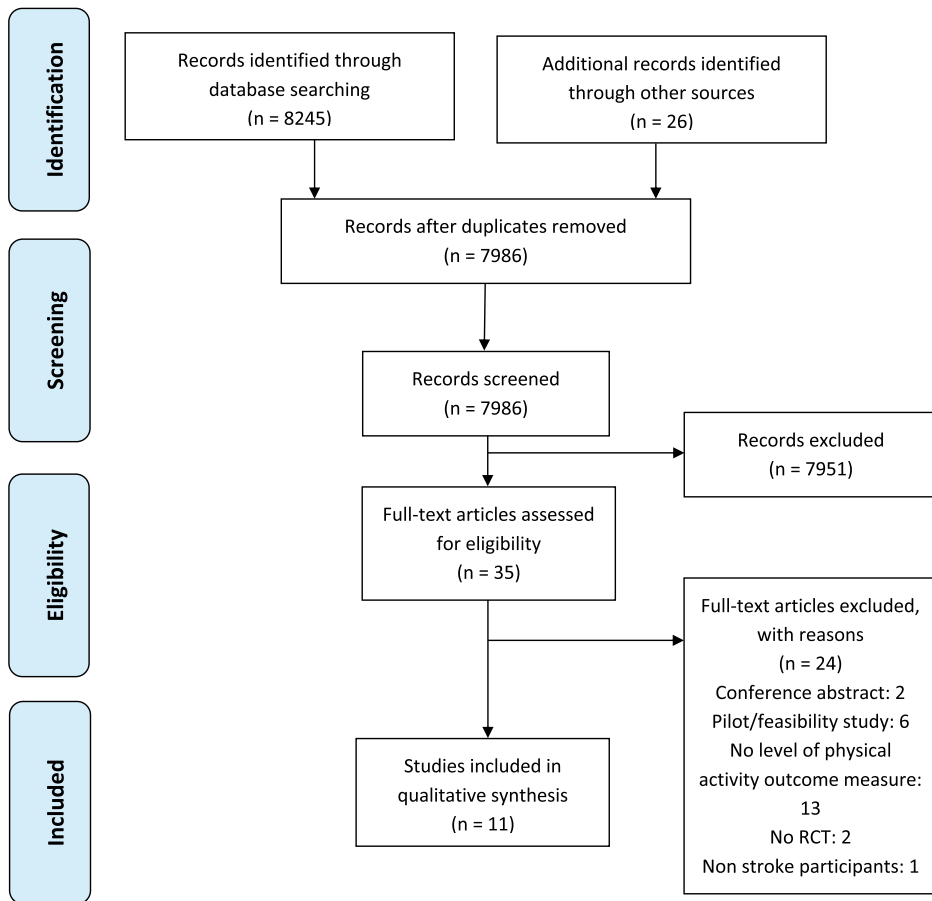


Figure 1 PRISMA Flow diagram, n=number, RCT=Randomised controlled trial.

Characteristics of participants and trials

Characteristics of included trials are reported in Table 1, 'Summary of included trials'. The 11 included trials reported data from n=2403 participants (n=1205 intervention and 1198 control). The mean age ranged from 57 to 72 years. In all trials, stroke or TIA was clinically diagnosed in a hospital,^{28,29,38,30–37} and most had a mild stroke or TIA,^{29–36,38} and enrolled in the trials after returning home.^{28–37} There was a wide range in the sample sizes, ranging from 29 to 283 per trial arm. Most trials (73%) targeted multiple risk factors without a specific focus on improving the levels of physical activity.^{28–30,32,33,35–37} Three trials (27%) specifically targeted improving physical activity.^{31,34,38}

Table 1. Summary of included trials

Study	Participants Age, y ^a mean (SD or range) or median (IQR, IQR) Sex, n male	Intervention		Frequency and duration of interventions	Outcome measures
		Content	Discipline delivering the intervention mode of delivery		
Kono et al. ³⁸ (2013)	Time since stroke unknown Exp: n = 35 Age 64 (7) Sex 21 M Con: n = 35 Age 63 (11) Sex 27 M	Exp: physical activity coaching + supervised exercise + home exercise program + a salt intake reduction e-learning program Con: 3 sessions advice to facilitate healthy lifestyle	Exp: health care professional interventionist, physiotherapist Face-to-face Con: health care professional interventionist Face-to-face	Exp: 3/wk for 24 wk Con: 3 sessions in 24 wk	Steps/day (accelerometer) Time in high, moderate and light intensity physical activity min/day (accelerometer)
Gillham et al. ³³ (2010)	Time since stroke or TIA unknown Exp: n = 26 Age 68 (12) Sex 4 M Con: n = 26 Age 69 (13) Sex 4 M	Exp: secondary prevention education + general lifestyle counselling using motivation interviewing Con: usual care, no additional support or information given unless requested by the patient	Exp: not reported Face-to-face and phone	Exp: 3 sessions over 6 wk Con: usual care	Self-reported exercise frequency (n of 20-min sessions/wk)
Joubert et al. ³³ (2009)	Time since stroke or TIA unknown Exp: n = 91 Age 63 (14) Sex 53 M Con: n = 95 Age 68 (13) Sex 49 M	Exp: secondary prevention education + general lifestyle counselling (protocolled according to ICARUSS model), Con: usual care	Exp: general practitioner, researcher Face-to-face and phone	Exp: frequency not specified over 12 mth Con: usual care	Self-reported exercise frequency (n of 'deliberate' walks/wk)

Table 1. Summary of included trials (*continued*)

Study	Participants Age, yr ^a mean (SD or range) or median (IQR, IQR) Sex, n male	Intervention		Frequency and duration of interventions	Outcome measures
		Content	Discipline delivering the intervention mode of delivery		
Adie et al ³⁰ (2010)	Time since stroke or TIA <1 months at recruitment Exp: n = 29 Age 73 (54-90) Sex NR Con: n = 27 Age 73 (54-90) Sex NR	Exp: usual care + secondary prevention education + lifestyle counselling using the TFU method, including motivational interviewing Provided by: Con: usual care	Exp: not reported Phone	Exp: at 7–10 days, 1, 2 and 4 months; 4 over 4 mth Con: usual care	Self-reported exercise min/ wk
Fleming et al ²⁸ (2013)	Time since stroke or TIA unknown Exp: n = 20 Age 70 (13) Sex 10 M Con: n = 21 Age 71 (9) Sex 14 M	Exp: secondary prevention education + lifestyle counselling using motivational interviewing + secondary prevention education to primary care physician Con: usual care	Exp: nurse with assistance of a research physician and an exercise physiologist Face-to-face	Exp: at week 6 and after 1-3-6-9-12 mth Con: usual care	% participants self-reported to be exercising n participants deemed to be physically active (criteria not reported)
Allen et al ²⁹ (2009)	Time since stroke unknown Exp: n = 190 Age 68 (1) Sex 91 M Con: n = 21 Age 69 (1) Sex 99 M	Exp: secondary prevention education + general lifestyle counselling + ad hoc multidisciplinary support Con: usual care + Primary care physician is informed about individuals risk factors	Exp: Nurse Face to face, phone Con: Nurse Written material	Exp: frequency not specified over 6 mth Con: usual care	% participants self-reported to be exercising

Table 1. Summary of included trials (*continued*)

Study	Participants Age, y ^a mean (SD or range) or median (IQR, IQR) Sex, n male	Intervention		Frequency and duration of interventions	Outcome measures
		Content	Discipline delivering the intervention mode of delivery		
Faulkner et al ³¹ (2015)	Time since stroke or TIA unknown Exp: n = 29 Age 65 (11) Sex 15 M Con: n = 29 Age 68 (10) Sex 14 M	Exp: usual care + secondary prevention education, including group discussion using health belief model for behaviour change + supervised exercise Con: usual care	Exp: health and exercise practitioners Face to face, written material	Exp: 2 90-min exercise sessions and 1 30-min education session/wk, over 8 wk Con: usual care	International Physical Activity Questionnaire (IPAQ) min/wk
Olaiya et al ³⁶ (2017)	Time since stroke or TIA unknown Exp: n = 283 Age median 69 (Q1:61, Q2:78) Sex 187 M Con: n = 280 Age median 71 (Q1:71, Q2:79) (10) Sex 176 M	Exp: secondary prevention education + general lifestyle counselling, including a management plan for the primary care physician. Con: usual care	Exp: General practitioner, nurse Face to face	Exp: frequency not specified over 6 mth Con: usual care	n participants self-reported as being physically active (≥30 min of moderate intensity activity or ≥20 min of vigorous intensity physical activity ≥3 times/ week)
Askim et al ³⁴ (2018)	Time since stroke, d mean (SD): Exp: 111.3 (24.5), Con: 112.0 (17.2) Exp: n = 186 Age 72 (12) Sex 104 M Con: n = 194 Age 72 (11) Sex 127 M	Exp: physical activity coaching including goal setting + ad hoc supervised exercise Con: usual care	Exp: physiotherapist Face to face	Exp: once a mth for 18 mth	International Physical Activity Questionnaire (IPAQ) min/wk

Table 1. Summary of included trials (continued)

Study	Participants Age, yr ^a mean (SD or range) or median (IQR, IQR) Sex, n male	Intervention		Frequency and duration of interventions	Outcome measures
		Content	Discipline delivering the intervention mode of delivery		
Cheng et al ³⁵ (2018)	Time since stroke: <90 days at inclusion Exp: n = 204 Age 57 (7) Sex 128 M Con: n = 200 Age 58 (7) Sex 116 M	Exp: secondary prevention education + general self- management counselling Con: usual care	Exp: nurse practitioners or physician assistants Face to face, phone	Exp: 3 group sessions and 3 individual sessions over 10 mth Con: usual care	n participants self-reported as exercising ≥3 day/wk
Teuschl et al ³⁷ (2017)	Time since stroke <3 months at recruitment Exp: n = 80 Age 63 (8) Sex 59 M Con: n = 87 Age 61 (10) Sex 63 M	Exp: cognitive training + secondary prevention education + general self-management and motivation counselling Con: usual care + advice on medical adherence	Exp: nutritionists, physiotherapists, occupational therapists, and neurologists Face to face, phone Con: phone	Exp: 45 group session over 24 months Con: usual care + 24 moths	% participants self-reported as more than 150 min moderate intensity or 75 min vigorous-intensity pa/ week

M = male, MVPA = moderate to vigorous intensity physical activity

All 11 interventions included a form of education, motivation and/or guidance to support the participants in changing their lifestyle. Regular supervised exercise was included in 2 of the trials that specifically targeted improving physical activity,^{31,38} and on an ad hoc basis in the third.³⁴ In 3 of the included trials a physiotherapist was involved in the intervention.^{34,37,38} In the other 7 trials the intervention was delivered by either a case manager, a general health care professional, a general practitioner, a nurse, an exercise practitioner, or it was not stated.

The type of outcome measures used to determine the level of physical activity varied. Only one trial used an objective outcome measure to measure steps and minutes spent in low, moderate and high intensity activity time per day.³⁸ The other 10 trials (91%) used self-reported outcome measures.^{28–37} Two trials used a standardized, validated questionnaire,^{31,34} and 8 trials used general non-validated questionnaires.^{28–30,32,33,35–37}

Methodological quality

The quality assessment of the included trials is reported in Table 2, 'PEDro scores'. Initial agreement among the 2 authors was 95% with full consensus reached through discussion. The PEDro scores ranged from 4 to 8 points (Table 2, 'PEDro scores'). No study achieved a full score of 10 points due to lack of blinding of the participants (question 5, Supplementary Materials 2, Table S1, PEDro scale) and the professionals responsible for the treatment (question 6, Supplementary Materials 2, Table S1, PEDro scale), which is not possible in these types of interventions. Eight studies had a score of 6 or higher and were therefore considered to be of high quality.

Table 2. PEDro scores

Study	Eligibility criteria specified*	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate variability reported	Total (0 to 10)
Kono et al ³⁸ (2013)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Gillham et al ³² (2010)	N	Y	N	N	N	N	N	Y	N	Y	Y	4
Joubert et al ³³ (2009)	Y	Y	Y	N	N	N	N	N	N	Y	Y	4
Adie et al ³⁰ (2010)	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Fleming et al ²⁸ (2013)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Allen et al ²⁹ (2009)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Faulkner et al ³¹ (2015)	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Olaia et al ³⁶ (2017)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Askim et al ³⁴ (2018)	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	7
Cheng et al ³⁵ (2018)	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	7
Teuschl et al ³⁷ (2017)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8

*excluded from total score

Results of individual trials

Five out of the 11 trials found significant differences in the level of physical activity in favour of the intervention.^{28,32–34,38} The effect size of the intervention could be determined by calculating the SMD (see Table 3, 'Results individual studies') in three trials only,^{32,33,38} and this ranged from 0.29 to 0.98.

As described above some of the trials specifically targeted improving physical activity levels and included either a standard or ad hoc supervised exercise component. Subgroup analyses of these 3 trials that included specific physical activity coaching and/or supervised exercise,^{31,34,38} showed that 2 trials found a significant difference in the levels of physical activity in favour of the intervention.^{34,38} For one of these trials the effect sizes of the intervention could be determined by calculating the SMD (see Table 3, 'Results individual studies'), which were 0.73 and 0.98.³⁸

Table 3. Results individual studies

Study	Outcome	Groups				Difference within groups		Difference between groups	Standardised mean difference
		Baseline		End intervention		End intervention minus Baseline			
		Exp	Con	Exp	Con	Exp	Con	Exp minus Con	
Kono et al ³⁸ (2013)	Steps/day (accelerometer), <i>n</i>	6,250 (2,234)	6,524 (2,349)	8,422 (2,360)	6,534 (1,366)	2,127 (1,075 to 3,268)	10 (-907 to 927)	1,888 (968 to 2,808)	0.98 (0.48 to 1.48)
	Time in moderate intensity physical activity, <i>min/day</i>	23 (17)	23 (20)	32 (17)	20 (15)	8 (0.2 to 126.4)	-3 (-11.1 to 5.7)	15 (7.7 to 22.9)	0.73 (0.25 to 1.22)
Gillham et al ³² (2010)	Self-reported exercise frequency, <i>n of 20-min sessions/wk</i>	1.2 (1.8)	1.4 (2.4)	2.6 (2.0)	1.9 (2.8)	1.4 (0.34 to 2.46)	0.5 (-0.95 to 1.95)	0.7 (-0.66 to 2.06)	0.29* (-0.26 to 0.83)
Joubert et al ³³ (2009)	Self-reported exercise frequency, <i>n of 'deliberate' walks/wk</i>	3.9 (2.9)	4.3 (2.8)	4.7 (2.5)	3.6 (2.7)	0.8 (0.01 to 1.59)	-0.7 (-1.49 to 0.09)	1.1 (0.35 to 1.85)	0.42 (0.13 to 0.71)
Adie et al ³⁰ (2010)	Self-reported exercise, <i>min/wk, (median [IQR])</i>	210 (350)	210 (300)	210 (225)	150 (340)	median diff 0	median diff -60	median diff 60 p=0.14	
Flemming et al ²⁸ (2013)	participants self-reported to be exercising, %	NR	NR	83%	33%				
	participants deemed to be physically active (criteria not reported), <i>n (%)</i>	6 (33)	11 (61)	3 (17)	12 (66)	-15% (-39.0 to 11.1) NNT = -7	-4.9% (-23.5 to 31.9) NNT = 21	42% (-63.0 to -12.7) NNT = -2	

Table 3. Results individual studies (*continued*)

Study	Outcome	Groups				Difference within groups		Difference between groups	Standardised mean difference
		Baseline		End intervention		End intervention minus Baseline			
		Exp	Con	Exp	Con	Exp	Con		
Allen et al ²⁹ (2009)	participants self-reported to be exercising, <i>n</i> (%)	NR	NR	81	71			10 (-0.1 to 20)	
Faulkner et al ³¹ (2015) [#]	IPAQ, <i>min/wk walking</i>	NR	NR	410 (463)	366 (430)			44 (-191.1 to 279.1)	
	IPAQ, <i>min/wk moderate intensity activity</i>	NR	NR	328 (376)	105 (249)			223 (55.2 to 390.8)	
	IPAQ, <i>min/wk vigorous intensity activity</i>	NR	NR	494 (631)	127 (587)			367 (46.4 to 687.6)	
Olaiya et al ³⁶ (2017) [^]	participants self-reported as being physically active (≥30 min of moderate intensity activity or ≥20 min of vigorous intensity physical activity ≥3 times/week), <i>n</i> (%)	33 (11.7)	37 (13.2)	30 (11.2)	28 (10.5)	0.4% (-5.00 to 5.79) NNT = 235	2.7% (-2.81 to 8.15) NNT = 37	0.7% (-4.65 to 6.08) NNT = 141	
Askim et al ³⁴ (2018) ^{**}	IPAQ, <i>min/wk walking</i> (<i>median</i> [Q1, Q3])	NR	NR	693 (198, 1386)	643 (198, 1386)			median diff 50 p=0.55	

Table 3. Results individual studies (*continued*)

Study	Outcome	Groups				Difference within groups		Difference between groups	Standardised mean difference
		Baseline		End intervention		End intervention minus Baseline			
		Exp	Con	Exp	Con	Exp	Con	Exp minus Con	
	IPAQ, min/wk moderate intensity activity (median [Q1, Q3])	NR	NR	240 (0, 720)	240 (0, 1350)			median diff 0	
								p=0.55	
	IPAQ, min/wk vigorous intensity activity (median [Q1, Q3])	NR	NR	0 (0, 1020)	0 (0, 240)			median diff 0	
								p=0.03	
Cheng et al ³⁵ (2018)	participants self-reported as exercising ≥3 day/wk, n (%)	153 (75)	140 (70)	135 (79)	125 (77)	-8.8% (17.5 to -0.02) NNT = -11	-7.5% (-16.6 to 1.76) NNT = -13	3.7% (-5.63 to 12.90) NNT = 27	
Teuschl et al ³⁷ (2017)	% participants self-reported as more than 150 min moderate intensity or 75 min vigorous-intensity pa/week	NR	NR	NR	NR	+1.3% (NR, p=1.000)	+0.0% (NR, p=1.000)	1.3% (NR, p=0.862)	

Mean (SD) of groups, mean (SD) or n (%) difference within groups, mean difference (95% CI) or absolute risk reduction (95% CI, number needed to treat) between groups and standardised mean difference (95% CI)

IPAQ = International Physical Activity Questionnaire

* In study the confidence interval of the effect calculation does not correspond to the articles conclusion that there was a significant between group difference.[32] After contacting the author it was decided to follow the study's conclusion. This study was not of high quality (PEDRO score: 4), and therefore not included in the best evidence syntheses.

*Week 8 post-intervention values reported

^ 12 mth post-intervention values reported

**18 mth post-intervention values reported

Best evidence synthesis

Based on PEDRO scores, 8 trials overall were considered to be of high quality and were included in the best evidence syntheses.^{29–31,34–38} Two of these trials (25%) found a significant difference in favour of the intervention,^{34,38} and 6 found (75%) no significant between group difference,^{29–31,35–37} therefore the domain of consistent findings ($\geq 75\%$, see methods) is met. The domain of precise data (see methods) is not met because in 38% of the trials the sample size was equal or below 35 for each treatment arm. Overall, this means there is moderate-quality evidence that lifestyle interventions do not lead to significant improvements in the level of physical activity in people with stroke or TIA, compared to usual care.

A subgroup best evidence synthesis including only trials with interventions that specifically targeted physical activity shows low quality evidence that such interventions are effective to improve the level of physical activity in people with stroke or TIA, compared to usual care. This is based on three high quality trials, of which two (67%) found a significant difference in favour of the intervention.^{34,38} One trial (33%) found no significant between group difference,³¹ therefore the domain of consistent findings ($\geq 75\%$, see methods) is not met. The domain of precise data (see methods) is not met because in 67% of the trials the sample size was equal or below $n=35$ for each treatment arm.

When only general lifestyle interventions were included in a best evidence syntheses there was high quality evidence they do not lead to significant improvements in the level of physical activity in people with stroke or TIA, compared to usual care. Of the five high-quality trials included in this analysis, all (100%) show no significant between group difference.^{29,30,35–37} This means that the domain of consistent findings ($\geq 75\%$, see methods) is met.

Discussion

This review found low-quality evidence that lifestyle interventions overall do not lead to significant improvements in the level of physical activity in people with stroke or TIA, compared to usual care, with only 2 (25%) of the 8 high-quality trials demonstrating positive findings. The results of the subgroup analyses suggest that only lifestyle interventions that include specific strategies targeting physical activity have a positive effect on the levels of physical activity. However, sample sizes were small, and in the majority of trials the levels of physical activity was a secondary outcome measure. Therefore, it is possible that some of the included trials were insufficiently powered to determine the effectiveness of the interventions on physical activity.

Counselling, advice, education, support and encouragement were commonly incorporated into the interventions, however descriptions were sparse. In those trials that included general lifestyle counselling, details about the relative emphasis on physical activity was not provided. Therefore, there is limited information to guide clinical practice regarding lifestyle counselling or physical activity coaching to improve physical activity levels of people with stroke or TIA.

There were more consistent findings of benefit for trials that included specific physical activity coaching and/or supervised exercise. The 2 high quality trials with significant positive findings included an exercise program as a standard part of their intervention or on an ad hoc basis.^{34,38} However, one high quality trial that included an exercise program found no significant between group differences.³¹ This study had a sample size of 29 participants per arm (compared to 35 and 186 in the other two), so might have been underpowered.³¹ This suggests that including an exercise program in the lifestyle intervention may lead to better results. In 2 of the 3 high quality trials that specifically targeted improving physical activity,^{34,38} a physiotherapist was involved in the intervention and both had positive findings.^{34,38} Since a specific focus on physical activity and/or adding an exercise component to a lifestyle intervention might be beneficial, the involvement of experts in physical activity and exercise, such as physiotherapists may be a critical component for success.

The outcome measures used across the included trials were too diverse to conduct meta-analyses in this review. This corresponds to the conclusions of earlier reviews.^{16–18} All but one study included self-reported physical activity outcome measures. Additionally, several trials measured one aspect of physical activity (e.g. taking exercise walks or participating in exercise sessions), instead of all possible types of physical activity combined. These factors may have influenced the effect estimation. Without an overall, objective measure of physical activity definitive conclusions cannot be drawn. Further high-quality research, using objective outcome measures, is needed. Our results on physical activity are in line with the recently updated Cochrane review on educational and behavioural interventions effects on physiological risk factors of recurrent stroke (e.g. blood pressure), which concluded these interventions did not lead to improvements in physiological risk factors.³⁹

Limitations

A meta-analysis was not possible and, though a best evidence synthesis was conducted, the limitations to sample sizes and the use of non-objective outcome measures still call for caution when interpreting the results. A systematic review on the use of different self-reported outcome measures of physical activity concluded that measurement properties were insufficiently addressed, specifically content validity.⁴⁰ Furthermore, the follow-up

period was less than 2 months in 5 of the 8 high quality trials which limits the determination of sustainability of the effects.

The search strategy used was thorough and included three of the most commonly used databases. Though, it is always possible that due to the build of the search string, not including other databases and the exclusion of papers not published in English or Dutch, trials on the subject may not have been identified. We also acknowledge that since the search was conducted it is possible that additional trials have been published on the subject. Though a search in one database (Pubmed) in March 2020 did not reveal new studies.

All studies included in this review were conducted in high income countries.^{28,29,38,30–37} However, the World Health Organisation concludes that the middle and low-income countries have the highest incidence and death rates for stroke.¹ Further trials are needed to determine the effectiveness of lifestyle interventions in middle and low-income countries.

Implications and recommendations for future research

Current clinical guidelines emphasise the importance of increasing physical activity levels as part of (secondary) stroke prevention.^{12–15} Clinicians therefore need clear guidance on the best way to improve physical activity levels for their patients. Although a positive trend is seen for trials that include specific physical activity coaching and/or supervised exercise programs, there is currently insufficient evidence to support definitive recommendations. There is also a lack of specific detail on the content and behaviour change techniques used in these interventions which further limits implementation. In light of the fact that sustainable behaviour change has been proven very difficult both in research and clinical practice, this information is crucial.^{41,42} Recommendations for further research include better description of the content of the intervention in particular the behaviour change techniques used, more homogeneous objective outcome measures, adequate sample sizes, and longer follow-up periods.⁴³ Populations from middle and low income countries should also be included.

Conclusion

The results of this review demonstrate high-quality evidence that general lifestyle interventions seem insufficient to improve the levels of physical activity in people with stroke or TIA. The subgroup analyses indicate that lifestyle interventions specifically targeting the levels of physical activity might be effective. Further research is needed to

determine the effectiveness of combining lifestyle interventions that include behaviour change strategies specifically focusing on improving physical activity and/or supervised exercise programs to sustainably improve physical activity after stroke.

References

1. WHO | Global atlas on cardiovascular disease prevention and control. *WHO*. 2015.
2. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
3. Burn J, Dennis M, Bamford J, Sandercock P, Wade D, Warlow C. Long-term risk of recurrent stroke after a first-ever stroke. The Oxfordshire Community Stroke Project. *Stroke*. 1994;25(2):333-337.
4. Furie KL, Kasner SE, Adams RJ, et al. Guidelines for the prevention of stroke in patients with stroke or transient ischemic attack: A guideline for healthcare professionals from the American Heart Association/American stroke association. *Stroke*. 2011;42(1):227-276. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L51121482>.
5. European Stroke Organisation (ESO) Executive Committee, ESO Writing Committee. Guidelines for Management of Ischaemic Stroke and Transient Ischaemic Attack 2008. *Cerebrovasc Dis*. 2008;25(5):457-507. doi:10.1159/000131083
6. Billinger SA, Arena R, Bernhardt J, et al. Physical Activity and Exercise Recommendations for Stroke Survivors: A Statement for Healthcare Professionals From the American Heart Association/American Stroke Association. *Stroke*. 2014;45(8):2532-2553. doi:10.1161/STR.0000000000000022
7. American Heart Association Recommendations for Physical Activity in Adults and Kids | American Heart Association. <https://www.heart.org/en/healthy-living/fitness/fitness-basics/aha-recs-for-physical-activity-in-adults>. Accessed March 13, 2020.
8. World Health Organization. *Global Recommendations on Physical Activity for Health*. World Health Organization.; 2010. <https://apps.who.int/iris/handle/10665/44399>. Accessed March 13, 2020.
9. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil*. 2016;38(4):362-367. doi:10.3109/09638288.2015.1041615
10. Butler EN, Evenson KR. Prevalence of Physical Activity and Sedentary Behavior Among Stroke Survivors in the United States. *Top Stroke Rehabil*. 2014;21(3):246-255. doi:10.1310/tsr2103-246
11. Fini NA, Holland AE, Keating J, Simek J, Bernhardt J. How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis. *Phys Ther*. 2017;97(7):707-717. doi:10.1093/ptj/pzx038
12. Stroke Foundation. Clinical Guidelines for Stroke Management 2017. *Stroke Found Melb Aust*. 2017. <https://informme.org.au/en/Guidelines/Clinical-Guidelines-for-Stroke-Management-2017>.
13. Rudd AG, Bowen A, Young GR, James MA. The latest national clinical guideline for stroke. *Clin Med (Northfield Il)*. 2017;17(2):154-155. doi:10.7861/clinmedicine.17-2-154
14. Wein T, Lindsay MP, Cote R, et al. Canadian stroke best practice recommendations: Secondary prevention of stroke, sixth edition practice guidelines, update 2017. *Int J Stroke*. 2018;13(4):420-443. doi:10.1177/1747493017743062

15. Koninklijk Nederlands Genootschap voor Fysiotherapie. KNGF-richtlijn Beroerte. 2017. www.kngfrichtlijnen.nl.
16. Lennon O, Galvin R, Smith K, Doody C, Blake C. Lifestyle interventions for secondary disease prevention in stroke and transient ischaemic attack: a systematic review. *Eur J Prev Cardiol*. 2014;21(8):1026-1039. doi:10.1177/2047487313481756
17. Lawrence M, Pringle J, Kerr S, Booth J, Govan L, Roberts NJ. Multimodal secondary prevention behavioral interventions for TIA and stroke: a systematic review and meta-analysis. *PLoS One*. 2015;10(3):e0120902. doi:10.1371/journal.pone.0120902
18. Deijle IA, Van Schaik SM, Van Wegen EEH, Weinstein HC, Kwakkel G, Van den Berg-Vos RM. Lifestyle Interventions to Prevent Cardiovascular Events After Stroke and Transient Ischemic Attack: Systematic Review and Meta-Analysis. *Stroke*. 2017;48(1):174-179. doi:10.1161/STROKEAHA.116.013794
19. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339(jul21 1):b2535-b2535. doi:10.1136/bmj.b2535
20. PEDro scale (English). <http://www.pedro.org.au/english/downloads/pedro-scale/>. Accessed August 10, 2018.
21. Teasell R, Foley N, Salter K, Bhogal S, Jutai J, Speechley M. Evidence-Based Review of Stroke Rehabilitation: Executive Summary, 12th Edition. *Top Stroke Rehabil*. 2009;16(6):463-488. doi:10.1310/tsr1606-463
22. Furlan AD, Pennick V, Bombardier C, van Tulder M, Editorial Board, Cochrane Back Review Group. 2009 Updated Method Guidelines for Systematic Reviews in the Cochrane Back Review Group. *Spine (Phila Pa 1976)*. 2009;34(18):1929-1941. doi:10.1097/BRS.0b013e3181b1c99f
23. Cochrane Handbook for Systematic Reviews of Interventions | Editorial and Publishing Policy Resource | Cochrane Community. <https://community.cochrane.org/editorial-and-publishing-policy-resource/cochrane-review-development/cochrane-handbooks/cochrane-handbook-systematic-reviews-interventions>. Accessed September 26, 2018.
24. Guyatt GH, Oxman AD, Kunz R, et al. What is "quality of evidence" and why is it important to clinicians? *BMJ*. 2008;336(7651):995-998. doi:10.1136/bmj.39490.551019.BE
25. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924-926. doi:10.1136/bmj.39489.470347.AD
26. Rosenthal R. The handbook of research synthesis. In: Cooper H, Hedges L, eds. *The Handbook of Research Synthesis*. New York: Russell Sage Foundation; 1994:231-244.
27. Cohen J. *Statistical Power Analysis for the Behavioural Sciences*. 2nd ed. (Hillsdale, ed.). Lawrence Erlbaum Associates; 1988.
28. Flemming KD, Allison TG, Covalt JL, Herzig DE, Brown RD. Utility of a post-hospitalization stroke prevention program managed by nurses. *Hosp Pract (1995)*. 2013;41(3):70-79. doi:10.3810/hp.2013.08.1070
29. Allen K, Hazelett S, Jarjoura D, et al. A randomized trial testing the superiority of a postdischarge care management model for stroke survivors. *J Stroke Cerebrovasc Dis*. 2009;18(6):443-452. doi:10.1016/j.jstrokecerebrovasdis.2009.02.002

30. Adie K, James MA. Does telephone follow-up improve blood pressure after minor stroke or TIA? *Age Ageing*. 2010;39(5):598-603. doi:10.1093/ageing/afq085
31. Faulkner J, McGonigal G, Woolley B, Stoner L, Wong L, Lambrick D. 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. *Clin Rehabil*. 2015;29(8):783-794. doi:10.1177/0269215514555729
32. Gillham S, Endacott R. Impact of enhanced secondary prevention on health behaviour in patients following minor stroke and transient ischaemic attack: a randomized controlled trial. *Clin Rehabil*. 2010;24(9):822-830. doi:10.1177/0269215510367970
33. Joubert J, Reid C, Barton D, et al. Integrated care improves risk-factor modification after stroke: initial results of the Integrated Care for the Reduction of Secondary Stroke model. *J Neurol Neurosurg Psychiatry*. 2009;80(3):279-284. doi:10.1136/jnnp.2008.148122
34. Askim T, Langhammer B, Ihle-Hansen H, Gunnes M, Lydersen S, Indredavik B. Efficacy and Safety of Individualized Coaching After Stroke: the LAST Study (Life After Stroke). *Stroke*. 2018;49(2):426-432. doi:10.1161/STROKEAHA.117.018827
35. Cheng EM, Cunningham WE, Towfighi A, et al. Efficacy of a Chronic Care-Based Intervention on Secondary Stroke Prevention Among Vulnerable Stroke Survivors: A Randomized Controlled Trial. *Circ Cardiovasc Qual Outcomes*. 2018;11(1):e003228. doi:10.1161/CIRCOUTCOMES.116.003228
36. Olaiya MT, Kim J, Nelson MR, et al. Effectiveness of a shared team approach between nurses and doctors for improved risk factor management in survivors of stroke: a cluster randomized controlled trial. *Eur J Neurol*. 2017;24(7):920-928. doi:10.1111/ene.13306
37. Teuschl Y, Matz K, Firlinger B, et al. Preventive effects of multiple domain interventions on lifestyle and risk factor changes in stroke survivors: Evidence from a two-year randomized trial. *Int J Stroke*. 2017;12(9):976-984. doi:10.1177/1747493017702662
38. Kono Y, Yamada S, Yamaguchi J, et al. Secondary prevention of new vascular events with lifestyle intervention in patients with noncardioembolic mild ischemic stroke: a single-center randomized controlled trial. *Cerebrovasc Dis*. 2013;36(2):88-97. doi:10.1159/000352052
39. Bridgwood B, Lager KE, Mistri AK, Khunti K, Wilson AD, Modi P. Interventions for improving modifiable risk factor control in the secondary prevention of stroke. *Cochrane Database Syst Rev*. 2018;(5). doi:10.1002/14651858.CD009103.pub3
40. Martins JC, Aguiar LT, Nadeau S, Scianni AA, Teixeira-Salmela LF, Faria CDCDM. Measurement properties of self-report physical activity assessment tools for patients with stroke: a systematic review. *Brazilian J Phys Ther*. 2019;23(6):476-490. doi:10.1016/j.bjpt.2019.02.004
41. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions*. Silverback Publishing Great Britain; 2014.
42. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci*. 2011;6(1):42. doi:10.1186/1748-5908-6-42
43. Kwakkel G, Lannin NA, Borschmann K, et al. Standardized measurement of sensorimotor recovery in stroke trials: Consensus-based core recommendations from the Stroke Recovery and Rehabilitation Roundtable. *Int J Stroke*. 2017;12(5):451-461. doi:10.1177/1747493017711813

Supplementary Materials 1: Search strategy.

Databases: Pubmed, Embase and CINAHL

#1	Search ("Stroke"[Mesh]) OR "Brain Infarction"[Mesh] OR "Stroke"[Title/Abstract] OR "Cerebro Vascular Accident"[Title/Abstract] OR CVA"[Title/Abstract] OR "Brain infarction"[Title/Abstract] OR "Cerebral apoplexy" OR Poststroke*[Title/Abstract])
#2	Search (((("Secondary Prevention"[Mesh]) OR "Risk Reduction Behavior"[Mesh])) OR (((("Secondary prevention"[Title/Abstract]) OR "Lifestyle interventions"[Title/Abstract]) OR "Behavioural interventions"[Title/Abstract]) OR "Lifestyle modification"[Title/Abstract]))
#3	Search #1 AND #2
#4	Search (((("Motor Activity"[Mesh]) OR "Exercise"[Mesh]) OR "Walking"[Mesh]) OR "Physical Fitness"[Mesh])) OR (((("Motor Activity"[Title/Abstract]) OR "Exercise"[Title/Abstract]) OR "Walking"[Title/Abstract]) OR "Physical Fitness"[Title/Abstract])
#5	Search #3 AND #4
#6	Search ("Risk Reduction Behavior"[Mesh] OR "Life Style"[Mesh]) OR "Lifestyle intervention*"[Title/Abstract] OR "Life style intervention*"[Title/Abstract] OR "Behaviour* intervention*"[Title/Abstract] OR "Lifestyle modification*"[Title/Abstract] OR "Life style modification*"[Title/Abstract])
#7	Search #1 AND #6
#8	Search #5 AND #7

Supplementary Materials 2: Table S1. PEDro scale.

1. eligibility criteria were specified	Yes	No
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	Yes	No
3. allocation was concealed	Yes	No
4. the groups were similar at baseline regarding the most important prognostic indicators	Yes	No
5. there was blinding of all subjects	Yes	No
6. there was blinding of all therapists who administered the therapy	Yes	No
7. there was blinding of all assessors who measured at least one key outcome	Yes	No
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	Yes	No
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	Yes	No
10. the results of between-group statistical comparisons are reported for at least one key outcome	Yes	No
11. the study provides both point measures and measures of variability for at least one key outcome	Yes	No



CHAPTER 5

It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive.

Wendy Hendrickx
Roderick Wondergem
Martijn F. Pisters
Céline Lecluse
Coralie English
Johanna M.A. Visser-Meily
Cindy Veenhof

Under review

Abstract

Purpose: To identify Capabilities, Opportunities and Motivational factors influencing movement behaviour throughout the day in people with stroke who are highly sedentary and inactive to enable intervention development.

Methods: A qualitative study was conducted using semi-structured interviews with people with stroke. The interview guide was based on the Capabilities, Opportunities and Motivation Behavioural model.

Results: Eleven interviews were conducted. Participants reported a lack of knowledge regarding healthy movement behaviour patterns, a lack of insight into their own movement behaviour and some physical and cognitive limitations to engage in certain physical activities. Several social and environmental elements affecting movement behaviours were mentioned, their impact on movement behaviour varied among participants. Movement behaviour was mostly driven by habits and daily routine, without conscious regulation.

Conclusion: Our findings show that people with stroke are unaware of their own movement behaviour or of the consequences of these behaviours on health. Movement behaviour is, for the most part, based on daily routine and personal habits. This indicates the need for a behaviour change intervention. Such interventions will need to include providing information about healthy movement behaviour, feedback on individual's movement behaviour and individualized support, taking into account the social and environmental context and personal capabilities.

Introduction

People who have suffered a stroke are at high risk of recurrence.^{1–3} The impact of (recurrent) stroke on mortality and disability makes secondary prevention critical. Low levels of physical activity and high levels of sedentary behaviour increase the risk of stroke.^{4–11} Sedentary behaviour is defined as “any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task while in a sitting, reclining, or lying posture”.^{12,13} Large observational studies have shown that high amounts of sedentary time (over 9.5 hours per day), combined with limited moderate to vigorous physical activity (MVPA) (less than 24 minutes per day), increase the risk of cardiovascular mortality by 74% (hazard ratio R 1.74, CI 1.60 to 1.90).^{9,10} Light-intensity physical activity (LPA) was found to be protective (maximum risk reduction at 375 minutes per day).¹⁰ Combining these findings suggests that all aspects of movement behaviour; physical activity levels (MVPA and LPA) and time spent sedentary are important, thus highlighting the need to consider movement patterns throughout the day.^{12,14}

The majority of people with stroke living in the community are not sufficiently active and spend large portions of their day sitting down.^{15–19} Our previous observational study (the RISE-cohort study) identified three different movement behaviour patterns across a day in people with a first-ever stroke.¹⁵ All patterns show high amounts of sedentary time (>9 hours of sedentary time), though *sedentary exercisers* (about 23% of the population) still engaged in sufficient amounts of MVPA.¹⁵ *Sedentary movers* (46% of the population) did not engage in sufficient amounts of MVPA, though they did interrupt their sedentary time with some bouts of LPA.¹⁵ The remaining 31% of the population, *sedentary prolongers*, had a movement pattern that is highly sedentary (>10 hours) with little engagement in MVPA or LPA.¹⁵ This indicates the need for interventions to support movement behaviour change, specifically for those with a *sedentary prolonger* movement pattern.

Currently, to our knowledge, there are no interventions aiming to improving movement behaviour throughout the day. Some pilot studies aiming at reducing sedentary behaviour exist though these interventions have not been proven effective.^{20–22} To support people with stroke who are highly sedentary and inactive to change behaviour, we need to understand their perspective regarding factors important for altering movement patterns. Previous studies in general stroke population have investigated barriers and facilitators regarding physical activity or sedentary behaviour in isolation,^{23,24} not whole-day movement behaviour.

Looking at behaviour across the day, it is important to make sure all relevant factors are identified,^{25–27} including those on a less conscious level. A model often used to understand

behaviour is the *Capabilities* (physical and psychological skill, strength, knowledge etc.), *Opportunities* (conducive social and physical environment) and *Motivation* (reflective and automatic processes) Behaviour (COM-B) model.^{25–27} This model helps identify factors that influence behaviour from all three behaviour domains.^{25–27} Therefore, this study aims to identify *Capabilities*, *Opportunities* and *Motivational* factors influencing movement behaviour throughout the day, in people with stroke, who are highly sedentary and inactive.

Method

Design

We used an interpretive qualitative approach and the Standards for Reporting Qualitative Research (SRQR) reporting guideline, as advised by the Equator network²⁸. Semi-structured interviews were conducted within an iterative process between data collection and thematic analyses.^{29,30} The theoretical Domains Framework (TDF), a framework designed to identify all aspects of the COM-B model related to the behaviour was used to structure the interview guide, and to inform the analyses.^{25–27} This study was approved by the Ethics review board of the UMC Utrecht, number 16/715.

Participants

We used purposive sampling techniques to recruit participants, guided by a theoretical sampling process.³⁰ We chose to include people with stroke with a daily movement behaviour pattern that put them at highest risk of stroke; that is people who fitted the highly sedentary and inactive movement pattern ("*sedentary prolongers*"), as identified in the RISE-cohort study.¹⁵

Inclusion and exclusion criteria for the RISE cohort were:

1. Adults, e.g. 18 years or over, living in the community;
2. Had a stroke, diagnosed in hospital setting
3. High risk movement behaviour pattern as identified within the cohort study;
4. Sufficient knowledge of the Dutch language to participate in the interviews;
5. Able to walk independently (Functional ambulation categories score ≥ 3);
6. A Score >4 on the Utrecht Communication Assessment (UCO) to enable sufficient communication skills;
7. Independent in activities of daily living prior to the stroke (score >18 on the Barthel Index).

Participants who had indicated in the informed consent for the RISE Cohort study that they could be contacted for follow-up studies were invited to participate. Informed consent was obtained before conducting the interviews.

Data collection

Semi-structured interviews were conducted using the Theoretical Domains Framework (TDF) domains to ensure all aspects of the related to the behaviour (COM-B model) were covered.^{25–27} The TDF consists of 14 domains that together cover *physical capabilities*, *psychological capabilities*, *physical opportunities*, *social opportunities*, *reflective motivation* and *automatic motivation*. Table 1 presents the domains and definitions of the TDF, and the corresponding elements of the COM-B model. The domains were used as the topic list for the interviews, from which an interview guide was derived (see Supplementary Material 1). Since sedentary behaviour is an abstract concept for most people, we expected participants would need some guidance to be able to reflect on this behaviour and on their movement behaviour pattern and the activities they undertake each day. Therefore, participants received a booklet one week before the interview, which introduced the overall aim of the interview and definitions of movement behaviour. The booklet also included a one-day activity diary and some reflective questions on their activities and movement behaviour. This allowed participants to prepare for the interview without influencing their perceptions and, therefore, interview data. We also collected objective data on movement patterns for one day, using the Activ8 activity monitor, a valid and reliable tool for determining movement behaviour³¹ Data were provided to the participants during the interview to enable in-depth reflection.

Table 1. COM-B model components and the Theoretic Domains Framework

COM-B	Components	TDF Domains
Capability	Physical	Physical skills
	<i>Physical skill, strength or stamina</i>	<i>An ability or proficiency acquired through practise</i>
	Psychological	Knowledge
	<i>Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes</i>	<i>An awareness of the existence of something</i>
		Cognitive and interpersonal skills
		<i>An ability or proficiency acquired through practise</i>
		Memory, attention and decision processes
		<i>The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives</i>
		Behaviour Regulation
		<i>Anything aimed at managing or changing objectively observed or measured actions</i>

Table 1. COM-B model components and the Theoretic Domains Framework (*continued*)

COM-B	Components	TDF Domains
Opportunity	Social <i>Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way that we think about things, e.g. the words and concepts that make up our language</i>	Social influences <i>Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours</i>
	Physical <i>Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'</i>	Environmental Context and Resources <i>Any circumstance of a person's situation or environment or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour</i>
Motivation	Reflective <i>Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)</i>	Social or Professional Role and Identity <i>A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting</i>
		Beliefs about Capabilities <i>Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use.</i>
		Optimism <i>The confidence that things will happen for the best or that desired goals will be attained</i>
		Intentions <i>A conscious decision to perform a behaviour or a resolve to act in certain way</i>
		Goals <i>Mental representations of outcomes or end states that an individual wants to achieve</i>
	Automatic <i>Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex responses</i>	Beliefs about consequences <i>Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation.</i>
		Reinforcement <i>Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus</i> Emotion <i>A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event</i>

The interviews were conducted by one researcher (W.H.) who had no relation to the participants prior to this study, allowing for open, unbiased enquires. Though interviews were focussed on the people with stroke, caregivers were invited to be present during the interviews if the participant wanted them to. The interviews were audio recorded and a second researcher (R.W.) checked the first two interviews for completeness. The recordings were transcribed for analyses.

Sample size

Data saturation was the desired endpoint of this study.^{29,30} We estimated *a priori* that at least 8 interviews would be required.^{23,24} The 8 interviews were analysed by at least two researchers (W.H. and R.M or C.L.). To determine if saturation had been reached, the subsequent 3 interviews were then analysed sequentially, noting if any new themes emerged.

Data analysis

Data analyses were conducted by at least two researchers (W.H., R.W. and/or C.L.) using directed content analyses guided by the TDF domains (Table 1). Analyses were conducted using an iterative process in which quotes were derived from the transcripts and coded to the TDF domains. After initial coding, the quotes for each domain were combined to identify the factors that influence movement behaviour for each domain. Disagreements were settled by discussion. Where consensus could not be reached, a fourth researcher was consulted (M.F.P). Atlas.ti version 8 was used for the analyses.

Results

Of the 11 participants, 5 were female, and the mean age was 68 (range 55-83). Information from all 15 domains of the TDF was obtained in the interviews. No new themes were identified in the final 3 interviews, meaning we are confident that we reached data saturation. Figure one shows an overview of all factors identified from the interviews relevant to changing movement behaviour.



Figure 1. Overview of results per domain. Note: The distribution within the figure is not representative of the importance of the result categories; this is due to the uneven number of domains for each main category

Table 2 in Supplementary Material 2 (table 2 Results per TDF Domain) describes each factor identified within the TDF domains, linked to the three overarching domains. The text below describes the findings for each overarching domain. Illustrative quotes have been added, with the abbreviation *P* for participant, *I* for interviewer, and *C* for caregiver or spouse.

Capabilities

Lack of knowledge regarding movement behaviour was the main factor identified within the domain of *Capabilities*. Participants were somewhat aware of the importance of moderate to vigorous physical activity (MVPA) when it comes to healthy living, though how much is needed was not clear. Also, only a couple of participants reported having heard of the risk of sedentary behaviour (SB). None were aware of the specifics regarding time spent in SB or light physical activity (LPA) required to have a healthy movement behaviour pattern.

*"I: Because do you know how much exercise you need each week to? P: I have no idea.
I: And how much time you should spend sitting, how many hours maximum, you are
allowed to spend sitting? P: I really wouldn't know. I: Would you like to know? P: Yes" 3:36*

Participants also mentioned the importance of the information provided regarding movement behaviour. Insight into their movement behaviour was considered necessary, as most did not know how much time they spend sedentary or physically active. This means they were for the most part unaware of the risk that comes from their movement behaviour patterns and were, Therefore, unable to regulate their behaviour.

*"P: And then use the keep track and see if it is really better or am I relapsing? I: and then
you would like to hear how much sitting it was? P: Yes, sure.Because you have no idea
yourself and then it is really good to hear about it. I: Because it is more then you expected?
P: Yes. I: and when you get this information this is something you would like to try
improving? P: Yes." 3:30*

Almost all participants stated that they did not apply any conscious regulation regarding their movement behaviour, i.e. they did not actively think about their movement behaviour or adjusted their actions accordingly. Some reported consciously engaging in concrete activities, such as going for a walk, from the perspective of health benefits, though almost none reported actively regulating how much time they spent engaged in physical activity (PA). None reported regulating how much time they spent sedentary.

*"P: Well, sometimes in the morning I go into town on my bike or something. But I didn't do
that, that day. I did not do anything extra, just because that is what it was for that day....
I: You didn't really think about it specifically? P: No it was just way that day went." 10:44*

Most participants mentioned some physical limitations, related to their stroke, or other comorbidities. Despite these limitations, several participants stated that they were already planning to increase their amounts of physical activity, mainly MVPA.

*"P: Yes, then I did cycle for 10-15 kilometers and I'm going to be doing that again soon, but
then a friend will be with me." 8:25*

When asked directly, most participants were able to formulate ideas about how to decrease sedentary time. One participant expressed wanting support to regulate (movement) behaviour, as for their lack of initiative was a sequela of her stroke. Others confirmed that support from a health care professional and/or someone from the social environment might be helpful in regulating movement behaviour.

Opportunity

Participants reported that having some sort of device that gives feedback regarding their movement behaviour and healthy movement behaviour would be useful. Some participants mentioned the possible benefits of having a reminder to get up and move.

"P: Always, that gives insight."

Participants reported certain social influences are relevant when it comes to movement behaviour, for example the joy of interactions with others when doing physical activities like playing tennis. On the other hand, participants stated that certain social activities lead to sitting more, for instance when people come to visit and sit for hours.

"P: when walking outside you bump into people. I: So, that social aspect is important to you? P: It is very important." 7.53

"P: And then she sits opposite me and we play a card game." 5.4

Related to this are the environmental factors, like the layout at home and/or work setting, sitting while using a computer, watching television or reading, that increases the amount of time spent sitting. Other environmental aspects, like having stairs in the house, having a dog that needs walking, or groceries being on sale in different shops, lead to more PA.

"P: I keep busy, so yes with puzzles, doing crossword puzzles and reading." 8.2

The attitude of the social environment was also deemed important. For instance, one participant mentioned not undertaking certain physical activities, such as vacuuming or going out by themselves, often due to fear expressed by their spouse.

"P: But my wife always does the vacuuming.... C: Yes, it's just that the hose and the cable are lying around then I'm afraid he might trip." 8.37

Motivation

Within the domain of *Motivation*, reinforcement was found to be highly relevant. Participants mentioned that most factors influencing their movement behaviour were on a subconscious level, as a matter of habit, i.e. daily routine. Daily habits are closely related to the influencing factors within the domain of *Opportunity*, like the need to perform household chores or the habit of sitting when people come to visit or while reading. Some participants specifically stated that activities involving physical activity have been replaced by sedentary ones without giving it much thought.

"P: The worst part is in the evening. A routine from the past I guess ... I used to work in construction and then I would sit down after work and not get up out of my chair again unless I needed to mow the lawn or something." 7.28

"P: I eat sitting down, I sit at the computer at home, at work, I do everything at work sitting down." 12.27

"I: You used to do jobs and hiking and cycled a lot, but you can't do that anymore and you said you have replaced this by watching sports on tv. P:Yes." 8.30

As mentioned, a few participants were intending specifically to increase the levels of PA (mostly MVPA), and some had already thought of a plan to do so. Most had no previous intention to reduce the time spent sedentary. Several participants did formulate the intention to change the amount of time spent sedentary based on the information about their movement behaviour from the activity monitor provided during the interview. Some even formulated plans to reduce time spent sedentary during the interview. Several participants mentioned that setting goals, could be helpful in increasing the level of physical activity and reducing the time they spend sedentary.

"P: Well the fact that you have just told me, that I sit so much, that in itself is for me already a reason to move more, that is a given." 10.62

"P: If it is just about doing stuff around the house, if it is really about sitting, then I would, say, then I could just walk a little more often in between, right? Or do something around the house." 10.31

When it comes to beliefs about capabilities, several participants expressed the belief they can expand on or take up PA-related activities. When asked, they also mentioned they believed that they will be able to interrupt and reduce sedentary time if they set out to do so. In contrast, other participants mentioned a lack of self-efficacy in reducing sedentary time or improving PA.

Discussion

In this study, we identified a wide variety of factors that influence movement behaviour. Within the domain of *Capabilities*, we found a lack of knowledge regarding healthy movement behaviour and personal movement behaviour patterns, a lack of regulation of movement behaviour and some physical limitations to be key factors limiting peoples' abilities to have a healthy movement behaviour pattern. In terms of *Opportunities*, participants reported that it is necessary to have feedback regarding personal and healthy movement behaviour. Also mentioned were several social and environmental elements

that can influence movement behaviour in both a positive and a negative manner, which differed among participants. Within the domain of *Motivation*, it was found that movement behaviour is highly related to reinforcement, i.e. it is largely driven by habits and daily routines. For the most part, there is a lack of prior intentions or plans to improve movement behaviour, though some intentions did emerge during the interview due to the information provided. Differing levels of self-efficacy among participants were also found within the domain of *Motivation*.

The results of our study support earlier findings that there is a need to assess all behavioural aspects and not just (physical) capabilities when looking for ways to improve movement behaviour.^{15,17,18,32,33} Aspects such as self-efficacy, and social influences were found to be relevant in multiple studies.^{15,24} There were also key differences with the existing literature. Our results show the importance of information regarding one's own movement behaviour. This was not found in studies looking into barriers and facilitators of MVPA.^{24,34} However, it was reported in a qualitative study on SB in people with stroke.²³ The importance of habits, reinforcing elements from the physical and social environment, and the need for conscious regulation of behaviour found in our study are new findings. This may be explained by the fact that we looked at movement behaviour as a whole during the day instead of looking at one part, and specifically in people with stroke that are highly sedentary and inactive. It indicates the need to take all these aspects into account when addressing movement behaviour as a whole.

Strengths and limitations

Our study had a number of strengths. Firstly, we examined movement behaviour as a whole, thereby providing a complete overview of factors that influence movement behaviour throughout the day. This is important because across a 24 hour period, the different types of movement are not independent.^{9,10,12,14} indicating the need to address movement behaviour as a whole. Secondly, we used the TDF framework to develop an interview guide that included all behavioural domains and enabled us to gain rich insight into all factors influencing behaviour. Because this framework is complete and does not allocate value or make pre-assumptions about the outcome, the risk of influencing results by using a pre-existing model is limited. Thirdly we used a purposeful sample of people with stroke, who have a high-risk movement pattern. This means the findings have a high validity for designing interventions for people with a high-risk movement behaviour. In terms of limitations, caution should be taken about generalising to people with different movement patterns. In addition, participants were community-dwelling and, for the most part, able to walk independently, making our findings less representative for people with more severe stroke sequelae.

Implications

To enable effective regulation of movement behaviour, people need to be aware of healthy movement behaviour and their own personal movement behaviour pattern.

How people accumulate their movement behaviour, both inactive and highly sedentary, is, for the most part, based on daily routine. Influencing factors, like environmental and social elements, self-efficacy and physical and cognitive capabilities, depend greatly on habits and the individuals' personal situation. Therefore, there is a need to identify habits and routines related to movement behaviour to enable movement behaviour change.

The unconscious replacing of active activities for sedentary activities described by the participants also highlights the need to provide people with feedback and support them in developing conscious regulation of their movement behaviour. A promising finding was the fact that the small amount of information regarding their movement behaviour, provided to participants during the interview, led to intentions and ideas being formed to change, or at least think about changing their movement behaviour. This indicates that once awareness is created, participants are open to undertaking behaviour changes and most believe they are capable of improving their movement behaviour.

Several of the key factors mentioned above can be addressed using behaviour change techniques within an intervention. Techniques such as providing information on health risks and providing feedback on personal movement behaviour seem of key importance. Increasing behaviour regulation with, for instance, supported goal-setting and action planning are also considered helpful. These techniques will help identify and learn to overcome habits and factors that have a negative influence and strengthen those that have a positive influence. Supporting the creation of positive social support also seems to be a relevant aspect for intervention development. Technological support can be included in interventions to provide real-time feedback and reminders to help regulate behaviour and overcome sedentary and inactive habits. Our research group is now using the findings of this study to create an intervention to support people with stroke, who are highly sedentary and inactive, to improve their movement behaviour: the RISE intervention.

Conclusion

Our findings show that people with stroke are unaware of their own movement behaviour and the health consequences. Movement behaviour is for the most part based on daily routine and personal habits. This indicates the need for a behaviour change intervention, providing information about healthy movement behaviour, feedback on individuals' movement behaviour, individualized support, taking into account the social and environmental context and personal capabilities, for people with stroke to actively improve their movement behaviour.

References

1. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
2. Pennlert J, Eriksson M, Carlberg B, Wiklund P-G. Long-term risk and predictors of recurrent stroke beyond the acute phase. *Stroke*. 2014;45(6):1839-1841. doi:10.1161/STROKEAHA.114.005060
3. GBD 2016 Stroke Collaborators. Global, regional, and national burden of stroke, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18(5):439-458. doi:10.1016/S1474-4422(19)30034-1
4. WHO | Global atlas on cardiovascular disease prevention and control. *WHO*. 2015.
5. Kernan WN, Ovbiagele B, Black HR, et al. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2014;45(7):2160-2236. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L53124424>.
6. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338-1353. doi:10.1093/ije/dys078
7. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-132. doi:10.7326/M14-1651
8. Dunstan DW, Howard B, Healy GN, Owen N. Too much sitting--a health hazard. *Diabetes Res Clin Pract*. 2012;97(3):368-376. doi:10.1016/j.diabres.2012.05.020
9. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
10. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*. 2019;366:l4570. doi:10.1136/bmj.l4570
11. Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association. *Stroke*. 2021;52(7). doi:10.1161/STR.0000000000000375
12. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi:10.1186/s12966-017-0525-8
13. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev*. 2008;36(4):173-178. doi:10.1097/JES.0b013e3181877d1a

14. Chastin SFM, De Craemer M, Lien N, et al. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. *Int J Behav Nutr Phys Act*. 2016;13(1):83. doi:10.1186/s12966-016-0409-3
15. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behavior Patterns in People With First-Ever Stroke. *Stroke*. 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
16. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. *Phys Ther*. 2016;96(2):193-201. doi:10.2522/ptj.20140522
17. Tieges Z, Mead G, Allerhand M, et al. Sedentary behavior in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil*. 2015;96(1):15-23. doi:10.1016/j.apmr.2014.08.015
18. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil*. 2016;38(4):362-367. doi:10.3109/09638288.2015.1041615
19. Fini NA, Holland AE, Keating J, Simek J, Bernhardt J. How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis. *Phys Ther*. 2017;97(7):707-717. doi:10.1093/ptj/pzx038
20. Saunders DH, Mead GE, Fitzsimons C, et al. Interventions for reducing sedentary behaviour in people with stroke. *Cochrane Database Syst Rev*. 2018;2018(4). doi:10.1002/14651858.CD012996
21. Hendrickx W, Vlietstra L, Valkenet K, et al. General lifestyle interventions on their own seem insufficient to improve the level of physical activity after stroke or TIA: a systematic review. *BMC Neurol*. 2020;20(1):168. doi:10.1186/s12883-020-01730-3
22. Castilla Guerra L, Fernandez Moreno MC, Alvarez Suero J. [Non-pharmacological measures in the secondary prevention of atherothrombotic stroke of the elderly. Current status of the subject]. *Rev Clin Esp*. 2008;208(7):356-357.
23. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil*. 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764
24. Nicholson SL, Donaghy M, Johnston M, et al. A qualitative theory guided analysis of stroke survivors' perceived barriers and facilitators to physical activity. *Disabil Rehabil*. 2014;36(22):1857-1868. doi:10.3109/09638288.2013.874506
25. Michie S, Richardson M, Johnston M, et al. The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Ann Behav Med*. 2013;46(1):81-95. doi:10.1007/s12160-013-9486-6
26. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci*. 2011;6(1):42. doi:10.1186/1748-5908-6-42
27. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions*. Silverback Publishing Great Britain; 2014.

28. The EQUATOR Network | Enhancing the QUALity and Transparency Of Health Research. <https://www.equator-network.org/>. Accessed October 30, 2022.
29. Boeije H. *Analysis in Qualitative Research*. SAGE; 2010.
30. Holloway I, Wheeler S. *Qualitative Research in Nursing and Healthcare*. Wiley; 2013. <https://www.wiley.com/en-ma/Qualitative+Research+in+Nursing+and+Healthcare%2C+3rd+Edition-p-9781118713556>. Accessed February 21, 2020.
31. Fanchamps MHJ, van den Berg-Emons HJG, Stam HJ, Bussmann JBJ. Sedentary behavior: Different types of operationalization influence outcome measures. *Gait Posture*. 2017;54:188-193. doi:10.1016/j.gaitpost.2017.02.025
32. Hendrickx W, Riveros C, Askim T, et al. Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies. *Top Stroke Rehabil*. 2019;26(5):327-334. doi:10.1080/10749357.2019.1601419
33. English C, Healy GN, Coates A, Lewis LK, Olds T, Bernhardt J. Sitting time and physical activity after stroke: physical ability is only part of the story. *Top Stroke Rehabil*. 2016;23(1):36-42. doi:10.1179/1945511915Y.0000000009
34. Outermans J, Pool J, van de Port I, Bakers J, Wittink H. What's keeping people after stroke from walking outdoors to become physically active? A qualitative study, using an integrated biomedical and behavioral theory of functioning and disability. *BMC Neurol*. 2016;16(1):137. doi:10.1186/s12883-016-0656-6

Supplementary Material 1: Interview guide based on the Theoretical Domains Framework (TDF)

Introduction

Explanation of the interview + signing of informed consent

Opening: Start by referring to the start of the day before (the day for which the diary was kept);

1. Can you tell me about how that day started?
2. How do you feel about that day?

Follow-up and example questions:

1. Was yesterday a normal day when it comes to activities (sitting and physical activities [PA])? If not, what was different?
2. Has anything changed in your activities or movement pattern (sitting and PA) since your stroke? If so, what and how do you feel about that?

Capabilities

3. Do you need any help with activities? If so, can you tell me more about that?
4. What makes your activity/movement pattern (sitting and PA) look like this?
5. Is there anything limiting you in your activities? (physical limitations, memory, praxis etc., see table below)
6. How easy or hard is it to move and undertake your activities?
7. Is there anything that could make it easier?
8. Would you be able to change how much you move and/or sit? Can you tell more about this (why)?
9. Is there anything you need to help you make a change?

Motivation (in follow-up to what has not been covered by earlier questions)

10. What activities during the day do you like in particular? And what do you dislike?
11. What motivates you to do these activities? (referring to the diary and what has been said about the movement behavior)
12. Are you able to contribute to your environment (family, household, work, social) the way you want to? Why is that?
13. Has anything changed in your motivation since your stroke?
14. Is there anything you would like to change about your activities/ movement pattern (sitting and PA)? And why is that?
15. Do you have any (concrete) plans to make changes regarding sitting or moving? What are they and why do you want to make this change?

16. Do you think you will be able to make the change and why?
17. Is there anything you need to make a change? (if not completely covered)
18. Is physical activity important to you? Why is that? What motivates or stops you?
19. How do you feel about your health?
20. How do you think physical activity relates to (your) health?
21. How do you think sitting relates to health?
22. Looking at how much time you spend sitting (input activity monitor), do you think that influences your health and, if so, how?
23. Knowing about the health consequences of sitting and PA (info to be provided if needed), does this motivate you to change anything?

Opportunities (in follow-up to what has not been covered by earlier questions)

24. Is there anything you need or anything that needs changing for you to do the activities you want to do? (Practical/social/..)
25. Are there any activities that you cannot take part in? If so, why? (social or professional)
26. Are there enough opportunities for you to be active in your environment?
27. What did you think of wearing the activity monitor?
28. What would you need to make a change when it comes to sitting and/or moving? (refer to above, specifically practical/social)
29. Who could help you make that change?
30. What do you think of the feedback the activity monitor provides? (Could it help you move more and/or sit less?)
31. Would things like setting goals or action planning help you? (Could they help you move more and/or sit less?)
32. Is there any information, advice or support you need to move more and/or sit less?
33. Would someone supporting you to make changes help? (For instance a health care professional.)

Relevant items per domain

COM-B	Components Domains	Possibly relevant aspects in people with stroke
Capability	Physical	Functional abilities; ability to stand, walk etc.
	Physical skills	
	Psychological	Memory
	Knowledge	Communicative skills
	Cognitive and interpersonal skills	Concentration
	Memory, attention and decision processes	Mood
	Behavior Regulation	Praxis
Opportunity	Social	Role and/or interaction spouse, family, friends
	Social influences	Work (professional)
		Work (Volunteer)
		Social activities
	Physical	Living environment
	Environmental Context and Resources	Working environment
		Aids
		Time
Motivation	Reflective	Role or identity in work activities (professional or volunteer)
	Social or Professional Role and Identity	Role or identity within the household
	Beliefs about Capabilities	Confidence
	Optimism	Self-efficacy
	Intentions	Belief in health consequences
	Goals	
	Beliefs about consequences	
	Automatic	Role or identity in work activities (professional or volunteer)
	Reinforcement	Role or identity within the household
	Emotion	

Supplementary Materials 2: Table 2 Results per TDF Domain

COM-B	TDF Domain	Factor / construct
Capability	Physical skills	Physical limitations stroke-related <i>Physical limitations due to stroke influence physical activities</i> Several participants mention physical limitations, like loss of strength, impaired balance and reduced stamina related to stroke, which in some cases lead to limitations in, for instance, duration of walking outdoors, cycling or working in the garden and therefore a reduction in the amount of time spent in previous commonly practiced PA-related activities. Several people have indicated planning to increase their levels of PA gradually, for instance, with compensation strategies such as a walking aid, alternative activities or having someone accompany them for safety.
		Physical limitations due to comorbidities <i>Physical limitations due to comorbidities influence physical activities</i> Quite a few participants experienced physical limitations influencing their levels of PA, not related to stroke sequelae but to comorbidities such as osteoarthritis. Or even due to side-effects of medication such as beta-blockers.
Knowledge		Health risks <i>The risks related to movement behavior;</i> Most participants are aware of the importance of being physically active, mostly in relation to exercising and sports. The risk of sedentary time is known to a few but the importance of light physical activity is not known.
		Healthy movement behavior <i>The recommendations when it comes to physical activity and sedentary behavior:</i> Participants are not aware of what is needed to have healthy movement behavior when it comes to time spent sitting or being physically active. When people were asked what they think they can do to reduce their sedentary time, they often talk about MPVA options, such as cycling rather than LPA activities. The suggestion to increase the amount of LPA did seem feasible to these participants; it had simply not occurred to them.
		Personal movement behavior <i>Knowledge about what the participant's own movement behavior looks like</i> Participants are barely aware of their own movement behavior. Most underestimate the time spent sedentary. Participants do indicate that they want information about their own movement behavior and what needs to change, to enable them to improve their movement behavior by conscious regulation.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
	Cognitive and interpersonal skills	Impaired cognitive functions <i>Deficits in cognitive functions due to stroke</i> Participants report taking longer to perform cognitive tasks which are conducted while sitting; hence they spend more time being sedentary. Also, some participants mention needing to rest more often between physical tasks that include a cognitive component so as not to make mistakes, e.g. making sure they use a ladder safely, or getting fatigued due to by cognitive stimuli from the environment. Both factors limit the number of (physical) activities that can be undertaken in a day.
		Ideas to improve movement behavior <i>Participants seem able to come up with ways to improve movement behavior</i> When asked to suggest possible ways to adjust their movement behavior, several participants do have some ideas for improving PA or reducing sedentary time. Also, while reflecting on their daily routines, some realization of the high-risk moments develops.
	Memory, attention and decision processes	Neuropsychological function disorders <i>Deficits in neuropsychological functions due to stroke</i> Aspects such as impaired initiative, planning and memory are mentioned as effects of the stroke by some participants. This sometimes leads to limitations in daily tasks, such as (volunteer) work or household chores and thereby a decrease in physically active tasks and an increase in time spent sedentary.
	Behavior Regulation	Regulation of PA <i>Some regulate the amounts of PA, though how much is needed is not taken into account.</i> Some participants consciously plan activities, such as walking or cycling to improve their levels of PA. Only a couple of participants mention using devices that keep track of the numbers of steps taken and give feedback accordingly. Participants are not aware of how much is needed, for instance when it comes to time spent being physically active, and therefore the regulation is not related to the amount required to ensure a healthy movement behavior pattern. There are also participants who mention some regulation of PA, taking the view that is important to have sufficient rest between PA-related activities, leading to increased sedentary time. Regulation of Sedentary time <i>No regulation regarding sedentary time</i> None of the participants consciously regulated the amount of time spent sedentary or the duration of sedentary bouts in relation to healthy movement behavior. A few participants did mention consciously interrupting sedentary time to avoid joint stiffness; this was related to osteoarthritis. Participants emphasize the need for knowledge about personal movement behavior to enable conscious regulation. Behavior regulation capabilities <i>Participants' capabilities to regulate activities of daily living.</i> Participants are often able to regulate their activities, such as household tasks, social obligations or (volunteer) work and sometimes PA. A few, however, mention limitations in regulation due to impaired planning skills or loss of initiative as part of stroke sequelae. They expressed a need for support in regulating their behavior from their social environment or a health care professional. Some participants, whose regulation skills are not impaired, also mention that support in behavior regulation from a health care professional might be helpful in improving movement behavior. Being in control of their own movement behavior was deemed important if case support was given.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
Opportunity	Social influences	Social aspects of PA activities <i>Certain PA-related activities have a social component that is appealing</i> The social aspect of group physical activities, such as tennis, was viewed as a motivator to engage in these activities. Also, undertaking activities such as walking or cycling together with others was enjoyable and therefore stimulated the engagement in such activities.
		Social activities that stimulate sitting <i>Certain social activities are usually conducted sitting down</i> Participants mentioned that certain social activities, such as having visitors, leads to an increase in time spent sedentary.
		Attitude and support of social environment <i>The attitude of the social environment towards sitting, PA-related activities and the amount of support provided for PA-related activities influence the levels of PA</i> Some spouses mentioned a positive attitude towards sitting more and also some reinforce the belief that the participant is not all that sedentary. Also, a participant said he did not undertake certain physical activities, such as vacuuming or going out on his own often, due to fear expressed by the spouse. Another mentioned leaving the support in certain PA-related activities around the house from others in the family in place after recovery, leading to a reduction in daily PA-related activities. Some participants felt enabled by statements about movement behavior by healthcare professionals.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
	Environmental Context and Resources	Element that influence sedentary time <i>Certain environmental objects or settings influence the amount of time spent sedentary</i> Participants mention that the layout at home and/or at work is arranged for sitting while using a computer or watching television. This increases the amount of time spent sedentary unconsciously. Also, the availability of cars and scooters/mopeds was mentioned, objects that increase sedentary time. Elements that influence the levels of PA <i>Certain environmental objects or settings influence the levels of PA</i> Environmental objects or aspects like having stairs in the house, having a dog that needs walking or groceries being on sale in different shops lead to more time spent in PA. Also mentioned as being relevant are materials required to enable PA-related activities, such as a bike with a low setting to get on and off safely. The availability of sporting facilities was mentioned by a few participants as stimulating for PA, especially if costs were low or covered by health insurance. A few participants mentioned the weather as influencing the time they spent walking outdoors. Some believed that a health care professional coaching them to improve their movement behavior would be helpful. Also some participants expressed the need for someone to help them safely engage in certain physical activities. Devices to provide movement behavior feedback <i>Feedback on movement behavior is needed.</i> Participants have expressed the need for insight into their own movement behavior in order to be able to improve their behavior, for instance via a smart watch.
Motivation	Social or Professional Role and Identity	Loss of social or professional role. <i>Changes in of (volunteer) work or social tasks</i> Several participants mention a loss of (volunteer) work or social tasks due to, for instance, retirement or limitations as a result of stroke sequelae. PA-related activities conducted during work or social tasks are lost and in some cases replaced by sedentary activities. Social or professional role leading to PA <i>Certain professional or social tasks lead to an increase in PA</i> The role within the household or as caregiver was identified by participants as leading to physical activity. Also, one participant mentioned that volunteer work led to both structure and PA-related activities.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
	Beliefs about Capabilities	Beliefs in physical capabilities <i>Loss of confidence in being able to perform certain physical activities</i> Several participants have mentioned they no longer believe they are able to perform certain PA-related tasks, for instance due to fear of falling or believing that stamina/fitness was reduced, resulting in a reduction of these PA-related activities.
		Self-efficacy <i>Self-efficacy related to improving the levels of PA or reducing sedentary time</i> Several people have expressed the belief they are able to expand on certain PA-related activities or, with some help or adjustment, regain the ability to perform PA-related activities. When asked, several participants mentioned they believed they would be able to interrupt and reduce sedentary time if they set out to do so. A few participants did mention a lack of self-efficacy with regard to reducing sedentary time or improving PA.
	Optimism	Confidence <i>Perceived confidence in ability to increase PA and reduce sedentary time</i> Several participants are optimistic about their abilities to perform physical tasks, being able to reduce sedentary time or improve the amount of time engaged in physical activities. Other people are more pessimistic about their ability to improve their movement behavior, for instance because of lack of interest due to the stroke.
	Intentions	Improving the levels of PA <i>The intention to improve the levels of PA</i> Some participants have mentioned the intention to specifically increase the levels of PA (mostly MVPA) and have already thought of a plan of how to do so. Increase PA-related activities <i>The intention to increase activities with a PA component.</i> Some participants have mentioned that they are planning to increase or take up certain activities, such as volunteer work, that will lead to an increase in actions involving physical activity. Reduce sedentary time <i>The intention to reduce the time spent sedentary</i> When asked, a few participants do mention the intention to spend less time sedentary, although they have not formulated a concrete plan. Others have no previous intention to reduce sedentary time. Several participants did state their intention to change sedentary time, based on the information about their movement behavior from the activity monitor, worn the previous day. This information was provided during the interview and therefore the intention only originated during the interview. Some even formulated plans during the interview.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
	Goals	Concrete goals regarding movement behavior <i>Hardly any concrete goals were set to improve movement behavior</i> A few participants formulated more or less concrete goals to increase the levels of PA, such as increasing the time spent walking outdoors to 45 minutes, though most participants had no concrete goals to improve their PA and none mentioned goals to reduce sedentary time.
		Goal-setting <i>Goal-setting to support improving movement behavior</i> Several people mentioned that setting goals, either by themselves or with the support of a healthcare professional, was helpful in increasing the level of physical activities and reducing sedentary time. Setting concrete goals and planning activities was even mentioned as a way of compensating for loss of initiative to engage more in physical activity-related tasks.
		Beliefs about consequences Perceived health benefits <i>Beliefs about the importance of movement behavior for health</i> Several participants expressed their belief that PA was important for their health, also stating this as a motivator to engage in PA. When specifically asked, participants said they thought increased sedentary time reduces health, though no personal beliefs about sedentary time and health were mentioned. One participant mentioned the strong belief that their stroke was purely caused by a period of stress just before the stroke.
		Perceived other benefits <i>Beliefs about other benefits of PA</i> The belief that PA leads to improvements in vitality and feeling good was mentioned by some participants.
		Perceived risk of PA <i>The perceived risk of engaging in certain PA-related activities</i> Some participants said they believed that certain actions involving physical activity lead to increased risk of falling, which prohibits them from conducting that activity.

Supplementary Materials 2: Table 2 Results per TDF Domain (continued)

COM-B	TDF Domain	Factor / construct
	Emotion	Pain <i>Pain related to certain physical activities</i> Some participants have mentioned pain resulting from prolonged physical activities, such as long walks or strenuous work around the house, as a reason to reduce time spent in such activities. Pain was also identified as a factor related to reducing prolonged sitting: two participants with osteoarthritis interrupted their sedentary time to avoid pain and stiffness in joints.
		Negative emotions <i>Negative emotions that influence movement behavior</i> Emotions such fear of falling or straining oneself by physical activity and fatigue were mentioned as negatively influencing the time spent on PA and/or sedentary. One participant mentioned feeling guilty if he/she left the (active) household chores to others.
		Joy <i>Joy as a positive emotion brought on by sedentary activities</i> Finally, enjoyment of activities such as reading, usually conducted sitting down, were mentioned as a reason to conduct these activities and thereby increase time spent sedentary. Enjoyment perceived during activities that include PA were also mentioned, such as nice weather. An anticipated positive emotion was the pride on achieving goals set to improve movement behavior.
		Reinforcement <i>Emotions and experiences as a reinforcing factor for time spent on PA and/or sedentary</i> Participants mentioned negative experiences or emotions related to PA, such as (fear of) falling, pain, fatigue (both cognitive and physical), as a reinforcing factor, decreasing the time spent on such activities. Also the ease of using passive aids and the joy obtained from activities often conducted sitting down, such as watching television was mentioned. On the other hand, some participants with osteoarthritis mentioned interrupting their sedentary time to avoid pain and stiffness in joints.
		Habits <i>Automated activities influencing movement behavior</i> Automatic activities and habits are mentioned as influencing time spent on PA or sedentary. Activities related to PA and to sedentary time during the day are, for the most part, conducted on the basis of motivators other than movement behavior itself. They are mentioned as a matter of habit, part of the daily routine. For instance, the need to do household chores or going for a walk or bike ride with someone from the social environment; or the habit of sitting down when people come to visit, or while reading or a sedentary work environment. Some participants specifically stated that due to changes in physical capabilities, physically active activities had been replaced by sedentary ones, without giving this much thought.



CHAPTER 6

RISE, a blended behavioural intervention
to support people to reduce and
interrupt their sedentary behaviour.

Wendy Hendrickx & Roderick Wondergem
Coralie English
Johanna M.A. Visser-Meily
Cindy Veenhof
Martijn F. Pisters

Under review

Abstract

Introduction: Research has shown that sedentary behaviour increases the risk of stroke, cardiovascular disease, and mortality. Most people with stroke are highly sedentary and inactive and are at high risk of recurrent stroke and other cardiovascular diseases. Therefore, strategies to reduce sedentary behaviour in this population are needed. Currently, interventions reducing sedentary behaviour aiming for sustainable behavioural change are lacking in people with stroke.

Objective: This study aimed to develop an innovative intervention to support community-dwelling people with stroke who are highly sedentary and inactive to sustainably reduce and interrupt their sedentary behaviour.

Methods: The intervention development process was guided by the Behaviour Change Wheel. Three stages were distinguished: Stage 1: Understanding the behaviour, Stage 2: Identifying intervention functions and Stage 3: Identifying behaviour change techniques and modes of delivery. The intervention and digital delivery system was co-created with people with stroke and their relatives, physiotherapists, (inter)national behavioural and movement behaviour experts, people with previous experience developing blended interventions, hard and software developers, and technical experts.

Results: The RISE intervention is a 15-week blended behavioural intervention in which a primary care physiotherapist coaches participants to reduce and interrupt their sedentary time. Physiotherapists provide personalised coaching to people with a stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, 3) a monitoring dashboard for the physiotherapist. Participants receive participatory support from someone from their social network (e.g., a partner or close friend) who joins them in the intervention.

Conclusion: This study used a co-design process to develop the RISE intervention, which was developed together with relevant stakeholders. It is a blended behavioural intervention, and further research will be conducted to assess its preliminary effectiveness and feasibility as well as determine the added value of participatory support.

Introduction

Globally, stroke affects 13 million individuals every year, and its incidence continues to increase. People who have suffered a stroke are at high risk of recurrent stroke and other cardiovascular diseases.^{1–4} In the first year after stroke, up to 25% will have another major cardiovascular event.⁴ The importance of lifestyle, such as sufficient physical activity levels, is well known.^{5–7} Sedentary behaviour is another part of movement behaviour across the day and is defined as ‘any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task while in a sitting, reclining, or lying posture’.^{8,9} High amounts of sedentary behaviour, especially when accumulated in prolonged bouts (>30 min), increase the risk of cardiovascular diseases, including stroke.^{10–19}

Over seventy-five percent of people with stroke are highly sedentary and inactive.^{20–24} Reducing total sedentary time reduces modifiable risk factors for secondary stroke, including hypertension and impaired glucose tolerance.^{15,17,25} Furthermore, interrupting sedentary behaviour may lead to clinically relevant reductions in blood pressure in people with stroke.²⁶ Therefore, reducing and interrupting sedentary behaviour may benefit people with stroke by maintaining functions and reducing the risk of recurrent stroke and premature death.^{15,19,27–29} The advice to improve movement behaviour, including reducing and interrupting sedentary behaviour, is part of current secondary prevention guidelines.^{5,6,27}

Within post-stroke care, the main focus is to regain physical and cognitive capabilities to reduce functional limitations in daily living.^{30,31} Additional attention for improving movement behaviour, including reducing and interrupting sedentary behaviour, seems appropriate given the high risk of recurrent stroke.^{1–4} In particular since, proven effective interventions that aim to improve sedentary behaviour are lacking.³² The American Heart Association/American Stroke Association recommends developing and testing interventions to promote active lifestyles, including reducing and interrupting sedentary time, for secondary prevention in people with stroke and TIA.⁶ It is recommended that such interventions include behavioural change techniques that empower people towards sustainable behavioural change.^{32,33} Tailoring the intervention to the individual improves adherence, uptake and sustainable behaviour change in people with stroke.³⁴

Physiotherapists are often involved in post-stroke care and are experts on physical capabilities, they also aim to support sufficient levels of moderate to vigorous physical activity after stroke.³⁰ Since reducing and interrupting sedentary behaviours means replacing it with (light, moderate or vigorous) physical activity, their involvement in interventions could be beneficial. The literature also indicates this perception regarding

lifestyle interventions.³⁵ Currently, there are no evidence-based interventions for reducing and interrupting sedentary behaviour in people with stroke living in the community who are highly sedentary and inactive.³² This study aims to develop an innovative physiotherapeutic intervention to support community-dwelling people with stroke who are highly sedentary and inactive to sustainably reduce and interrupt their sedentary behaviour.

Methods

To co-create and develop the intervention, we used the Behaviour Change Wheel (BCW).^{36–38} The BCW is a step-by-step, theory-based approach to developing behaviour change interventions. It is based on all existing behaviour change frameworks and theories (see Figure 1).^{36,37} At the base is the behaviour model COM-B, i.e., Capability (physical and psychological), Opportunity (social and physical), Motivation (automatic and reflective) and Behaviour. This is further specified in the Theoretical Domains Framework, which consists of 14 domains that cover the three COM-B categories (Figure 1). From there, the intervention functions, the behaviour change techniques and the modus of delivery were determined to support sustainable behaviour change.^{36–38} The development approach consisted of three stages: 1) understanding the behaviour, 2) identifying the intervention options, and 3) identifying content and implementation options (see supplementary materials 2, Figure 2). Figure 2 outlines the stages of intervention development of the BCW as conducted within our study. Co-creation with relevant stakeholders was a crucial element in each stage to optimize the fit of the intervention and the uptake and achieve more sustainable results.^{39,40} Relevant stakeholders included people with stroke and their relatives, physiotherapists, (inter)national behavioural and movement behaviour experts, people with previous experience developing blended interventions, hard and software developers, and technical experts.

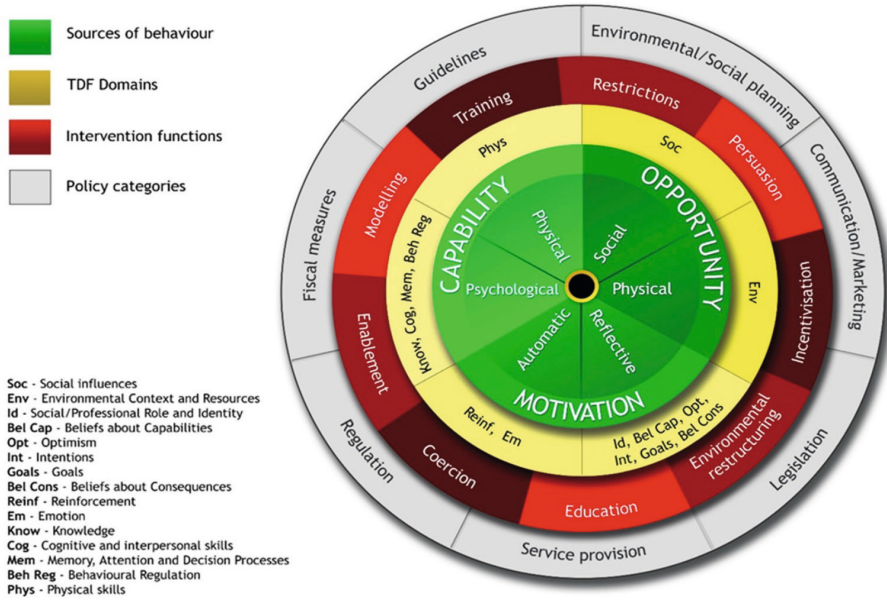


Figure 1. The behaviour change wheel and Theoretical Domains Framework. Reprinted with permission from Michie et al. (Michie et al., 2011).³⁶

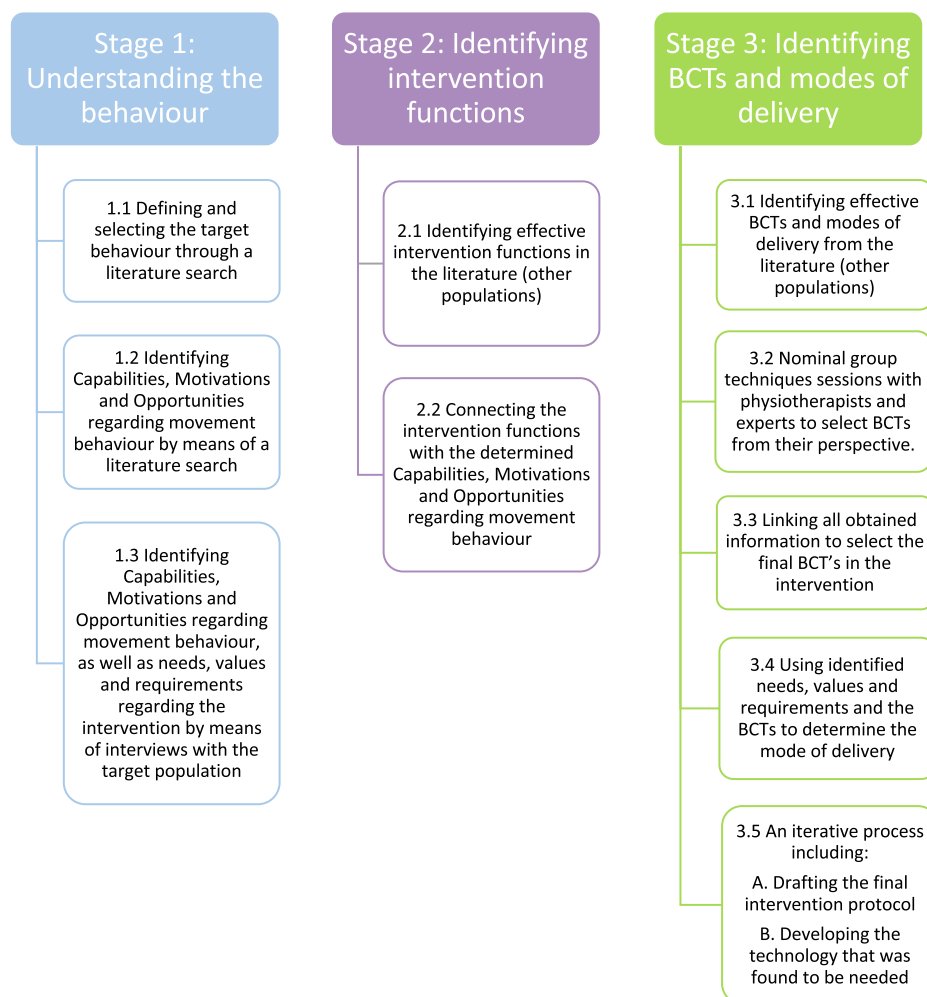


Figure 2. Stages of the Behaviour Change Wheel and the conducted development steps for each stage.³⁶

Stage 1: Understanding the behaviour

Stage 1 consists of 3 steps to understanding the behaviour (see Figure 2). In stage 1.1, the research team defined the target behaviour based on the existing literature. The research team (n=6) consisted of experts in stroke, rehabilitation, physiotherapy, movement behaviour, and/or behavioural change. A targeted literature review (stage 1.2) was undertaken to identify barriers and facilitators influencing sedentary behaviour in people with stroke (see supplementary material 2, Table 1 for the search terms used in PubMed and CINAHL) or in non-stroke populations if insufficient evidence was available. The

barriers and facilitators identified were mapped to the COM-B model and the Theoretical Domains Framework (TDF) (see supplementary materials 2, Table 1) by WH and RW. To further explore Capabilities, Opportunities and Motivation more fully, semi-structured interviews with people with stroke who were highly sedentary and inactive were conducted (stage 1.3), the methods and results of which have been published elsewhere.⁴¹ Within the interviews, we also identified any needs, values and requirements regarding the intervention (stage 1.3).

Stage 2: Identifying intervention functions

Stage 2 was conducted to identify the intervention functions to be included. In the third layer of the BCW, nine intervention functions are distinguished (Education, Persuasion, Incentivisation, Coercion, Training, Enablement, Modelling, Environmental Restructuring, and Restrictions, see Figure 1).^{36–38} Another literature search was performed to identify effective intervention functions (stage 2.1) to support changing sedentary behaviour. The literature search was not limited to the stroke populations because no literature was available in people with stroke (search terms are presented in supplementary materials 3, Table 1). Effective intervention functions were retrieved from the literature by WH and RW. First independently, then consensus was reached via discussion. The identified effective intervention functions were connected to Capabilities, Motivation and Opportunities (stage 1) influencing sedentary behaviour by WH and RW to determine the intervention functions to be included (stage 2.2).

Stage 3: Identifying behaviour change techniques and modes of delivery

Behaviour change techniques (BCTs) are the observable, replicable, irreducible, and active components of an intervention to change behaviour.^{36–38} Determining effective BCTs and modalities of delivery was an extension of the literature review as described in stage 2. An overview was made of BCTs that were found to be effective or not effective, with conflicting evidence or no evidence to reduce sedentary behaviour. International experts (n=5) and physiotherapists (n=6) selected what they believed were the essential BCTs to reduce sedentary and interrupt sedentary behaviour in people with stroke within Nominal Group Technique (NGT) sessions (stage 3.2).⁴² The physiotherapists were working with people with stroke in a hospital, rehabilitation centre, or private practice. The international experts were from the field of behavioural change, stroke, and/or movement behaviour. Participants received an overview of all BCTs before the interview or NGT sessions. There were no a priori restrictions to selecting the BCTs, although they did receive information on effectiveness from the literature search. Then, participants were asked individually to identify possible relevant BCTs supporting community-dwelling people with stroke to reduce and interrupt sedentary behaviour. Then, these possible BCTs were shared and

discussed, and finally, participants chose and ranked the eight most essential BCTs.⁴² The scores of the individuals were summed, resulting in an overview of the critical BCTs to reduce sedentary behaviour. The information from the literature, interviews and the NGT sessions was combined to determine the intervention's final intervention functions, BCTs, and modes of delivery (stages 3.3 and 3.4).

The selected BCTs and modes of delivery called for the development of monitoring, feedback and coaching technology. To develop this technology in a thorough manner, we used the CeHRes roadmap (stage 3.5.B.).⁴³ This model is specifically for designing eHealth technology and is based on business modelling, persuasive design, participatory design, and human-centred design principles (supplementary materials 2, figure 3).^{40,43} All stakeholders must be part of the intervention's development to improve the uptake and effect.⁴⁰ An iterative process with end-users and experts followed, specifying and designing the technological system. Two focus groups with people with stroke and their spouses were conducted, and experts were consulted to develop the prototype of the technological system. Scenario-based think-aloud and cognitive walkthroughs were undertaken to finalize the technological prototype.

The development of the technology was done in an iterative process that was combined with drafting the actual intervention protocol (stage 3.5.A.), following the different phases of behavioural change as described in the HAPA model.⁴⁴ Which starts with the creation of intention to change, followed by action/coping planning and, finally, with action initiation and maintenance (supplementary materials 6, Figure 1).⁴⁴ The final intervention protocol was included in the scenario-based think-aloud and cognitive walkthrough sessions to ensure that it met end-users' needs.⁴⁵

Results

The development process led to the RISE intervention (Figure 3), a 15-week blended behavioural intervention, in which a primary care physiotherapist coaches participants to reduce and interrupt their sedentary time. Physiotherapists provide personalised coaching to people with stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, 3) a monitoring dashboard for the physiotherapist. Participants received participatory support from someone from their social network (e.g., a partner or close friend) who joined them in the intervention. The core behaviour change techniques of the intervention are *goal-setting (on behaviour and outcome), action planning, social support, self-monitoring on*

behaviour, feedback on behaviour, the discrepancy between current behaviours and goals, information about health consequences, problem-solving, restructuring the social environment, prompts and cues, habit formation, and instructions on how to perform the behaviour. The modes of delivery are face-to-face meetings with a coach (physiotherapist), an activity monitor to measure sedentary behaviour and physical activity, an application to provide real-time feedback and sign-in the behaviour. These modes of delivery necessitated the development of the RISE e-coaching system. Below, a more detailed description of the intervention is given. For the results of the different development stages leading up to the final intervention, we refer to the supplementary materials. The supplementary materials contain a written summary and include the result tables of different development stages. The description in supplementary materials one will guide the reader through the different supplementary materials.

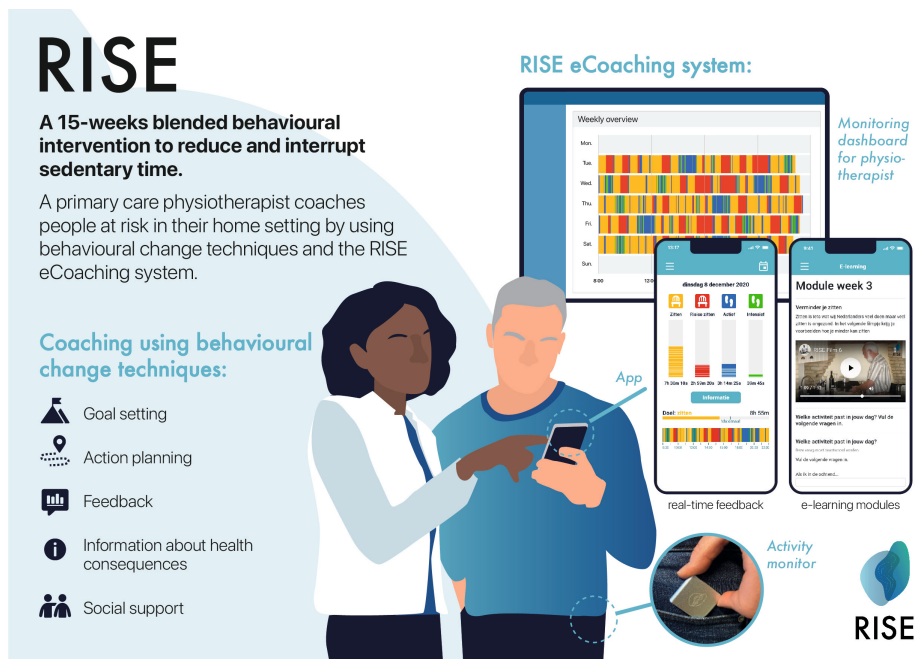


Figure 3. The RISE intervention

The RISE Intervention

During the 15 weeks, ten face-to-face sessions are planned in the participant's home setting (with increasing intervals). Motivational interviewing techniques form the basis of the coaching sessions. Although the intervention has a protocol with prescribed topics, see Table 1 (for extensive description see supplementary materials 6, Table 1), and key BCTs following the HAPA model sequences (from intention, motivation, goal

setting and action planning phase towards action and maintenance phase),⁴⁴ the RISE coaching intervention is individually tailored to the personal needs and circumstances. The physiotherapist first conducts a behavioural analysis with the individual participant using the COM-B model. Based on this information, the intervention can be tailored. Every session starts with a reflection on the movement behaviour pattern of the previous week, identifying possibilities for change and reviewing the goals and action plans followed by the prescribed topic for that week when appropriate; see Table 1 for the outline of the intervention per week.

With social support identified as highly important, Participatory Support, an intensive form of social support, is included in the RISE intervention.^{46,47} This means that someone from the participants' direct social network (with contact at least twice a week), such as their partner, a close friend or a relative, joins them in the intervention as a buddy to provide meaningful support. They will be present at the face-to-face sessions with the physiotherapist and receive the RISE system. The participants' buddy will gain insight into relevant self-management information (e.g., why reducing and interrupting sedentary time and increasing physical activity is essential in people with stroke), the individual goals of the participant, and how to provide meaningful support.

Table 1. The sequence of the RISE intervention with the mode of delivery and delivered topics.

Week	Mode of delivery	Topics
1	Face-to-face (meeting 1)	Introduction of the RISE intervention
	eCoaching	Benefits of sitting less (1)
2	Face-to-face (meeting 2)	Making a behavioural diagnosis
	eCoaching	Benefits of sitting less (2)
3	Face-to-face (meeting 3)	Self-monitoring
	eCoaching	What is self-monitoring
4	Face-to-face (meeting 4)	Action planning and goal setting
	eCoaching	Cues and memories
5	Face-to-face (meeting 5)	Building social support
	eCoaching	Preservation of self-efficacy
6	Face-to-face (meeting 6)	Building confidence to avoid sitting
7	eCoaching	Mapping your own behaviour and social environment
8	Face-to-face (meeting 7)	Introduction relapse
9	eCoaching	Creating Habit and Coping Planning
10	Face-to-face (meeting 8)	Creating a habit and relapse
11	eCoaching	Sustainable behavioural change
12	Face-to-face (meeting 9)	Self-monitoring in the future
13-14	eCoaching	Planning specific actions and coping planning for the future
15	Face-to-face (meeting 10)	Future proof

RISE eCoaching system

The RISE system contains an activity monitor, a smartphone application for the participant and a dashboard for the physiotherapist. The RISE activity monitor (see Figure 3) is based on the Activ8 activity monitor, a valid tool for community ambulatory people with stroke.^{48,49} The RISE activity monitor is a 3-axial accelerometer and must be worn in a pocket at the height of the thigh or with a leg strap. The RISE activity monitor detects sedentary behaviour, prolonged sedentary behaviour (accumulated in bouts > 30 minutes), light physical activity (LPA) and moderate to vigorous physical activity (MVPA). The RISE monitor is connected to the participants' smartphone via Bluetooth and can provide prompt cues. After 25 minutes of sedentary time, the RISE monitor can provide a tactile cue by vibration to remind the participant. This can be switched on and off in the RISE application.

The RISE smartphone app contains four screens/functions. The first screen (see Figure 4) provides an overview of the levels of movement behaviour (sedentary behaviour, prolonged sedentary behaviour, LPA and MVPA) and the accumulation pattern of the current day (swipe to see previous days), including the goal set. An optional goal for the upcoming week is automatically generated based on the movement behaviour from the previous week, and the eventual goal is set by the physiotherapist together with the participant. This information is also displayed in the dashboard of the physiotherapist (see Figure 4), which is used to set the goal. The second screen, the Trend line, shows the levels from the start of the intervention to the present; by swiping, the participant can switch between sedentary behaviour and physical activity. The third screen of the app is the concrete action plan for the upcoming week, which is also filled out via the dashboard. The final screen contains the e-learning modules with the topics presented in Table 1. Additionally, participants receive questions to reflect on their personal situation. The physiotherapist can see the participant's answers in the dashboard application. Within the dashboard, there is a behavioural diagnosis tool to determine the most important facilitators and barriers for the specific individual.

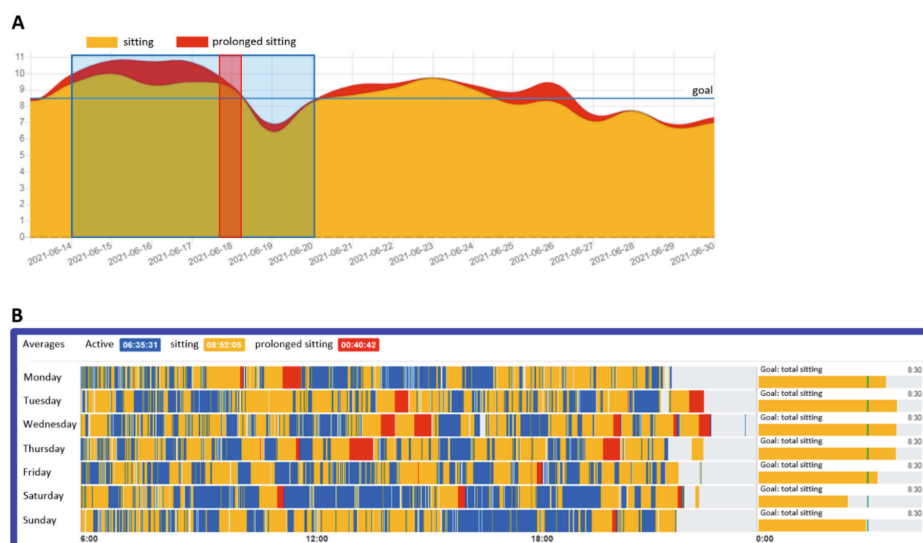


Figure 4. RISE Dashboard with the overview of an individual's movement behaviour. 4A Trend of sedentary behaviour. 4B. Movement behaviour during the week with mean values of sitting, prolonged sitting and activity, and sedentary behaviour goal.

Discussion

In this study, we designed the RISE intervention, a blended behavioural intervention to support community-dwelling people with stroke who are highly sedentary and inactive. The results of this co-creation design process, using the stages of the BCW, showed the need for an intervention including a core of thirteen behaviour change techniques. The RISE intervention is delivered via face-to-face coaching sessions delivered by a physiotherapist in the participant's home setting and uses a technological eCoaching system to give real-time feedback, show the set goals and action plan, and provide e-learning modules. Within the intervention, participants receive participatory support from someone from their social network (e.g., a partner or close friend) who joins them in the intervention to facilitate changes, encourage support, increase enjoyment and provide greater accountability for a more active lifestyle.

To develop the RISE intervention, we used the behaviour change wheel methodology.^{36–38} This comprehensive methodology led to the BCTs included in the intervention. Key BCTs were, for instance, goal setting, action planning, social support and feedback on behaviour. New systematic reviews have looked at sedentary behaviour change strategies in cardiovascular diseases and clinical populations.^{50,51} Although they concluded that

further research is needed to determine which BCTs are most effective, they also found that goals and action planning, feedback and social support might be promising.^{50,51}

Two pilot studies on sedentary behaviour interventions in people with stroke showed the need for further research to effectively support reducing sedentary behaviour.^{52,53} When comparing the intervention content, we see that providing information about health consequences and general goals was included. The one study that found some preliminary effects regarding sedentary time post-intervention (no significant effects were left at 8 weeks follow-up) also included (general) goal setting and feedback on step counts. The step count was not specified in the RISE e-coaching system because standing is also part of (light) physical activity. The more extensive behaviour change techniques, such as weekly personalised goal setting and action planning, problem-solving and detailed real-time feedback regarding sedentary behaviour patterns provided within the RISE eCoaching system, are novel.

A blended intervention seems warranted with the BCTs and modes of delivery selected within the design process. The 'STARFISH' trial,⁵⁴ which primarily focused on physical activity (walking) in people with stroke, was the only other intervention with a blended character and showed promising results. A smartphone app and activity monitor can be helpful in reducing sedentary behaviour.^{12,55} Activity monitors are vital to gain insight into individual behaviour and give real-time feedback on behaviour.¹ Self-monitoring or using a mobile self-management application independently showed only short-term effects.¹² In contrast, monitoring and/or self-management applications integrated into supervised face-to-face coaching showed better sustainable behavioural change effects.³² This finding matches what has been identified as necessary to support people with stroke to reduce and interrupt their sedentary behaviour in our studies. Further research should investigate the intervention's feasibility in the stroke population since cognitive complaints are prevalent after stroke and show if it is indeed feasible for people with different educational backgrounds. Furthermore, behavioural interventions are relatively new within physiotherapy care. Therefore, the skill level of physiotherapists delivering the intervention needs to be addressed before the intervention can be delivered. This will be included in the next steps to determine the preliminary effectiveness and feasibility of the RISE intervention.

Within the design process, both literature and interviews with highly sedentary and inactive people with stroke showed the importance of the social and physical environment and social support.^{33,41} With sedentary behaviour patterns being highly dependent on habits and routines, involving someone from the direct social network (e.g., a partner, relative or close friend) seems necessary to address this aspect and enable sustainable

behaviour change. Participatory support is a fairly extensive form of social support, and although promising,^{46,47} it demands a certain amount of engagement of someone from the social network of the person with a stroke. Therefore, the feasibility and added value of participatory support will be examined in our future research.

Strengths and limitations

A strength is that we used the BCW stages to account for all aspects related to sedentary behaviour, thereby creating a comprehensive intervention for sustainable behaviour change. Additionally, the CeHRes roadmap was used to develop the RISE system for the thorough development of the technology identified as needed within the intervention design. Another strength of this study is that the intervention was developed in co-creation with relevant stakeholders, including end-users and experts. With this approach, we tried to overcome problems with the uptake and implementation of interventions at a later stage. Future research to determine actual implementation strategies is needed.

Our intervention development included a co-design involving people with stroke and their relatives and physiotherapists. It could be that different Capabilities, Opportunities, and Motivations might be present in other countries. This should be taken into account when generalizing our findings to other countries.

Conclusion

The RISE intervention aims to support people with stroke who are highly sedentary and inactive to reduce and interrupt their sedentary behaviour. It is a blended behavioural intervention that integrates face-to-face coaching by a physiotherapist and eCoaching using the RISE eCoaching system and includes participatory support provided by someone from the participant's social network (e.g., partner or close friend) who joins them in the RISE intervention. Further research will be conducted to assess its preliminary effectiveness and feasibility as well as to determine the added value of participatory support.

References

1. GBD 2016 Stroke Collaborators. Global, regional, and national burden of stroke, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol.* 2019;18(5):439-458. doi:10.1016/S1474-4422(19)30034-1
2. Pennlert J, Eriksson M, Carlberg B, Wiklund P-G. Long-term risk and predictors of recurrent stroke beyond the acute phase. *Stroke.* 2014;45(6):1839-1841. doi:10.1161/STROKEAHA.114.005060
3. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke.* 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
4. Carlsson A, Irewall A-L, Graipe A, Ulvenstam A, Moos T, Ögren J. Long-term risk of major adverse cardiovascular events following ischemic stroke or TIA. *Sci Rep.* 2023;13(1):8333. doi:10.1038/s41598-023-35601-x
5. Feigin VL, Barker-Collo S, Krishnamurthi R, Theadom A, Starkey N. Epidemiology of ischaemic stroke and traumatic brain injury. *Best Pract Res Clin Anaesthesiol.* 2010;24(4):485-494. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L360073169>.
6. Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association. *Stroke.* 2021;52(7). doi:10.1161/STR.0000000000000375
7. Perk J, De Backer G, Gohlke H, et al. European Guidelines on cardiovascular disease prevention in clinical practice (version 2012). The Fifth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of nine societies and by invited experts). *Eur Heart J.* 2012;33(13):1635-1701. doi:10.1093/eurheartj/ehs092
8. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act.* 2017;14(1):75. doi:10.1186/s12966-017-0525-8
9. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev.* 2008;36(4):173-178. doi:10.1097/JES.0b013e3181877d1a
10. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet.* 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
11. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ.* 2019;366:l4570. doi:10.1136/bmj.l4570
12. van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med.* 2012;172(6):494-500. doi:10.1001/archinternmed.2011.2174

13. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338-1353. doi:10.1093/ije/dys078
14. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-132. doi:10.7326/M14-1651
15. Bauman AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep*. 2013;7(4):293-298. doi:10.1007/s12170-013-0316-y
16. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
17. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-666. doi:10.2337/dc07-2046
18. Benatti FB, Ried-Larsen M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Med Sci Sports Exerc*. 2015;47(10):2053-2061. doi:10.1249/MSS.0000000000000654
19. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity (Silver Spring)*. 2015;23(9):1800-1810. doi:10.1002/oby.21180
20. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behavior Patterns in People With First-Ever Stroke. *Stroke*. 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
21. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. *Phys Ther*. 2016;96(2):193-201. doi:10.2522/ptj.20140522
22. Tiegies Z, Mead G, Allerhand M, et al. Sedentary behavior in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil*. 2015;96(1):15-23. doi:10.1016/j.apmr.2014.08.015
23. Paul L, Brewster S, Wyke S, et al. Physical activity profiles and sedentary behaviour in people following stroke: a cross-sectional study. *Disabil Rehabil*. 2016;38(4):362-367. doi:10.3109/09638288.2015.1041615
24. Fini NA, Holland AE, Keating J, Simek J, Bernhardt J. How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis. *Phys Ther*. 2017;97(7):707-717. doi:10.1093/ptj/pzx038
25. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev*. 2010;38(3):105-113. doi:10.1097/JES.0b013e3181e373a2
26. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: Breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke*. 2018;13(9):932-940. doi:10.1177/1747493018798535
27. Bell AC, Richards J, Zakrzewski-Fruer JK, Smith LR, Bailey DP. Sedentary Behaviour—A Target for the Prevention and Management of Cardiovascular Disease. *Int J Environ Res Public Health*. 2022;20(1):532. doi:10.3390/ijerph20010532

28. Manns PJ, Dunstan DW, Owen N, Healy GN. Addressing the nonexercise part of the activity continuum: a more realistic and achievable approach to activity programming for adults with mobility disability? *Phys Ther.* 2012;92(4):614-625. doi:10.2522/ptj.20110284
29. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab.* 2010;35(6):725-740. doi:10.1139/H10-079
30. Koninklijk Nederlands Genootschap voor Fysiotherapie. KNGF-richtlijn Beroerte. 2017. www.kngfrichtlijnen.nl.
31. Living stroke guidelines | Stroke Foundation - Australia. <https://strokefoundation.org.au/what-we-do/for-health-professionals/living-stroke-guidelines>. Accessed July 19, 2023.
32. Saunders DH, Mead GE, Fitzsimons C, et al. Interventions for reducing sedentary behaviour in people with stroke. *Cochrane Database Syst Rev.* 2018;2018(4). doi:10.1002/14651858.CD012996
33. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil.* 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764
34. Kim J, Thrift AG, Nelson MR, Bladin CF, Cadilhac DA. Personalized medicine and stroke prevention: Where are we? *Vasc Health Risk Manag.* 2015;11:601-611. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L607202492>.
35. Hendrickx W, Vlietstra L, Valkenet K, et al. General lifestyle interventions on their own seem insufficient to improve the level of physical activity after stroke or TIA: a systematic review. *BMC Neurol.* 2020;20(1):168. doi:10.1186/s12883-020-01730-3
36. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions*. Silverback Publishing Great Britain; 2014.
37. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011;6(1):42. doi:10.1186/1748-5908-6-42
38. Michie S, Richardson M, Johnston M, et al. The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Ann Behav Med.* 2013;46(1):81-95. doi:10.1007/s12160-013-9486-6
39. Farao J, Malila B, Conrad N, Mutsvangwa T, Rangaka MX, Douglas TS. A user-centred design framework for mHealth. *PLoS One.* 2020;15(8):e0237910. doi:10.1371/journal.pone.0237910
40. Santana MJ, Manalili K, Jolley RJ, Zelinsky S, Quan H, Lu M. How to practice person-centred care: A conceptual framework. *Health Expect.* 2018;21(2):429-440. doi:10.1111/hex.12640
41. Hendrickx W, Wondergem R, Pisters MF, et al. It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive. *Submitt to peer Rev J.* 2023.
42. Delbecq A, Ven A Van de, Gustafson D. Group techniques for program planning: A guide to nominal group and Delphi processes. 1975. <https://eduq.info/xmlui/handle/11515/11368>. Accessed July 19, 2023.

43. van Gemert-Pijnen JEW, Nijland N, van Limburg M, et al. A holistic framework to improve the uptake and impact of eHealth technologies. *J Med Internet Res*. 2011;13(4):e111. doi:10.2196/jmir.1672
44. Schwarzer R. Modeling Health Behavior Change: How to Predict and Modify the Adoption and Maintenance of Health Behaviors. *Appl Psychol*. 2008;57(1):1-29. doi:10.1111/j.1464-0597.2007.00325.x
45. Jaspers MWM. A comparison of usability methods for testing interactive health technologies: methodological aspects and empirical evidence. *Int J Med Inform*. 2009;78(5):340-353. doi:10.1016/j.ijmedinf.2008.10.002
46. Albert NM, Forney J, Slifcak E, Sorrell J. Understanding physical activity and exercise behaviors in patients with heart failure. *Hear Lung*. 2015;44(1):2-8. doi:10.1016/j.hrtlng.2014.08.006
47. Lindsay Smith G, Banting L, Eime R, O'Sullivan G, van Uffelen JGZ. The association between social support and physical activity in older adults: a systematic review. *Int J Behav Nutr Phys Act*. 2017;14(1):56. doi:10.1186/s12966-017-0509-8
48. Fanchamps MHJ, Horemans HLD, Ribbers GM, Stam HJ, Bussmann JBJ. The Accuracy of the Detection of Body Postures and Movements Using a Physical Activity Monitor in People after a Stroke. *Sensors (Basel)*. 2018;18(7). doi:10.3390/s18072167
49. Medical physical activity monitors & motion tracking solutions - Activ8. <https://www.activ8all.com/>. Accessed February 21, 2020.
50. Patterson K, Davey R, Keegan R, Kunstler B, Woodward A, Freene N. Behaviour change techniques in cardiovascular disease smartphone apps to improve physical activity and sedentary behaviour: Systematic review and meta-regression. *Int J Behav Nutr Phys Act*. 2022;19(1):81. doi:10.1186/s12966-022-01319-8
51. Martín-Martín J, Roldán-Jiménez C, De-Torres I, et al. Behavior Change Techniques and the Effects Associated With Digital Behavior Change Interventions in Sedentary Behavior in the Clinical Population: A Systematic Review. *Front Digit Heal*. 2021;3:620383. doi:10.3389/fdgth.2021.620383
52. Ezeugwu VE, Manns PJ. The Feasibility and Longitudinal Effects of a Home-Based Sedentary Behavior Change Intervention After Stroke. *Arch Phys Med Rehabil*. 2018;99(12):2540-2547. doi:10.1016/j.apmr.2018.06.014
53. English C, Healy GN, Olds T, et al. Reducing Sitting Time After Stroke: A Phase II Safety and Feasibility Randomized Controlled Trial. *Arch Phys Med Rehabil*. 2016;97(2):273-280. doi:10.1016/j.apmr.2015.10.094
54. Paul L, Brewster S, Wyke S, et al. Increasing physical activity in older adults using STARFISH, an interactive smartphone application (app); a pilot study. *J Rehabil Assist Technol Eng*. 2017;4:2055668317696236. doi:10.1177/2055668317696236
55. Patterson K, Davey R, Keegan R, Freene N. Smartphone applications for physical activity and sedentary behaviour change in people with cardiovascular disease: A systematic review and meta-analysis. *PLoS One*. 2021;16(10):e0258460. doi:10.1371/journal.pone.0258460

Supplementary Materials 1: Description results stage of development

Stage 1: Understanding the behaviour

Two targets regarding sedentary behaviour were selected (stage 1.1): reducing the total sedentary time and increasing the interruption of sedentary time.¹⁻¹² All facilitators and barriers identified from the literature (stage 1.2) were categorized into the COM-B model and the Theoretical Domains Framework and can be found in Table 1 (at the end of this document).

The characteristics of the participants from the interviews (stage 1.3) with people with stroke who were highly sedentary and inactive, is shown in Supplementary Materials 5, Tables 1 and 2. Figure 1 provides an overview of all aspects identified regarding capabilities, opportunities and motivations for sedentary behaviour in daily life. Important factors were identified within the domains of psychological capabilities regarding knowledge of one's own movement behaviour, including sedentary behaviour; people were not aware of levels, nor the risk their behaviour pattern confers. Additionally, related to this lack of awareness, there was a lack of behaviour regulation. Movement behaviour was for the most part determined by reinforcing factors from the social and physical environment and thus based on habits and daily routines. The results also showed individual differences in the influence factors such as physical limitations, had on movement behaviour. Details on the results and conclusions of the interviews can be found elsewhere.¹³



Figure 1. Results from interviews of people with stroke: reprint, details published elsewhere.¹³

Stage 2: Identify intervention functions

No evidence was found regarding specific intervention functions for reducing sedentary behaviour in people with stroke. Three systematic reviews that focused on reducing sedentary behaviour in the general population were identified.^{14–16} The following intervention functions (stage 2.1) were found to be effective and relevant: persuasion, incentivization (according to one study), training, environmental restructuring, and restriction. Table 1 (at the end of this document) shows how the identified intervention functions are associated with the determined capabilities, motivation and opportunities influencing sedentary behaviour (stage 2.2).

Stage 3: Identify behaviour change techniques and modes of delivery

In terms of BCTs and modes of delivery specific to reducing sedentary behaviour in people with stroke (stage 3.1), only one qualitative study was identified.¹⁷ The results of this study suggested that strategies including using wearable technologies for self-monitoring, engaging in movement throughout the day, and action planning to reduce sedentary behaviour may be useful. Three systematic reviews were found on how to reduce sedentary behaviour in the general population.^{14–16} These reviews concluded that only lifestyle interventions that aimed to reduce sedentary behaviour specifically or in addition

to increasing physical activity were effective for reducing sedentary time.^{14–16} In total, 20 effective BCTs were identified from the literature (see Supplementary Material 4, Table 1). The identified modes of delivery were face-to-face groups, web-based personal, written materials, and activity monitors (see Supplementary Materials 4, Table 1).

In total, 6 professionals and 5 researchers participated in the Nominal Group Techniques sessions (stage 3.2). Participants' characteristics are presented in Supplementary Materials 5. The participants identified a total of 75 BCTs as possibly eligible to include in an intervention to reduce sedentary behaviour. The top ten BCTs, according to the participants, are listed in Supplementary Materials 4, Table 2. Additionally, an overview of the ranking and frequency of the BCTs is presented in Supplementary Materials 4, Tables 3–6.

The BCTs and modes of delivery identified were combined with the information obtained from the interviews to determine the final selection to be included in the intervention (stages 3.3 and 3.4). These can be found in Table 1, categorized into the COM-B model, TDF domains and identified barriers and facilitators. The core BCTs were *goal-setting (on behaviour and outcome)*, *action planning*, *social support*, *self-monitoring on behaviour*, *feedback on behaviour*, *the discrepancy between current behaviour and goal*, *information about health consequences*, *problem-solving*, *restructuring the social environment*, *prompts and cues*, *habits formation*, and *instructions how to perform the behaviour*. The modes of delivery included are face-to-face meetings with a coach (physiotherapist), an activity monitor to measure sedentary behaviour and physical activity, an application to provide real-time feedback, sign-in the behaviour and eLearning.

The required combination of an activity monitor that provides input to an application and the application that gives real-time feedback based on the input and includes eLearning modules necessitated the development of a comprehensive technological system. These requirements were the bases for the iterative process conducted with end-users and experts (stage 3.5.B) to develop such a system. Subsequently, the RISE system was specified and designed for integration into the final version of the RISE intervention protocol (stage 3.5.A.). The RISE intervention (Supplementary Materials 6) is a 15-week blended behavioural intervention in which a primary care physiotherapist coached participants to reduce and interrupt their sedentary time. Physiotherapists provided personalized coaching to people with a stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, 3) a monitoring dashboard for the physiotherapist. Participants received participatory

support from someone from their social network (e.g., partner or close friend) who joined them in the intervention.

References

1. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
2. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*. 2019;366:l4570. doi:10.1136/bmj.l4570
3. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab*. 2010;35(6):725-740. doi:10.1139/H10-079
4. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: Breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke*. 2018;13(9):932-940. doi:10.1177/1747493018798535
5. van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med*. 2012;172(6):494-500. doi:10.1001/archinternmed.2011.2174
6. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338-1353. doi:10.1093/ije/dys078
7. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-132. doi:10.7326/M14-1651
8. Bauman AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep*. 2013;7(4):293-298. doi:10.1007/s12170-013-0316-y
9. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
10. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-666. doi:10.2337/dc07-2046
11. Benatti FB, Ried-Larsen M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Med Sci Sports Exerc*. 2015;47(10):2053-2061. doi:10.1249/MSS.0000000000000654
12. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity (Silver Spring)*. 2015;23(9):1800-1810. doi:10.1002/oby.21180
13. Hendrickx W, Wondergem R, Pisters MF, et al. It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive. *Submitt to peer Rev J*. Published online 2023.

14. Prince SA, Saunders TJ, Gresty K, Reid RD. 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. *Obes Rev.* 2014;15(11):905-919. doi:10.1111/obr.12215
15. Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJH. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol Rev.* 2016;10(1):89-112. doi:10.1080/17437199.2015.1082146
16. Martin A, Fitzsimons C, Jepson R, et al. Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis. *Br J Sports Med.* 2015;49(16):1056-1063. doi:10.1136/bjsports-2014-094524
17. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil.* 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764

Table 1: Outline of the RISE intervention, including Capabilities, Opportunities, Motivation, and behavioural diagnosis; what needs to happen for people with stroke to reduce sedentary behaviour; the facilitators and barriers, the intervention functions, and the most critical behaviour change techniques included in the intervention

COM-B	COM-B Components	TDF	What needs to happen for people with stroke to reduce sedentary behaviour?	Barriers and facilitators	Intervention function	BCTs
Capability	Physical capability	Physical skills	Being capable of replacing sedentary behaviour PA: Reduce the duration between before commonly practised PA-related activities	Overcome motor impairments, short activities, moving throughout the day, loss of strength, impaired balance, reduced stamina, comorbidities	Training, enablement	Instruction on how to perform a behaviour, feedback on behaviour, problem-solving, action planning, goal setting (outcome/behaviour)
	Psychological capability	Knowledge	Have sufficient knowledge on the health consequences of sedentary time and sedentary bouts; Have sufficient knowledge of one's own movement behaviour; Have sufficient knowledge about how to reduce sedentary time and interrupt sedentary bouts; Have sufficient knowledge about the benefits of LPA and MVPA	Awareness of the health risks of sedentary behaviour, awareness of the benefits of light physical activity, amount of sedentary behaviour and/or physical activity, one's own movement behaviour during the week	Education	Information about health consequences, self-monitoring, information how to perform the behaviour, discrepancy between current behaviour and goal
	Cognitive and interpersonal skills		Have the skills to decrease sedentary time; Have the skills to develop specific plans to interrupt sedentary bouts and reduce sedentary time; Know that physical fatigue is different than cognitive fatigue	Self-motivation and determination, action planning, self-monitoring, cognitive fatigue followed by sitting, cognitive tasks take longer time, ideas to improve movement behaviour	Training, education, enablement	Self-monitoring, action planning, problem solving, goal-setting, information about health consequences

Table 1: Outline of the RISE intervention, including Capabilities, Opportunities, Motivation, and behavioural diagnosis; what needs to happen for people with stroke to reduce sedentary behaviour; the facilitators and barriers, the intervention functions, and the most critical behaviour change techniques included in the intervention (*continued*)

COM-B	COM-B Components	TDF	What needs to happen for people with stroke to reduce sedentary behaviour?	Barriers and facilitators	Intervention function	BCTs
		Memory, attention and decision processes	Remember to decrease sedentary time and interrupt sedentary bouts; Planning strategies;	Deficits in neuropsychological function due to stroke, e.g. impaired initiative, planning and memory.	Training, enablement	Prompts and cues, action planning, social support
		Behavioural regulation	Break sitting habits; Self-monitoring to observe sedentary behaviour; Reminders to break habits; Plans to break habits; Social support to reduces sedentary behaviour	Regulation the amounts of PA and sedentary time, behaviour regulation capabilities	Education, training, enablement	Habit formation, self-monitoring, prompts and cues, action planning, problem solving, goal setting
Opportunity	Physical opportunity	Environmental context and resources	Access to activities that are not while seated; Have the opportunity to interrupt sedentary behaviour during work or at home; Have the in-house and outside environmental factors	All activities are in sitting position, nothing to do, sedentary occupation or unable to get back to work, in-house environmental factors, outside environmental factors, safe environment, go to community-based activities, fear of walking outside because there are not enough places to rest, fear of embarrassment if unable to manage without rest, movement throughout the day, the weather, having someone to pick me up from an activity	Training, environmental restructuring, enablement	Action planning, coping planning, problem solving, goal setting,

Table 1: Outline of the RISE intervention, including Capabilities, Opportunities, Motivation, and behavioural diagnosis, what needs to happen for people with stroke to reduce sedentary behaviour; the facilitators and barriers, the intervention functions, and the most critical behaviour change techniques included in the intervention (*continued*)

COM-B	COM-B Components	TDF	What needs to happen for people with stroke to reduce sedentary behaviour?	Barriers and facilitators	Intervention function	BCTs
	Social opportunity	Social influences	Relatives need to have sufficient knowledge about sedentary time and interrupting sedentary bouts; Encouragement and stimulation to decrease sedentary time and interrupt sedentary bouts from friends and family; Activities with friends other than drinking coffee	Lack of support from friends and family, pressure from family and friends to rest, sit because they do not want to burden others, feeling useful, social support, socializing, relieve boredom, not just being the old person in the chair	Environmental restructuring, modelling, enablement	Restructuring the social environment, social support
Motivation	Reflective motivation	Professional/ social role and identity	Decrease sedentary time and interrupt sedentary bouts at the (volunteer) workplace; Engage in social activity incorporating PA	Sedentary occupation or loss of (volunteer) work, social tasks lead to an increase in PA	Education, persuasion, incentivization	Action planning, feedback on behaviour, self-monitoring, social support, goal-setting, problem solving, goal setting, habit formation
	Beliefs about capabilities	Beliefs about capabilities	Overcome fatigue, depression, cognitive problems, pain, poor sleep: (self)-Monitoring of behaviour to achieve insight about sedentary time and sedentary bouts; Have self-motivation and determination; Have self-efficacy	Fatigue, cognitive problems, pain, poor sleep, lack of motivation, feeling capable of self-caring, self-motivation and determination, self-efficacy related to improving the levels of PA and reducing sedentary time	Education, persuasion, training	Problem solving, action planning, self-monitoring, feedback in behaviour

Table 1: Outline of the RISE intervention, including Capabilities, Opportunities, Motivation, and behavioural diagnosis; what needs to happen for people with stroke to reduce sedentary behaviour; the facilitators and barriers, the intervention functions, and the most critical behaviour change techniques included in the intervention (*continued*)

COM-B	COM-B Components	TDF	What needs to happen for people with stroke to reduce sedentary behaviour?	Barriers and facilitators	Intervention function	BCTs
		Optimism	Be optimistic about abilities and capability to improve PA and reduce sedentary behaviour	Perceived confidence to increase PA and reduce sedentary behaviour, optimistic about abilities, pessimistic about abilities	Education, persuasion, incentivization	Social support, information about health consequences, problem solving, action planning
		Beliefs about consequences	Believe in the benefits of reducing sedentary behaviour in terms of the risk of recurrent stroke, pain, depression, feelings of guilt, feelings of independence, boredom, poor sleep	Beliefs about the importance of movement for health, beliefs about other benefits of PA	Education, persuasion, incentivization	
	Intentions	Have the intention to reduce sedentary time and interrupt sedentary bouts; Have the intention to increase PA levels		Intention to improve the levels of PA, intention to increase meaningful activities with a PA component, intention to reduce sedentary time	Education, persuasion, incentivization	Self-monitoring of behaviour, feedback on behaviour, information about health consequences

Table 1: Outline of the RISE intervention, including Capabilities, Opportunities, Motivation, and behavioural diagnosis, what needs to happen for people with stroke to reduce sedentary behaviour; the facilitators and barriers, the intervention functions, and the most critical behaviour change techniques included in the intervention (*continued*)

COM-B	COM-B Components	TDF	What needs to happen for people with stroke to reduce sedentary behaviour?	Barriers and facilitators	Intervention function	BCTs
		Goals	Action planning; Be active during the day; Set meaningful goals; Learn strategies to be active	Action planning, being active during the day, no concrete goal or plan to be or improve PA, goal setting	Education, persuasion, incentivization, training	Goal-setting (outcome/behaviour), problem solving, action planning, feedback on behaviour, discrepancy between current behaviour and goal, social support
Automatic motivation	Reinforcement	Establish routines to interrupt sedentary bouts; Create habits other than sitting; Learn other associations with PA, enjoy engaging in PA	Sitting is a habit, nothing to do, (fear of) falling, pain, fatigue (cognitive and physical), using passive aids, joy derived from activities, interrupting sedentary time to avoid pain and stiffness	Persuasion, incentivization, training, environmental restructuring, modelling, enablement	Prompts and cues, habit formation, action planning, problem solving, self-monitoring on outcome, information about health consequences, instructions how to perform the behaviour	
	Emotion	Experience a positive emotional response by decreasing sedentary time and interrupting sedentary bouts	Fatigue, depression, fear of walking, fear of embarrassment, fear of falling, feelings of independence, feeling useful, feeling less guilty	Incentivization	Problem solving, information about health consequences	

Com-B=Capabilities, Opportunities, Motivation and Behavioural Diagnosis, TDF=Theoretical Domains Framework, LPA=Light Physical Activity.

Supplementary Materials 2: BCW and CeHRes roadmap

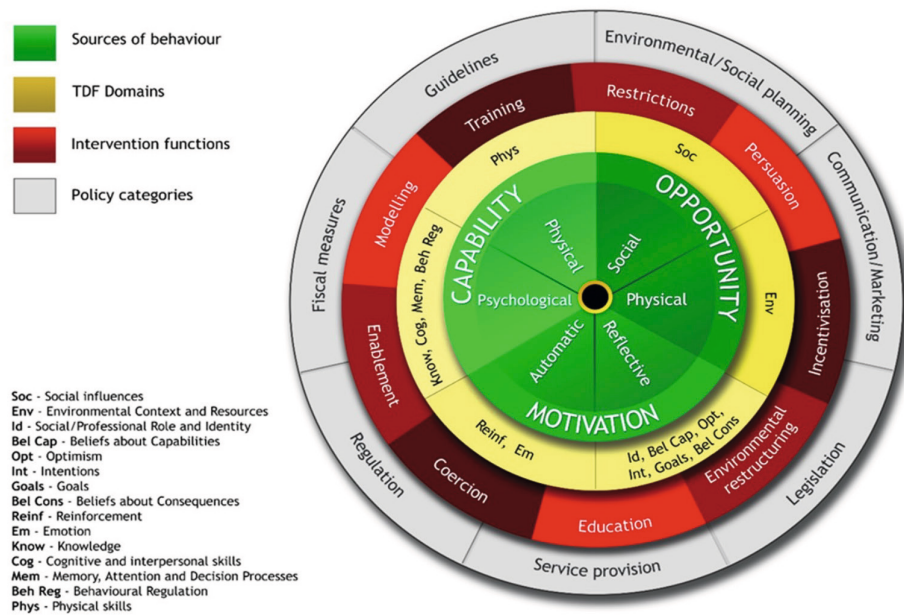


Figure 1. The behaviour change wheel. Reprinted with permission from Michie et al (Michie et al., 2011).¹

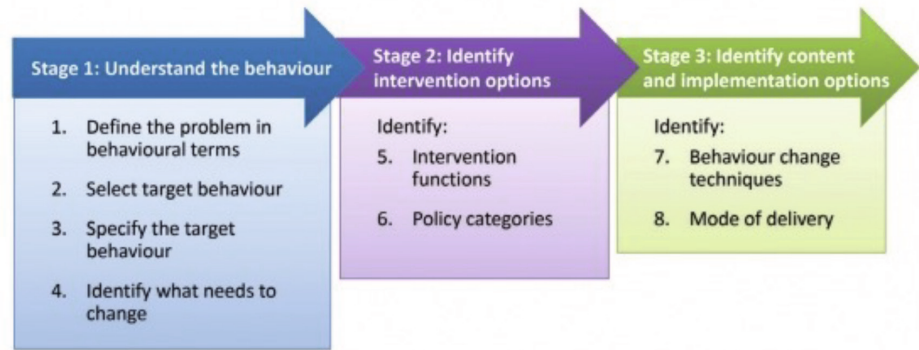


Figure 2. The stages of the behaviour change wheel approach. Reprinted with permission from Michie et al (Michie et al., 2011).¹

Table 1. COM-B model components and the Theoretic Domains Framework

COM-B	Components	TDF Domains
Capability	Physical	Physical skills <i>An ability or proficiency acquired through practise</i>
	Psychological Knowledge or psychological skills, strength or stamina to engage in the necessary mental processes	Knowledge <i>An awareness of the existence of something</i>
		Cognitive and interpersonal skills <i>An ability or proficiency acquired through practise</i>
		Memory, attention and decision processes <i>The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives</i>
		Behaviour Regulation <i>Anything aimed at managing or changing objectively observed or measured actions</i>
Opportunity	Social Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way that we think about things, e.g. the words and concepts that make up our language	Social influences <i>Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours</i>
	Physical Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance'	Environmental Context and Resources <i>Any circumstance of a person's situation or environment or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour</i>
Motivation	Reflective Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)	Social or Professional Role and Identity <i>A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting</i>
		Beliefs about Capabilities <i>Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use.</i>
		Optimism <i>The confidence that things will happen for the best or that desired goals will be attained</i>
		Intentions <i>A conscious decision to perform a behaviour or a resolve to act in certain way</i>
		Goals <i>Mental representations of outcomes or end states that an individual wants to achieve</i>
		Beliefs about consequences <i>Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation.</i>

Table 1. COM-B model components and the Theoretic Domains Framework (*continued*)

COM-B	Components	TDF Domains
	Automatic Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex responses	Reinforcement <i>Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus</i> Emotion <i>A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event</i>

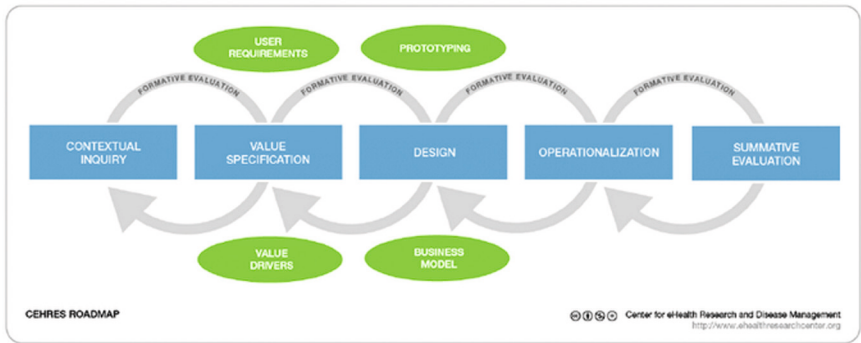


Figure 3. The CeHRes Roadmap.²

References

1. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions*. Silverback Publishing Great Britain; 2014.
2. van Gemert-Pijnen JEW, Nijland N, van Limburg M, et al. A holistic framework to improve the uptake and impact of eHealth technologies. *J Med Internet Res*. 2011;13(4):e111. doi:10.2196/jmir.1672

Supplementary Materials 3: search terms

Table 1: Search terms related to the step of the Behaviour Change Wheel

Questions per stage	Search terms
Stages 1 Understand the behavior	What should be the target behavior? Sedentary behavior* AND stroke OR risk
	What motivations, barriers and opportunities are identified with regards to reducing sedentary behavior? 'Sedentary behavior*' AND 'Barrier*' OR 'Motivation'
Stage 2 Identify intervention functions	What is the evidence on the effectiveness of the possible intervention functions in stroke survivors with regards to reducing sedentary behaviour? 'Behavioural interventions' OR 'lifestyle intervention' OR 'Selfmanagement' OR 'Education' AND 'Sedentary Behaviour' AND 'Stroke' [#]
Stage 3 Identify behaviour changes techniques and modes of delivery	What is the evidence on the effectiveness of the possible BCTs in stroke survivors with regards to reducing sedentary behaviour? 'Behavioural interventions' OR 'lifestyle intervention' OR 'Selfmanagement' OR 'Education' AND 'Sedentary Behaviour'
	What is the evidence on the effectiveness of the possible modes of delivery in stroke survivors with regards to reducing sedentary behaviour? 'Stroke' [#] AND 'Behavioural interventions' OR 'lifestyle intervention' OR 'Selfmanagement' OR 'Education' OR 'Secondary Prevention' OR 'Risk Reduction Behaviour' OR 'Lifestyle modification'

[#] 'Stroke' OR 'Brain Infarction' OR 'Cerebro Vascular Accident' OR 'CVA' OR 'Cerebral apoplexy' OR 'Poststroke*'

Supplementary Materials 4: BCT and NGT outcomes

Table 1. Intervention functions, BCT's and modus of delivery found effective in general population based on literature

Intervention functions	BCT	Modus of delivery
Education	Problem solving	Face to face group
Persuasion	Goal setting (outcome)*	Web-based personal*
Incentivisation*	Action planning	Written materials standard
Training	Commitment*	Pedo- / accelerometer not specified
Environmental restructuring	Monitoring behaviour by others without feedback*	
Restriction	Feedback on Behaviour	
	Self-monitoring (behaviour)	
	Instruction on how to preform behaviours	
	Information about health consequences	
	Demonstration of the behaviour	
	Remove access to the reward	
	Behavioural practice/rehearsal	
	Habit reversal*	
	Overcorrection*	
	Generalisation of target behaviour*	
	Graded tasks	
	Credible source*	
	Pros and cons*	
	Material reward for behaviour	
	Adding objects to the environment	

*Based on one study

Table 2. Top 10 BCTs identified in the Nominal Group Techniques sessions

Patients without physical nor cognitive impairments	Patients with cognitive impairments and without physical impairments	Patients with physical impairments and without cognitive impairments	Patient with both physical and cognitive impairments
1. Goal setting (behaviour)	Goal setting (behaviour)	Goal setting (behaviour)	Goal setting (behaviour)
2. Action planning	Action planning	Problem solving	Social support (unspecified)
3. Social support (unspecified)	Social support (unspecified)	Action planning	Prompts/cues
4. Self-monitoring (behaviour)	Prompts/cues	Social support (unspecified)	Problem solving
5. Goal setting (outcome)	Restructuring the physical environment	Self-monitoring (behaviour)	Restructuring the social environment
6. Feedback on behaviour	Problem solving	Restructuring the physical environment	Restructuring the physical environment
7. Discrepancy between current behaviour and goal	Social support (practical)	Restructuring the social environment	Action planning
8. Information about health consequences	Restructuring the social environment	Goal setting (outcome)	Social support (practical)
9. Problem solving	Graded tasks	Feedback on behaviour	Graded tasks
10. Restructuring the social environment	Social reward & review behaviour goal(s)	Information about health consequences	Social reward & review behaviour goal(s)

Table 3-6 Ranking per profile will be published online due to its large quantity. It is currently available on request from Wendy Hendrickx (w.hendrickx@fontys.nl).

Supplementary Materials 5: Participants' characteristics

Table 1. Patient characteristics focus group 1

	Sex	Age	Time after stroke	Physical disability due to stroke	Communication problems due to stroke	Cognitive impairments due to stroke	Use of tablet, smartphone or computer
Participant 1	Female	70	3 years	yes	yes	no	Yes/yes/yes
Participant 2	female	65	6 years	yes	no	no	Yes/yes/yes
Participant 3	male	68	1 year	Yes	no	no	No
Participant 4	male	51	1 year	yes	yes	yes	Yes/yes/no
Participant 5	Female	70	1 year	yes	no	yes	No/yes/yes
Participant 6	Male	52	2 years	yes	no	yes	No/yes/no
Participant 7	female	42	1 year	yes	no	no	Yes/yes/yes

Table 2. Patient characteristics focus group 2

	Sex	Age	Time after stroke	Physical disability due to stroke	Communication problems due to stroke	Cognitive impairments due to stroke	Use of tablet, smartphone or computer
Participant 1	male	65	3 years	yes	no	no	No/yes/yes
Participant 2	female	53	3 years	yes	no	no	Yes/yes/yes
Participant 3	female	51	10 years	yes	yes	yes	No/yes/yes
Participant 4	male	54	5 years	yes	yes	no	No
Participant 5	male	73	2 years	no	no	no	no
Participant 6	Female	74	4 years	no	yes	no	No
Participant 7	male	29	5 years	yes	no	yes	Yes/yes/yes

Supplementary Materials 6: HAPA model and RISE intervention

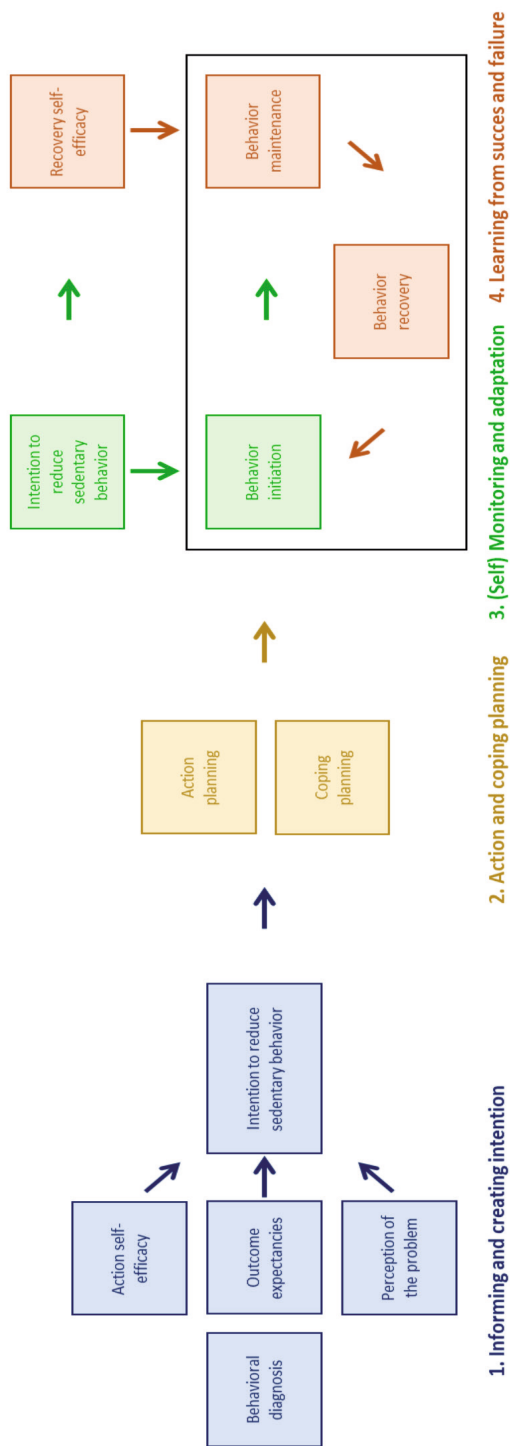


Figure 1. The Health Action Process Approach.¹

Table 1. A detailed description of the RISE intervention

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
1. Face-to-face: Introduction of the intervention	Intake	Motivating stage (preintender)	Education	Monitoring of behaviour by others without feedback Information about health consequences Salience of consequences Information about emotional consequences Pros and cons Feedback on behaviour
	Information about the intervention			
	Start self-monitoring			
1a. MHealth application: The added value of reducing sedentary behaviour and improving physical activity	Introduction to health consequences of lifestyle and movement behaviour	Motivating stage (preintender) Risk perception	Education Persuasion	Feedback on behaviour Goal setting behaviour Discrepancy between current behaviour and goal Graded task Non-specific reward Problem-solving
	o What is a stroke			
	o What is prevention o What is exercise behaviour			
2. Face-to-face: Movement Behavioural diagnosis	Motivational interviewing to identify barriers and facilitators	Motivating stage (preintender) Task self-efficacy	Education Persuasion Incentivization	Feedback on behaviour Information about health consequences Information about emotional consequences Verbal persuasion about capability Credible sources Graded task Goal setting behaviour Instruction on how to perform the behaviour Non-specific reward Discrepancy between goal and current behaviour
	Discuss movement behaviour			
2a. MHealth application: Added-value of sitting less and moving more	Self-monitoring: an introduction	Motivating stage (preintender) Risk perception	Education Persuasion Training Incentivization	Feedback on behaviour Information about health consequences Information about emotional consequences Verbal persuasion about capability Credible sources Graded task Goal setting behaviour Instruction on how to perform the behaviour Non-specific reward Discrepancy between goal and current behaviour
	What is movement behaviour part II			

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
3. Face-to-face: Evaluate movement behaviour	Discuss movement behaviour	Motivating stage (preintender)	Incentivization	Feedback on behaviour
	Discuss self-beliefs about reducing sedentary behaviour	Outcome expectancies	Training	Social reward
	What are possible barriers	Task self-efficacy		Behaviour substitution
	Enable cues			Habit reversal
				Graded task
				Goal setting behaviour
				valued self-identify
				Non-specific reward
				Verbal persuasion about capability
				Problem-solving
3a. MHealth application: Your daily activities	Self monitoring	Intention	Training	Feedback on behaviour
	Insight in behaviour	Environmental barriers	Enablement	Verbal persuasion about capability
	Which activities to implement		Education	Instruction on how to perform a behaviour
				demonstration of the behaviour
				Graded task
				Goal setting behaviour
				Non-specific reward
				Problem-solving
				Discrepancy between goal and current behaviour

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
4. Face-to-face: Action planning and goal setting	Goal setting	Volitional stage (intender)	Environmental restructuring	Feedback on behaviour
	Self-monitoring	Intention and planning	Training	Verbal persuasion about capability
	Strategies to sit less		Education	Graded task
			Incentivization	Action planning
4a. MHealth application: Trying prompts and cues				Demonstration of the behaviour
				Instruction on how to perform a behaviour
				Prompts and cues
				Habit formation
				Habit reversal
				Goal setting behaviour
				Non-specific reward
				Problem-solving
				Review behavioural goals
5. Face-to-face: Social support / social environment				Feedback on behaviour
				Prompts and cues
				Graded task
				Action planning
				Problem-solving
				Non-specific reward
				Discrepancy between goal and current behaviour
				Feedback on behaviour
				Focus on past success
				Social support (unspecified)
5. Face-to-face: Social support / social environment				Social support practical
				Review behavioural goals
				Problem-solving
				Habit reversal
				Habit formation
				Graded task
				Goal setting behaviour
				Restructuring the physical environment
				Non-specific reward

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
5a. MHealth application: What are habits?	Self-monitoring	Maintenance task	Education	Feedback on behaviour
	What are habits Celebrating success	self-efficacy Action	Persuasion	Prompts and cues Graded task Habit reversal Generalization of the target behaviour Non-specific reward Problem-solving Discrepancy between goal and current behaviour
6. Face-to-face: Self-efficacy to interrupt sedentary behaviour	Review current behaviour	Volitional stage (intender)	Persuasion	Feedback on behaviour
	Provide positive feedback Celebrate success Discuss action planning Discuss social support / social environment Decrease cues	Maintenance task self-efficacy Action	Education Incentivization	Feedback on outcome Verbal persuasion about capability Focusing on past success Review behavioural goals Graded task Goal setting behaviour Feedback on outcome Social support (unspecified) Non-specific reward Problem-solving
6a. MHealth application: New possibilities	Discuss new ideas/possibilities to interrupt sedentary behaviour	Volitional stage (intender/actor)	Education	Feedback on behaviour
	Discuss physical environment and possible changes Discuss set-backs	Maintenance self-efficacy Action	Persuasion Training Environmental restructuring Enablement	Graded task Goal setting behaviour Behaviour substitution Discrepancy between goal and current behaviour Restructuring the physical environment Adding objects to the environment Graded task Goal setting behaviour Problem-solving Non-specific reward
7a. MHealth application: adjust physical environment				

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
8. Face-to-face: Introduction set-backs	Discuss progress	Volitional stage (intender/actor)	Persuasion	Feedback on behaviour
	Celebrate success		Education	Pros and cons
	Discuss action plan	Maintenance	Environmental restructuring	Graded task
	Discuss an action plan to change the physical environment	self-efficacy Action Recovery self-efficacy		Focusing on past success Review behavioural goals Habit formation Goal setting behaviour Social support (unspecified) Restructuring the physical environment Problem-solving Non-specific reward
8a. MHealth application: Sedentary habits	Monitoring movement behaviour	Maintenance	Training	Feedback on behaviour
	Created habits	self-efficacy	Education	Graded task
	Self-belief	Action		Goal setting behaviour
		Recovery self-efficacy		demonstration of the behaviour habit formation Non-specific reward Problem-solving Discrepancy between goal and current behaviour
10. Face-to-face: Habit formation and setbacks	Discuss progress	Volitional stage (actor)	Training	Feedback on behaviour
	Feedback on behaviour		Education	Review behavioural goals
	Reflecting on action plans and adjusting or making a new one	Maintenance	Enablement	Habit reversal
	Habits and setbacks	self-efficacy Action Recovery self-efficacy	Persuasion	Behaviour substitution Graded task Goal setting behaviour Social support (unspecified) demonstration of the behaviour verbal persuasion about capability habit formation Non-specific reward Problem-solving

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
10a. MHealth application: Celebrate success	Celebrate success	Maintenance self-efficacy	Education	Feedback on behaviour
11a. MHealth application: Self-monitoring	Discuss self-monitoring tool or app for the future	Action	Training Enablement	Graded task Goal setting behaviour Instruction on how to perform a behaviour Demonstration of the behaviour Action planning Problem-solving Discrepancy between goal and current behaviour Non-specific reward
12. of 13. Face-to-face: Self-monitoring	Discuss progress Feedback on behaviour Reflecting on action plans and adjusting or making a new one Discuss the pros and cons of sitting Discuss self-monitoring tool future + action plan to implement	Volitional stage (actor) Action Recovery self-efficacy	Training Enablement Incentivisation Persuasion	Feedback on behaviour Review behavioural goals Graded task Goal setting behaviour Social support unspecified Habit formation Action planning Non-specific reward Problem-solving
13a. MHealth application: Are you future proof	Questions to prevent setbacks and recover behaviour	Maintenance self-efficacy Action Recovery self-efficacy	Persuasion Training	Feedback on behaviour Graded task Feedback on behaviour Goal setting behaviour Valued self-identity Focus on success Action planning Problem-solving Discrepancy between goal and current behaviour

Table 1. A detailed description of the RISE intervention (*continued*)

Weeks	Topic	Phase	Intervention function	Behaviour change techniques
14a. MHealth application: What did it bring you	What did it get you Questions to PT	Maintenance self-efficacy	Persuasion	Feedback on behaviour
		Action	Incentivization	Graded Task
		Recovery self- efficacy	Enablement	Review behaviour goals
				Goal setting behaviour
				Discrepancy between current behaviour and goal
15. Face-to-face: Sustainable movement behaviour	Discuss behaviour Questions? Future proof action plan to prevent setbacks or recover behaviour Closing			Non-specific reward
				Focus on past success
		Maintenance self-efficacy	Persuasion	Feedback on behaviour
		Action	Incentivization	Feedback on outcome
		Recovery self- efficacy	Enablement	Review behavioural goals
				Habit reversal
				Behaviour substitution
				Graded task
				Goal setting behaviour
				Social support (unspecified) pros and cons Commitment Non-specific reward

References

1. Schwarzer R. Modeling Health Behavior Change: How to Predict and Modify the Adoption and Maintenance of Health Behaviors. *Appl Psychol.* 2008;57(1):1-29. doi:10.1111/j.1464-0597.2007.00325.x



CHAPTER 7

Improving movement behaviour after stroke with the RISE intervention – a randomised multiple baseline study.

Wendy Hendrickx
Roderick Wondergem
Cindy Veenhof
Coralie English
Johanna M.A. Visser-Meily
Martijn F. Pisters

Under review

Abstract

Background: High amounts of sedentary behaviour increase the risk of cardiovascular disease. The objective of this study was to determine the preliminary effectiveness and feasibility of the RISE intervention to support community-dwelling people with stroke, who are highly sedentary, to reduce and interrupt sedentary time. Additionally, the added value of including participatory support within the RISE Intervention was determined.

Methods: A randomised multiple baseline study was conducted. Fourteen community-dwelling participants, were randomly allocated to different durations of baseline assessment, during which repeated measurements were conducted. All received the RISE intervention, a 15-weeks blended behavioural intervention, in which a primary care physiotherapist coached participants to reduce and interrupt their sedentary time. Physiotherapists provided personalised coaching, in the home setting, by using behaviour change techniques and the RISE eCoaching system; an activity monitor and app to provide real time feedback. Half of the participants (randomly allocated) received participatory support from someone from their social network (e.g., partner or close friend) who joined them in the intervention. Preliminary effectiveness was determined with significant changes in total sedentary time and fragmentation (interruption) of sedentary time using the Wampold and Worsham randomisation test. Effect size was determined using the Percentage Exceeding the Median. Feasibility was assessed by adherence with the intervention protocol, safety and satisfaction with the intervention.

Results: Participants significantly reduced total sedentary time ($p=0.01$) by 1.3 hours on average and increased their fragmentation ($p<0.01$). Twelve (85%) participants improved on at least one outcome of sedentary behaviour. Subgroup analyses showed significant improvements in total sedentary time ($p=0.03$) and fragmentation ($p=0.03$) in the group with participatory support. The group without participatory support only significantly improved fragmentation ($p=0.04$). Thirteen (93%) participants completed the intervention and no related adverse events occurred. Participants reported sufficient satisfaction with the intervention.

Conclusion: The RISE intervention appears promising to support people with stroke who are highly sedentary to reduce and interrupt their sedentary time. Participatory support appears to contribute to greater results.

Trial registration: ISRCTN international trial registry, 10694741

Introduction

Each year about 43,000 people have a stroke in the Netherlands.¹ Despite significant improvements in acute care, the risk of recurrent stroke is high.^{2–4} Consequently, secondary prevention is important for people with a stroke. Several risk factors for cardiovascular disease and stroke are known. Relevant risk factors include elevated systolic blood pressure, high body mass index, high fasting glucose and lifestyle factors, including physical inactivity and sedentary behaviour.^{5–11} Sedentary behaviour is defined as ‘any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task while in a sitting, reclining, or lying posture’.^{12,13} Large observational studies report that higher levels of total physical activity at any intensity and less time spent sedentary are associated with a substantially reduced risk for recurrent cardiovascular events and/or mortality.⁶ Furthermore, the risk from sedentary behaviour increases when sedentary time is accumulated in prolonged bouts.^{14–17} The Breaking Up Sitting Time after Stroke study found that when sedentary time is interrupted by short bouts of standing exercises or walking, systolic blood pressure reduced in people with stroke, even when participants were taking anti-hypertensive medication.¹⁸ High (systolic) blood pressure is the greatest modifiable risk factor contributing to first and recurrent stroke.¹⁹

A previous study measured the movement behaviours of 190 people after stroke who had returned home. Results showed that 79% of the population was highly sedentary (over 9.5 hours with 13.5 hours of activity monitor wear-time) and spent minimal time engaged in Moderate to Vigorous Physical Activity (MVPA).²⁰ Of these participants, 31% accumulated their sedentary time in prolonged bouts.²⁰ These results indicate that over three-quarters of the people with stroke have a movement behaviour pattern that may increase their risk of recurrent stroke and other cardiovascular events.

No effective interventions exist to support people living in the community who have had a stroke to reduce sedentary behaviour.²¹ Intervention development to reduce sedentary behaviour should target supporting behaviour change and self-management.²¹ Qualitative and quantitative studies indicate a need to focus on people’s awareness of their movement behaviour and health consequences, and to support people to consciously regulate their movement behaviour.^{20,22–27} Furthermore, factors related to the social and physical environment that influence movement behaviour and other individual factors like stroke sequelae and self-efficacy need consideration.^{20,22–27} Since these factors can vary across people with stroke, the ability to tailor the intervention to a person’s individual needs is required.^{20,22–27}

Our research group has developed the RISE intervention (*Reduce and Interrupt Sedentary behaviour using a blended behaviour intervention to Empower people at risk towards sustainable movement behaviour change*) to support highly sedentary people with stroke.²⁸ The RISE intervention aims to reduce and interrupt sedentary behaviour by replacing it with physical activity. Sustainable movement behaviour change can be challenging,²¹ so within the co-design process to develop a personalised intervention we considered all identified influencing factors from the behaviour domains (capabilities, opportunities and motivation) and accounted for the different phases of change.²⁷⁻²⁹ Social support and the social environment were identified as key elements for an effective intervention to reduce sedentary time in literature.^{25,27,28} Therefore, participatory support, where a member of the participant's immediate social environment participates as a buddy in the intervention, may contribute to adherence and improved movement behaviour.^{30,31} The added value of participatory support and the feasibility of integrating this within movement behavioural change interventions is currently unknown.

Therefore the objective of this study was to determine the preliminary effectiveness and feasibility of the RISE intervention to support community-dwelling people with stroke, who are highly sedentary, to reduce and interrupt sedentary time. Additionally, the added value of including participatory support within the RISE Intervention was determined.

Method

Design

A randomised, multiple baseline design was used³²⁻³⁷ This study was conducted according to the Consolidated Standard of Reporting Trials (CONSORT) 2010 statement extended with reporting N-of-1 trials (CENT).³⁸ Within multiple baseline designs, for each participant, the movement behaviour outcome variables are measured repeatedly in each of the phases (baseline phase, intervention phase and follow-up phase). The duration of the baseline measures is randomised for each participant. By applying multiple baselines of varying length, observed effects of the treatment can be distinguished from effects due to chance.^{32-37,39} This method was conducted for two groups, one receiving the RISE intervention alone (15 weeks) and a second group who had additional participatory support. Participants were randomly allocated by an independent researcher using a computer-generated random sequence table. The study was approved by the Ethics review board of the University Utrecht, number ABR NL73036.041.20, METC 20/250. The trial protocol was registered at ISRCTN international trial registry (10694741).

Participants

Participants were recruited via the stroke units of four hospitals in the Netherlands (region Utrecht and Eindhoven), between September 2020 and December 2021. Informed consent was obtained from each participant who was willing to participate and eligible. The eligibility criteria were:

Inclusion criteria

1. Aged >18 years;
2. Stroke diagnosed in hospital in previous six months and discharged to home setting;
3. Able to walk independently (Functional ambulation categories score ≥ 3);⁴⁰
4. Sedentary movement behaviour pattern; i.e. ≥ 9.5 hours of sedentary time per day and meeting at least one of the following criteria: >50% of the sedentary time is spent in bouts > 30 minutes and/or not reaching the physical activity guideline (150 minutes MVPA during the week).²⁰ This was determined by wearing the activ8 activity monitor during waking hours for one week.
5. Independent in activities of daily living pre-stroke (Barthel Index score >18⁴¹);
6. Have someone who could participate as a buddy in the RISE intervention with Participatory Support;

Exclusion criteria

1. Insufficient knowledge of the Dutch language to understand the intervention content;
2. Score <4 on the Utrecht Communication Assessment
3. Severe comorbidities that prevent that person from safely reducing and interrupting their sedentary time (e.g. severe pulmonary diseases, heart failure or malignity's), determined with the Physical Activity Readiness Questionnaire;⁴²
4. Receiving physiotherapy in any other setting than primary care.

The participatory support buddy of the participant with stroke had to be part of the participants immediate social environment with regular social contact, i.e. at least two times a week. They had to meet inclusion criteria 1 and 3, and were excluded based on exclusion criteria 1 and 3.

Sample size

The sample size was based on the incorporation of randomisation to assess the preliminary effectiveness with sufficient power.^{32–34,37} Randomisation was conducted based on the concealed allocation principle using the Wampold and Worsham method.^{32–34,37} Participants were randomised to a baseline measurement duration of either 4, 6, 8, 10, 12 or 14 days. Based on these six randomisation options a sufficient number of permutations is achieved to enable the analyses (minimal P-value of <0.01) to determine significant

changes in the movement behaviour.^{32–34,37} To ensure that dropout (for reasons not related to the intervention) after recruitment was finished, did not affect the rigour of the data analyses two times 7, so 14 participants in total were included.

Intervention

Participants received the RISE intervention, a 15-week blended behavioural intervention, in which a primary care physiotherapist coached participants to reduce and interrupt their sedentary time. Physiotherapists provided personalised coaching to people with a first-ever stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, 3) a monitoring dashboard for the physiotherapist. Participants received participatory support from someone from their social network (e.g., partner or close friend) who joined them in the intervention.

The coaching sessions included (among other aspects) discussion of movement behaviours and activities, and identifying possibilities for change. Goals were set and action plans were made. In between the coaching sessions, real-time feedback on movement behaviour was provided by using the RISE eCoaching system and eLearning modules were available to the participant. The eLearning modules included subjects such as stroke, healthy movement behaviour and behaviour change. Supplementary Materials 1, RISE intervention details, provides detailed information about the weekly intervention schedule.

The following behaviour change techniques were at the core of this blended intervention: goal-setting (on behaviour and outcome), action planning, social support, self-monitoring on behaviour, feedback on behaviour, the discrepancy between current behaviour and goal, information about health consequences, problem-solving, restructuring the social environment, prompts and cues, habits formation, instructions how to perform the behaviour. The RISE eCoaching system used the Activ8 activity monitor, a reliable and valid tool to determine movement behaviour.^{43,44} The intervention was delivered in the participants' home by four primary care physiotherapists who all received training to provide the RISE intervention. The training included subjects such as healthy movement behaviour, behaviour change and coaching on the job.

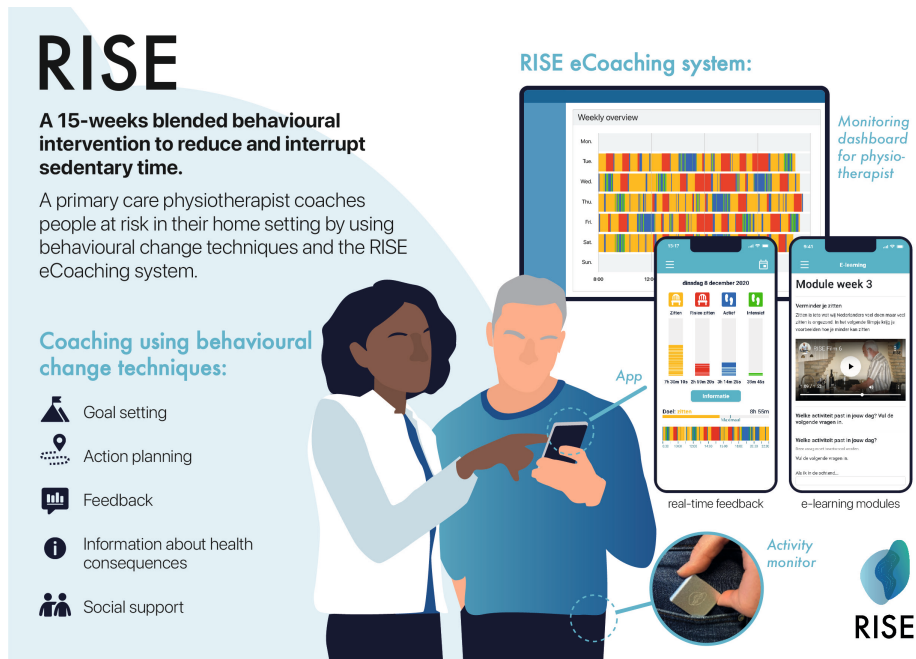


Figure 1. RISE intervention

The content of the RISE intervention was identical for participants with and without participatory support. The only difference was that those with participatory support had their buddy present at the face-to-face sessions. Buddy participants also received the RISE monitor with the app to gain insight and received information regarding healthy movement behaviour and how to provide meaningful support.

Outcome measures

Demographic and stroke related data were obtained from the medical file and a baseline questionnaire. The preliminary effectiveness of the intervention on sedentary behaviour and the added value of participatory support was assessed using the total amount of sedentary time (in hours) and the sedentary time interruption, using the fragmentation index. Sedentary behaviour was measured with the ActivPAL activity monitor. This monitor (PAL Technologies Ltd, Glasgow, United Kingdom) is reliable (Intraclass correlation coefficient 0.79-0.99) and valid (98-100% accuracy) for measuring movement behaviour during daily life in people with stroke.⁴⁵⁻⁴⁷ Participants were asked to keep a diary to keep track of the time they got up out of bed in the morning, and time they went to sleep at night and this information was used to determine waking hours.

Feasibility was assessed by measures of adherence with the intervention protocol, safety and satisfaction. Adherence and safety were determined by measuring; 1) the number of people that completed the intervention; 2) the number of participants that missed one or more of the face to face sessions and the reasons for missing sessions; 3) the number of adverse events.

The System Usability Scale (SUS) questionnaire was used to determine the participants' satisfaction with the RISE system. The SUS is a valid and reliable instrument to measure participants' perceived satisfaction.⁴⁸ Score ranges from 0-100, with a score of 70-80 representing medium satisfaction and a score over >80 high satisfaction.⁴⁸

Secondary outcomes included the amount of light physical activity (LPA) (hours) and moderate to vigorous physical activity (MVPA) (minutes) per day, measured with the ActivPAL activity monitor, and was used to determine what sedentary behaviour was replaced with if a reduction occurred. Other physical activity outcomes, additional sedentary outcomes, such as the percentage of waking hours spend sedentary, and sleep time are presented in Supplementary Materials 2, Data visualisation.

Data analyses

All analyses were conducted with R statistical software, version 3.6.1. The ActivPAL data were downloaded from the device using the manufacturer's software provided. A Knitter program was used to combine the repeated measurements into one dataset for each participant.⁴⁹ The ProcessingPAL software V1.3 was used to determine waking hours (in combination with diaries) and extract the relevant outcome variables.^{50,51} Available data for any participant that dropped out were included in the analyses in adherence to intention to treat principles.

To determine the intervention's preliminary effectiveness, both group and individual participant analyses were conducted. The Wampold and Worsham randomisation test,^{32-34,37,52,53} was used to determine if there was a statistically significant change at group level. The null hypothesis was that there was no effect of the intervention, i.e., no difference between the baseline and post-intervention period in sedentary time or fragmentation. We used a one tailed alternative hypothesis, with a significance level set at $\alpha=0.05$.

The data per participant were graphed and visually assessed to get an indication of any differences in the level, trend, variability, overlap or consistency of the data over time.⁵⁴⁻⁵⁶ The addition of a mean and 2-SD band (Standard Deviation) was used to support the visual analyses.³²⁻³⁴ The non-parametric effect size was then determined using the Percentage Exceeding the Median (PEM), which is the best fit when there is larger variability in baseline

data.^{54,55,57,58} The PEM represents the percentage of days, during and after the intervention, in which there was an improvement compared to the baseline median. For the PEM, >90% is considered a high effect, 70-90% moderate, 60-70% mild, 50-60 % questionable and <50% no effect.⁵⁸

To determine if there was any added value of participatory support, the above analyses were conducted separately for the group with and without added participatory support. The visual and PEM analyses were also used in the secondary analyses to get an indication of what type of physical activity participants replaced their sedentary time with.

Feasibility outcome variables were reported as total numbers and/or percentages. The reasons for drop out or any missing appointments were listed. The SUS score was calculated per participant, then the mean score and standard deviation were calculated.

Results

Fifty-one potential participants were screened for participation in the study and 14 participants were included, see figure 2. Four participants were female (29%), and the median age was 66.5 (49-78). Other participant characteristics can be found in Table 1. At baseline, the average time spent sedentary during waking hours was 11.4 (SD 1.1, range 10.0-13.7) hours. One participant, from the group without participatory support, dropped out after 5 weeks.

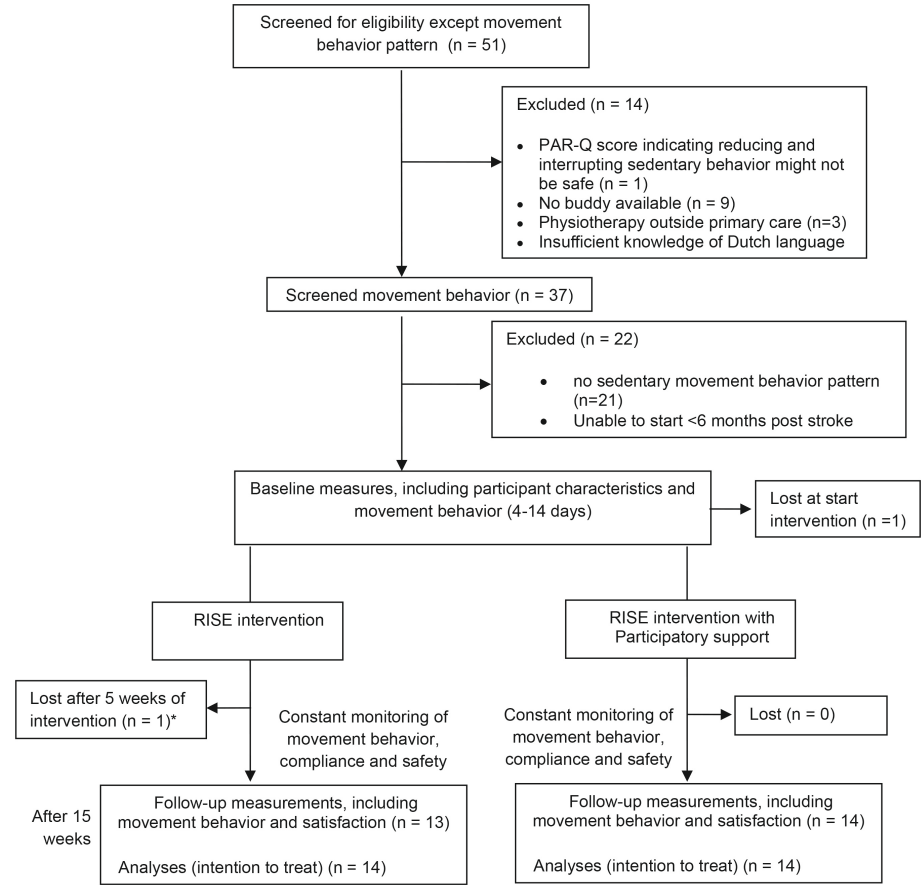


Figure 2. Flow of participants through the trial including measurements conducted. Note: * Reason for drop-out: no longer wanted to feel like a patient

Table 1. Participant characteristics

Characteristic	Complete sample (n = 14)	Group with PS (n=7)	Group without PS (n=7)
Age (years), median (range)	66.5 (49 - 78)	68 (49 - 71)	65 (55 - 78)
Gender, number female (%)	4 (29)	1 (14)	3 (43)
Education level, number (%)			
Low	3 (21)	2 (29)	1 (14)
Medium	6 (43)	3 (43)	3 (43)
High	5 (36)	2 (29)	3 (43)
Comorbidities, number ≥ 2 (% , range)	11 (79, 0-4)	5 (71, 0-4)	6 (86, 1-4)
Living with spouse, number yes (%)	11 (79)	6 (86)	5 (71)
Smoking number (%)			
Current	3 (21)	2 (29)	1 (14)
Previous	8 (57)	4 (57)	4 (57)
Alcohol consumption, number one or more per day (%)	6 (43)	2 (29)	4 (57)
Type of stroke, number infarct (%)	14 (100)	7 (100)	7 (100)
Side of stroke, number right side (%)	3 (21)*	2 (29)	1 (14)*
Stroke severity (NIHSS at time of hospital admission), number ≤ 4 (% , range)	12 (92, 0-8)**	6 (100, 0-4) **	6(86, 0-8)
Stroke impact (SIS physical), median (range)	88 (62-99)	86 (62-89)	89 (65-99)
Recovered (VAS)	79 (55-100)	78 (56-100)	80 (55-99)
Walking speed, number full community walkers (>0.93 m/s) vs limited community walkers (0.40–0.93 m/s) (%)***	9 (64)	6 (86)	3 (43)
General disability (mRS), number ≤ 1 (% , range)	11 (79, 0-2)	5 (71, 0-2)	6 (86, 0-2)
Cognitive impaired (MoCA <26), number (%)	7 (50)	4 (57)	3 (43)

SD: Standard deviation, NIHSS: National Institutes of Health Stroke Scale, SIS: Stroke Impact Scale, ADL: Activities of Daily Living, mRS: modified Rankin Scale, MoCA: Montreal Cognitive Assessment, Management Scale

* One participant had a central located stroke

** NIHSS was not in the medical record of one participant

*** All participants were able to walk independently within the community

Preliminary effectiveness

The randomisation test showed a significant change in both total sedentary time during waking hours ($p=0.01$) and in the fragmentation of sedentary time ($p<0.01$) for the overall group (all 14 participants). In individual level analyses, the PEM showed (score $>60\%$, table 2) that 12 participants (86%) improved on at least one outcome of sedentary

behaviour, and 7 (50%) improved on both outcomes. Examples of the visualisation of the data can be found in image 3, all visuals are included in Supplementary Materials 2.

Of the 11 participants that showed a change in total sedentary time, the reduction ranged from 0.1 to 5.2 hours, with an average of 1.3 hours (SD 1.4). Eight (73%) of the 11 participants had a reduction of sedentary time that exceeded 30 minutes, and 7 (64%) reduced sedentary time by greater than 60 minutes. Fragmentation index score increases ranged from 0.6 to 2.0 with an average change of 1.1 (SD 0.5).

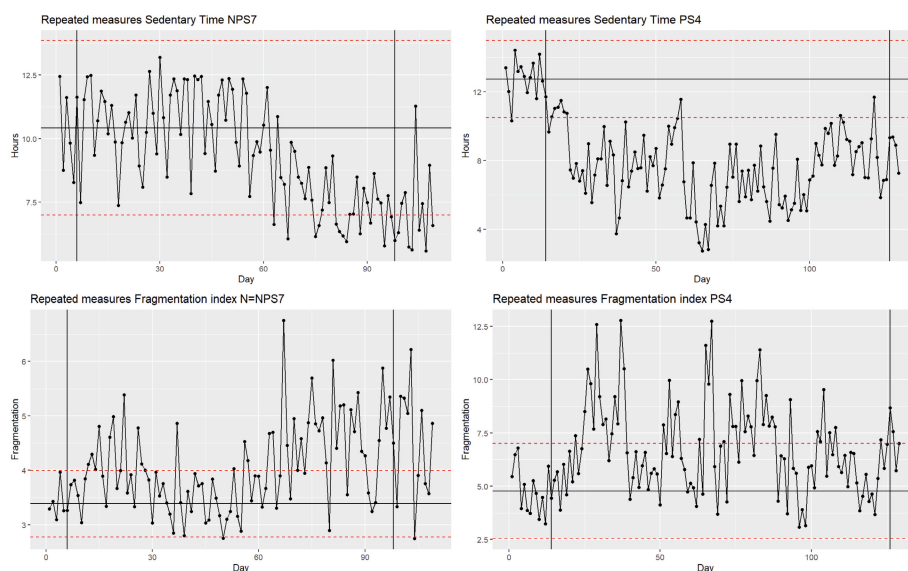


Figure 3 Examples of visualisation of movement behaviour

Note: PS: Participatory support, NPS: group without Participatory Support

The black vertical lines indicate the start and stop of the intervention

The black horizontal line represents the mean from the baseline measurements

The red dashed horizontal lines indicate the 2 standard deviation bands from the baseline measurement.

In total sedentary time a downward trend indicates a reduction in sedentary time. An upwards trend in fragmentation indicates an increase in the interruption of sedentary time.

Table 2. PEM and mean scores (SD)

With participatory support		Sedentary time (hr)		Fragmentation Index*		
Participant	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'
1	69%	10.3 (1.6) 10.1 (1.3)	0.2	65%	3.9 (1.1) 4.9 (1.9)	1
2	57%	11.8 (0.6) 11.7 (1.0)	0.1	76%	2.8 (0.4) 3.4 (0.7)	0.6
3	61%	10.1 (0.9) 10.0 (1.0)	0.1	59%	7.2 (1.6) 7.5 (1.8)	0.3
4	100%	12.7 (1.1) 7.5 (2.0)	5.2	87%	4.8 (1.1) 6.8 (2.1)	2
5	73%	11.4 (0.9) 10.0 (2.0)	1.4	70%	2.6 (0.7) 3.5 (1.9)	0.9
6	71%	11.2 (1.9) 9.8 (2.1)	1.4	90%	2.8 (1.3) 4.7 (1.8)	1.9
7	87%	12.4 (0.7) 11.1 (1.3)	1.3	87%	3.5 (1.1) 4.2 (0.8)	0.7
Without participatory support		Sedentary time (hr)		Fragmentation Index*		
Participant	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'
1	87%	13.7 (0.9) 12.0 (1.2)	1.7	46%	4.1 (0.7) 4.1 (1.1)	0
2	83%	12.0 (2.3) 10.6 (1.6)	1.4	71%	2.3 (0.5) 3.3 (1.1)	1.0
3	46%	11.0 (1.2) 11.0 (1.7)	0	52%	4.3 (1.0) 4.4 (1.5)	0.1
4	65%	11.0 (1.1) 10.9 (1.0)	0.1	24%	4.0 (1.0) 3.3 (0.7)	-0.7
5	68%	10.0 (1.7) 9.2 (2.2)	0.8	54%	5.6 (0.9) 5.9 (2.2)	0.3
6**	22%	10.9 (1.4) 11.0 (0.9)	-0.1	58%	6.0 (1.8) 5.7 (1.2)	-0.3
7	70%	10.4 (1.7) 9.2 (2.2)	1.2	83%	3.4 (0.3) 4.1 (0.8)	0.7

PEM: Percentage exceeding the median; represents the percentage of days, during and after the intervention, in which there was an improvement compared to the baseline median.

Hr: Hours

Phase A: baseline phase; Phase B: intervention phase; Phase A': post intervention phase

SD: standard deviation

Bold: effect of either high (>90), moderate (70-90), or mild (60-70); Non Bold: questionable effect (50-60) or no effect (<50);

* A higher fragmentation index means more interruption of sedentary behaviour

** Pt who dropped out early

When we looked at the groups with and without participatory support separately, there was a significant change in total sedentary time ($p=0.03$) with the addition of participatory support. In this group, there was also a significant change in fragmentation of sedentary time ($p=0.03$). In the group without participatory support only the change in the fragmentation was significant ($p=0.04$), the change in total sedentary time was not ($p=0.11$).

The PEM indicated that all participants in the group with participatory support improved (PEM score $>60\%$, see table 2) on at least one sedentary behaviour outcome and 5 (71%) of the participants improved on both. By comparison, only 5 (86%) and 2 (29%) participants in the group without participatory support improved on these metrics, respectively.

Feasibility

Thirteen participants (93%) completed the intervention, including all face-to-face sessions and use the RISE eCoaching system. One participant dropped out after 5 weeks citing not wanting to be monitored. Three adverse events were registered during the intervention period, though none were related to the intervention.

Participants' SUS questionnaire scores ranged from 60 to 92.5, with an average score of 73 points (SD 13.8). Indicating a medium level of satisfaction with the e-health component of the intervention.

Secondary outcomes

The PEM scores for physical activities were calculated (see Supplementary Materials 2, Table PEM Physical activity). Forty-five percent of the participants replaced their sedentary behaviour with both light and moderate to vigorous physical activity. A further 45% only increased their time spent in light physical activity and 9% only increased their time spent in moderate to vigorous activity.

Discussion

This study provides initial proof of concept that the RISE intervention may be effective in supporting people with stroke who are highly sedentary, to reduce and interrupt their sedentary time. Our preliminary effectiveness analyses showed significant positive effects on total sedentary time and the fragmentation of sedentary time. The intervention also appears feasible with 13 (93%) participants completing the intervention and no intervention-related adverse events. Participants reported sufficient satisfaction with the

intervention. Furthermore, the results of this study suggests the potential added value of integrating participatory support in the RISE intervention.

The changes seen in total sedentary time in our study (average 1.3 hours) may be clinically meaningful. There is no current consensus about the magnitude in reduction of sedentary time needed for a clinically meaningful effect, however several studies,^{21,59} report a dose response relationship between higher amounts of sedentary time and greater health risks.^{5,6,59–62} Increases of 30–60 minutes in sedentary time have been shown to be associated with all-cause mortality including stroke (hazard ratio [HR] 0.20–0.46 and HR 0.47–0.85 for 30 and 60 min increases in daily sedentary time, respectively).⁶ Similarly, others have reported a significant risk increase in cardiovascular mortality of 1.04 (95% CI 1.03, 1.04, $p < 0.001$) for each additional sedentary hour in individuals who were sedentary for >6 h per day.⁶¹

Several studies demonstrate an association between interrupting sedentary time and a reduction in health risk factors in both laboratory-based and free-living studies, although no clear dose response relationship has been identified.^{14–18,60} These studies indicate that the average increased interruption observed in our study, 1.1 points on the fragmentation index (about 10 additional interruptions for an average of 10 hours sitting), may be clinically relevant when it comes to cardiovascular disease risk.^{14–18,60}

It is also important to consider the magnitude of change we found, with the minimal detectable change (MDC) for the measures used. The MDC for total sedentary time was determined at around 30 minutes for older adults and about 60 minutes for office workers based on an average 16 hours wake time measured using the ActivPAL.⁶³ With an average change of 1.3 hours in our study, there appears to be a real change. The MDC for the fragmentation index was 1.2 for both older adults and office workers.⁶³

Studies of interventions aiming to reduce sedentary behaviour in other cardiovascular disease populations have reported small and non-significant effects. A recent randomised controlled study in a cardiac rehabilitation population showed a decrease in sedentary behaviour in the intervention group, though no significant between intervention and control group difference.⁶⁴ Another recent pilot study, in a cardiac population targeting moving more and sitting less only found a significant increase in daily steps, the time spent sedentary did not change.⁶⁵ This is consistent with recent reviews in the area of cardiovascular disease, who conclude the need for further research due to the lack of evidence.^{66,67} Similar conclusions can be found in a Cochrane review in community-dwelling older adults.⁶⁸ Our study shows promising results, which could be related to the behavioural approach and the blended nature of the intervention combining face-to-face

coaching with e-health by means of the RISE system that enabled real-time feedback on movement behaviour patterns. Another novelty in our study was the inclusion of extensive social support by means of participatory support. Though a randomised controlled trial including a longer follow-up is needed to confirm the efficacy of the RISE intervention.

When it comes to the addition of participatory support to the RISE intervention, our results suggest this form of social support may provide added value. In six cases, a spouse acted as buddy and in one it was a daughter, all completed the intervention period. These results match the insights from other studies which found that the direct social environment is important when it comes to influencing movement behaviour.^{25,27,30,31,69} Participatory support appears to influence both daily habits and routines, and seems capable of providing meaningful support to change behaviour.^{25,30,31,69}

Our results suggests that a blended intervention, delivered by a physiotherapist that combines coaching with an e-health system and includes several behaviour change techniques seems promising to change sedentary behaviour. This is consistent with recent studies that show an increase in the use of applications integrated with behaviour change techniques which are promising to improve movement behaviour.^{66,67,69} Although no clear recommendations could be made regarding which techniques are effective to improve sedentary behaviour.^{66,67,69} Our study could be a first step to fill this gap in knowledge. A randomised controlled trail including a long term follow-up is needed to draw definitive conclusions.

Strengths and limitations

This study had a number of strengths. Firstly, using the multiple baseline design enabled us to give a well-supported preliminary estimation of the effect of the RISE intervention with a minimal burden and small sample size.^{70,71} Secondly, the combination of the highly reliable and valid activity monitor,^{45–47} to measure movement behaviour, and the use of the ProcessingPAL software together with the diaries to determine wake time contributed to the rigour of the data collection and subsequent validity of the results. Thirdly, the intervention was delivered by physiotherapists specifically trained to provide the RISE intervention. Still physiotherapist afterwards stated they feel they need an even higher skill level to optimally support movement behaviour change.

Our study had some limitations. We experienced some technical difficulties with the use of the RISE monitor and app leading to a slow loading of movement behaviour data. Though this was improved during the study, this may have negatively influenced on our results, in terms of satisfaction with the intervention. In addition, large variability was seen in the sedentary behaviour data. Although the minimal baseline measurement duration used

(4 days) was in line with previous research to determine an accurate average, this may have affected the results. However, this limitation was mitigated by the use of analysis strategies that best suited datasets with large variability. Seventy percent of our sample was male, which limits generalisability. Lastly, though the randomised multiple baseline design accounts for within person variability, our sample size was still small and therefore more sensitive to the influence of any extraordinary occurrences within the setting of the participants.

Conclusion

The RISE intervention appears promising to support people with stroke who are highly sedentary to reduce and interrupt their sedentary time. Participatory support provided by someone from their social network (e.g. partner or close friend) who joins the participant in the RISE intervention appears to contribute to greater results. Our results show the potential of blended behavioural interventions for supporting movement behaviour change. A randomised controlled trial including a longer follow-up is needed to confirm the efficacy of the RISE intervention.

References

1. Bekijk de cijfers over hart- en vaatziekten | Hartstichting. <https://www.hartstichting.nl/hart-en-vaatziekten/feiten-en-cijfers-hart-en-vaatziekten>. Accessed October 17, 2019.
2. Mohan KM, Wolfe CDA, Rudd AG, Heuschmann PU, Kolominsky-Rabas PL, Grieve AP. Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*. 2011;42(5):1489-1494. doi:10.1161/STROKEAHA.110.602615
3. Pennlert J, Eriksson M, Carlberg B, Wiklund P-G. Long-term risk and predictors of recurrent stroke beyond the acute phase. *Stroke*. 2014;45(6):1839-1841. doi:10.1161/STROKEAHA.114.005060
4. GBD 2016 Stroke Collaborators. Global, regional, and national burden of stroke, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18(5):439-458. doi:10.1016/S1474-4422(19)30034-1
5. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
6. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*. 2019;366:l4570. doi:10.1136/bmj.l4570
7. Feigin VL, Brainin M, Norrving B, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2022. *Int J Stroke*. 2022;17(1):18-29. doi:10.1177/17474930211065917
8. Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association. *Stroke*. 2021;52(7). doi:10.1161/STR.0000000000000375
9. Ford ES, Caspersen CJ. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *Int J Epidemiol*. 2012;41(5):1338-1353. doi:10.1093/ije/dys078
10. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123-132. doi:10.7326/M14-1651
11. Bauman AE, Chau JY, Ding D, Bennie J. Too Much Sitting and Cardio-Metabolic Risk: An Update of Epidemiological Evidence. *Curr Cardiovasc Risk Rep*. 2013;7(4):293-298. doi:10.1007/s12170-013-0316-y
12. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi:10.1186/s12966-017-0525-8
13. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev*. 2008;36(4):173-178. doi:10.1097/JES.0b013e3181877d1a
14. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-666. doi:10.2337/dc07-2046

15. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
16. Benatti FB, Ried-Larsen M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Med Sci Sports Exerc*. 2015;47(10):2053-2061. doi:10.1249/MSS.0000000000000654
17. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity (Silver Spring)*. 2015;23(9):1800-1810. doi:10.1002/oby.21180
18. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: Breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke*. 2018;13(9):932-940. doi:10.1177/1747493018798535
19. Sacco RL, Benjamin EJ, Broderick JP, et al. American Heart Association Prevention Conference. IV. Prevention and Rehabilitation of Stroke. Risk factors. *Stroke*. 1997;28(7):1507-1517. <http://www.ncbi.nlm.nih.gov/pubmed/9227708>. Accessed July 18, 2018.
20. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behavior Patterns in People With First-Ever Stroke. *Stroke*. 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
21. Saunders DH, Mead GE, Fitzsimons C, et al. Interventions for reducing sedentary behaviour in people with stroke. *Cochrane Database Syst Rev*. 2018;2018(4). doi:10.1002/14651858.CD012996
22. Tieges Z, Mead G, Allerhand M, et al. Sedentary behavior in the first year after stroke: a longitudinal cohort study with objective measures. *Arch Phys Med Rehabil*. 2015;96(1):15-23. doi:10.1016/j.apmr.2014.08.015
23. Hendrickx W, Riveros C, Askim T, et al. Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies. *Top Stroke Rehabil*. 2019;26(5):327-334. doi:10.1080/10749357.2019.1601419
24. Hendrickx W, Riveros C, Askim T, et al. An Exploration of Sedentary Behavior Patterns in Community-Dwelling People With Stroke: A Cluster-Based Analysis. *J Neurol Phys Ther*. 2021;45(3):221-227. doi:10.1097/NPT.0000000000000357
25. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil*. 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764
26. English C, Healy GN, Coates A, Lewis LK, Olds T, Bernhardt J. Sitting time and physical activity after stroke: physical ability is only part of the story. *Top Stroke Rehabil*. 2016;23(1):36-42. doi:10.1179/1945511915Y.0000000009
27. Hendrickx W, Wondergem R, Pisters MF, et al. It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive. *Submitt to peer Rev J*. 2023.
28. Hendrickx W, Wondergem R, English C, Visser-Meily JMA, Veenhof C, Pisters MF. Developing RISE, a blended behavioural intervention to support people to reduce and interrupt their sedentary behaviour. *Submitt to peer Rev J*. 2023.

29. van Gemert-Pijnen JEW, Nijland N, van Limburg M, et al. A holistic framework to improve the uptake and impact of eHealth technologies. *J Med Internet Res*. 2011;13(4):e111. doi:10.2196/jmir.1672
30. Albert NM, Forney J, Slifcak E, Sorrell J. Understanding physical activity and exercise behaviors in patients with heart failure. *Hear Lung*. 2015;44(1):2-8. doi:10.1016/j.hrtlng.2014.08.006
31. Lindsay Smith G, Banting L, Eime R, O'Sullivan G, van Uffelen JGZ. The association between social support and physical activity in older adults: a systematic review. *Int J Behav Nutr Phys Act*. 2017;14(1):56. doi:10.1186/s12966-017-0509-8
32. Ferron J, Sentovich C. Statistical Power of Randomization Tests Used with Multiple-Baseline Designs. *J Exp Educ*. 2002;70(2):165-178. doi:10.1080/00220970209599504
33. Levin JR, Ferron JM, Gafurov BS. Additional comparisons of randomization-test procedures for single-case multiple-baseline designs: Alternative effect types. *J Sch Psychol*. 2017;63:13-34. doi:10.1016/j.jsp.2017.02.003
34. Levin JR, Ferron JM, Gafurov BS. Comparison of randomization-test procedures for single-case multiple-baseline designs. *Dev Neurorehabil*. 2018;21(5):290-311. doi:10.1080/17518423.2016.1197708
35. Hawkins NG, Sanson-Fisher RW, Shakeshaft A, D'Este C, Green LW. The Multiple Baseline Design for Evaluating Population-Based Research. *Am J Prev Med*. 2007;33(2):162-168. doi:10.1016/j.amepre.2007.03.020
36. Kratochwill TR, Levin JR. Enhancing the scientific credibility of single-case intervention research: Randomization to the rescue. *Psychol Methods*. 2010;15(2):124-144. doi:10.1037/a0017736
37. Wampold, Bruce E. Worsham NL. Randomization tests for multiple-baseline designs. - PsycNET. *Behav Assess*. 1986;8:135-143. <https://psycnet.apa.org/record/1987-09267-001>. Accessed February 21, 2020.
38. Shamseer L, Sampson M, Bukutu C, et al. CONSORT extension for reporting N-of-1 trials (CENT) 2015: explanation and elaboration. *J Clin Epidemiol*. 2016;76:18-46. doi:10.1016/j.jclinepi.2015.05.018
39. Nourbakhsh MR, Ottenbacher KJ. The statistical analysis of single-subject data: a comparative examination. *Phys Ther*. 1994;74(8):768-776. doi:10.1093/ptj/74.8.768
40. Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. *Phys Ther*. 1984;64(1):35-40. doi:10.1093/ptj/64.1.35
41. MAHONEY FI, BARTHEL DW. FUNCTIONAL EVALUATION: THE BARTHEL INDEX. *Md State Med J*. 1965;14:61-65. <http://www.ncbi.nlm.nih.gov/pubmed/14258950>. Accessed February 21, 2020.
42. American College of Sports Medicine, Lippincott, Williams, Wilkins. *ACSM's Guidelines for Exercise Testing and Prescription - American College of Sports Medicine - Google Boeken*. 9th ed.; 2013. <https://books.google.nl/books?hl=nl&lr=&id=hhosAwAAQBAJ&oi=fnd&pg=PP1&dq=American+College+of+Sports+Medicine.+ACSM's+Guidelines+for+exercise+testing+and+prescription&ots=jl40l4UOC&sig=qpu8Won2bZWcZdc3WfXOMBtv1tg#v=one-page&q=American+College+of+Sports+Medicine>. Accessed February 21, 2020.

43. Medical physical activity monitors & motion tracking solutions - Activ8. <https://www.activ8all.com/>. Accessed February 21, 2020.
44. Fanchamps MHJ, Horemans HLD, Ribbers GM, Stam HJ, Bussmann JBJ. The Accuracy of the Detection of Body Postures and Movements Using a Physical Activity Monitor in People after a Stroke. *Sensors (Basel)*. 2018;18(7). doi:10.3390/s18072167
45. Taraldsen K, Askim T, Sletvold O, et al. Evaluation of a body-worn sensor system to measure physical activity in older people with impaired function. *Phys Ther*. 2011;91(2):277-285. doi:10.2522/ptj.20100159
46. Godfrey A, Culhane KM, Lyons GM. Comparison of the performance of the activPAL Professional physical activity logger to a discrete accelerometer-based activity monitor. *Med Eng Phys*. 2007;29(8):930-934. doi:10.1016/j.medengphys.2006.10.001
47. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc*. 2012;44(11):2243-2252. doi:10.1249/MSS.0b013e318260c477
48. Bangor A, Kortum PT, Miller JT. An Empirical Evaluation of the System Usability Scale. *Int J Hum Comput Interact*. 2008;24(6):574-594. doi:10.1080/10447310802205776
49. Hamels B. palcsvknitter program. palcsvknitter program. <https://github.com/BjornHamels/palcsvknitter/releases/tag/v0.1-beta5>. Published 2022.
50. Winkler EAH, Bodicoat DH, Healy GN, et al. Identifying adults' valid waking wear time by automated estimation in activPAL data collected with a 24 h wear protocol. *Physiol Meas*. 2016;37(10):1653-1668. doi:10.1088/0967-3334/37/10/1653
51. Winkler EAH, Ette S. ProcessingPAL software. ProcessingPAL software. <https://github.com/UOL-COLS/ProcessingPAL/releases>.
52. Bulté I, Onghena P. An R package for single-case randomization tests. *Behav Res Methods*. 2008;40(2):467-478. doi:10.3758/brm.40.2.467
53. Bulté I, Onghena P. Randomization tests for multiple-baseline designs: an extension of the SCRT-R package. *Behav Res Methods*. 2009;41(2):477-485. doi:10.3758/BRM.41.2.477
54. Manolov R, Moeyaert M. Recommendations for Choosing Single-Case Data Analytical Techniques. *Behav Ther*. 2017;48(1):97-114. doi:10.1016/j.beth.2016.04.008
55. Manolov R, Losada JL, Chacón-Moscó S, Sanduvete-Chaves S. Analyzing Two-Phase Single-Case Data with Non-overlap and Mean Difference Indices: Illustration, Software Tools, and Alternatives. *Front Psychol*. 2016;7:32. doi:10.3389/fpsyg.2016.00032
56. Lane JD, Gast DL. Visual analysis in single case experimental design studies: Brief review and guidelines. *Neuropsychol Rehabil*. 2014;24(3-4):445-463. doi:10.1080/09602011.2013.815636
57. Parker RI, Vannest KJ, Davis JL. Effect size in single-case research: a review of nine nonoverlap techniques. *Behav Modif*. 2011;35(4):303-322. doi:10.1177/0145445511399147
58. Ma H-H. An alternative method for quantitative synthesis of single-subject researches: percentage of data points exceeding the median. *Behav Modif*. 2006;30(5):598-617. doi:10.1177/0145445504272974
59. Duran AT, Romero E, Diaz KM. Is Sedentary Behavior a Novel Risk Factor for Cardiovascular Disease? *Curr Cardiol Rep*. 2022;24(4):393-403. doi:10.1007/s11886-022-01657-w

60. Bell AC, Richards J, Zakrzewski-Fruer JK, Smith LR, Bailey DP. Sedentary Behaviour—A Target for the Prevention and Management of Cardiovascular Disease. *Int J Environ Res Public Health*. 2022;20(1):532. doi:10.3390/ijerph20010532
61. Patterson R, McNamara E, Tainio M, et al. Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis. *Eur J Epidemiol*. 2018;33(9). doi:10.1007/S10654-018-0380-1
62. Hooker SP, Diaz KM, Blair SN, et al. Association of Accelerometer-Measured Sedentary Time and Physical Activity With Risk of Stroke Among US Adults. *JAMA Netw open*. 2022;5(6):e2215385. doi:10.1001/jamanetworkopen.2022.15385
63. Chastin SFM, Winkler EAH, Eakin EG, et al. Sensitivity to Change of Objectively-Derived Measures of Sedentary Behavior. *Meas Phys Educ Exerc Sci*. 2015;19(3):138-147. doi:10.1080/1091367X.2015.1050592
64. van Bakel BMA, Kroesen SH, Bakker EA, et al. Effectiveness of an intervention to reduce sedentary behaviour as a personalised secondary prevention strategy for patients with coronary artery disease: main outcomes of the SIT LESS randomised clinical trial. *Int J Behav Nutr Phys Act*. 2023;20(1):17. doi:10.1186/s12966-023-01419-z
65. Swartz AM, Wamsley C, Crownover E, et al. Move more and sit less pilot intervention for individuals with heart failure. *Int J Cardiol*. 2022;366:57-62. doi:10.1016/j.ijcard.2022.06.071
66. Patterson K, Davey R, Keegan R, Freene N. Smartphone applications for physical activity and sedentary behaviour change in people with cardiovascular disease: A systematic review and meta-analysis. *PLoS One*. 2021;16(10):e0258460. doi:10.1371/journal.pone.0258460
67. Patterson K, Davey R, Keegan R, Kunstler B, Woodward A, Freene N. Behaviour change techniques in cardiovascular disease smartphone apps to improve physical activity and sedentary behaviour: Systematic review and meta-regression. *Int J Behav Nutr Phys Act*. 2022;19(1):81. doi:10.1186/s12966-022-01319-8
68. Chastin S, Gardiner PA, Harvey JA, et al. Interventions for reducing sedentary behaviour in community-dwelling older adults. *Cochrane database Syst Rev*. 2021;6(6):CD012784. doi:10.1002/14651858.CD012784.pub2
69. Martín-Martín J, Roldán-Jiménez C, De-Torres I, et al. Behavior Change Techniques and the Effects Associated With Digital Behavior Change Interventions in Sedentary Behavior in the Clinical Population: A Systematic Review. *Front Digit Heal*. 2021;3:620383. doi:10.3389/fdgth.2021.620383
70. Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ*. 2008;337:a1655. doi:10.1136/bmj.a1655
71. Bernhardt J, Hayward KS, Dancause N, et al. A stroke recovery trial development framework: Consensus-based core recommendations from the Second Stroke Recovery and Rehabilitation Roundtable. *Int J Stroke*. 2019;14(8):792-802. doi:10.1177/1747493019879657

Supplementary Materials 1: RISE intervention details

Table 1. RISE intervention details

See Chapter 6, page 156 'Supplementary Materials 6: HAPA model and RISE intervention; Table 1. A detailed description of the RISE intervention'

Supplementary Materials 2: Data visualisation and Table PEM Physical activity

Images repeated measurement

This data will be published online due to its large quantity. It is currently available on request from Wendy Hendrickx (w.hendrickx@fontys.nl)

Table Percentage Exceeding the Mean scores Physical Activity

Table PEM and mean scores (SD) Physical Activity

With Participatory Support		Time in LPA (hr)		Time in MVPA (min)		
Participant	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'
1	74%	3.4 (1.1)	0.6	89%	48.8 (36.6)	21.3
2	63%	4.0 (1.2)	0.4	80%	70.1 (26.1)	12
3	57%	3.2 (0.8)	0.2	53%	32.4 (10.5)	4
4	100%	3.6 (1.0)	4.2	52%	44.4 (17.8)	-0.7
5	59%	3.5 (0.9)	0.5	54%	45.1 (13.6)	4.6
6	78%	2.1 (0.4)	1.5	93%	15.9 (6.6)	37.2
7	93%	6.3 (1.9)	1.2	57%	15.2 (5.4)	8.2
		2.6 (0.7)			22.8 (5.7)	
		3.1 (1.4)			27.4 (16.3)	
		2.4 (1.5)			26.4 (21.3)	
		3.9 (2.0)			63.6 (31.0)	
		2.5 (0.6)			54.1 (15.1)	
		3.7 (1.1)			62.3 (29.3)	
Without Participatory Support		Time in LPA (hr)		Time in MVPA (min)		
Participant	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'	Percentage Exceeding baseline Median (PEM, %)	mean [SD] phase A phase B+A'	Difference phase A phase B+A'
1	84%	1.7 (0.5)	0.8	83%	14.7 (3.3)	11.4
2	72%	2.5 (0.8)	1	64%	26.1 (12.3)	23.1
3	34%	2.6 (0.8)	-0.3	47%	54.2 (16.6)	-12
4	40%	3.6 (1.5)	-0.3	34%	77.3 (39.1)	-6.6
5	72%	3.0 (0.9)	0.6	40%	92.4 (37.0)	-10.9
6*	58%*	2.7 (0.9)	-0.1	69%*	42.3 (17.6)	6.1
7	70%	2.2 (0.5)	1.4	26%	35.7 (17.7)	-13.6
		4.3 (0.7)			42.4 (14.9)	
		4.9 (1.4)			52.9 (30.7)	
		4.1 (1.2)			48.5 (14.6)	
		4.0 (0.7)			97.9 (27.3)	
		3.4 (1.0)			84.3 (28.8)	
		4.8 (2.0)				

PEM: Percentage exceeding the median; represents the percentage of days, during and after the intervention, in which there was an improvement compared to the baseline median.

Hr: Hours

Phase A: baseline phase; Phase B: intervention phase; Phase A': post intervention phase

SD: standard deviation

Green: effect of either high (>90) or moderate (70-90); Blue: mild (60-70); Black: questionable effect (50-60) or no effect (<50);

* Pt who dropped out early



CHAPTER 8

General discussion

People who have had a stroke have a high risk of recurrent stroke. High levels of sedentary behaviour and low levels of physical activity have been identified as risk factors for cardiovascular disease, including stroke. A large proportion (79%) of people who have had a stroke engage in high levels of sedentary behaviour and barely interrupt their sedentary time, and few meet the recommended levels of moderate to vigorous physical activity. Therefore, improving movement behaviour is of vital importance for secondary prevention after stroke. There are no effective interventions to support people who have had a stroke to reduce and interrupt their sedentary behaviour and increase their levels of (light) physical activity.¹

The aim of this thesis was to identify what is needed to support people with stroke who are highly sedentary and inactive to sustainably change their movement behaviour patterns. This enabled the development of an intervention that aims to improve movement behaviour, by reducing and interrupting sedentary behaviour and determine the preliminary effectiveness and feasibility of the intervention.

Main findings

1. We combined ActivPAL data from 9 original studies to identify which personal and stroke-related factors are associated with high amounts of sedentary time (Chapter 2). Only low walking speed was found to be associated with high amounts of sedentary time and high proportions of sedentary time spent in prolonged bouts, which accounted for 11-19% of the variability. This indicates a need to investigate the influence of environmental and behavioural factors. These factors were not included in this study, although they may be highly relevant to address within an intervention.
2. When looking at the accumulation patterns of sedentary time, people within the highest quartile of sedentary time accumulated a significantly higher proportion of their sedentary time in prolonged bouts (Chapter 3).
3. Large variability was seen in the accumulation pattern of sedentary time. Even for highly sedentary people with stroke, there is not one single accumulation pattern of movement behaviour (Chapter 3). Personal and stroke-related factors explain only a very small part of the variability in the accumulation of sedentary behaviour. This shows the need to determine individual movement behaviour patterns to enable personalized coaching (Chapter 3).

4. General lifestyle interventions do not seem to be effective in supporting increasing levels of physical activity in people after stroke or TIA (Chapter 4). A specific focus on movement behaviour seems necessary.
5. People who have had a stroke are mostly unaware of their own movement behaviour pattern, especially their level of sedentary behaviour, and the risks associated with their movement behaviour pattern (Chapter 5).
6. Movement behaviour across the day (i.e., accumulation patterns) is, for the most part, based on daily routine and personal habits. People rarely think about how much time they spend sitting or standing during the day. The accumulation of sedentary time (and physical activity) is highly dependent on what activities they people engage in during the day and is therefore influenced by factors from their physical and social environment. This needs to be taken into account during intervention development (Chapter 5).
7. The RISE (***R**educe and **I**nterrupt **S**edentary behaviour using a blended behaviour intervention to **E**mpower people at risk towards sustainable movement behaviour change*) intervention was developed through an extensive development process using the principles of co-design (Chapter 6). The RISE intervention is a 15-weeks blended behavioural intervention in which a primary care physiotherapist coaches participants to reduce and interrupt their sedentary time. Physiotherapists provide personalized coaching to people with a first-ever stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, 3) a monitoring dashboard for the physiotherapist. Participants receive participatory support from someone from their social network (e.g., a partner or close friend) who joins them in the intervention.
8. The blended behavioural intervention called RISE appears promising. Preliminary effectiveness was shown by a significant reduction in sedentary time (1.3 hours on average) and a significant improvement in interrupting sedentary time. Additionally, the intervention was considered feasible (Chapter 7).
9. Including participatory support appears to contribute to the effectiveness of the RISE intervention (Chapter 7).

Interpretation and discussion

Movement behaviour interventions and the new focus on secondary prevention

The high stroke recurrence rate calls for effective secondary prevention strategies. With the development of the RISE intervention, we aimed to address this need. A combination of medication and lifestyle changes can lead to a risk reduction of 80% for recurrent vascular events.² This shows the need for secondary prevention with attention to lifestyle, such as movement behaviour (including sedentary behaviour). In general, a transition to a more (secondary) preventative focus seems necessary in health care due to increases in the number of people living with a chronic condition and increases in health costs.³⁻⁵ This has led to an expansion of the view of health care from merely the absence of illness and care to a broader perspective including daily functioning, lifestyle and the living environment as well as maintaining and promoting health in everyday life.^{5,6} In fact, one of the aims of the Knowledge and Innovation Agenda 2020-2023 health and care developed by the Ministry of Health, Welfare and Sport (VWS) and partners is that *'by 2040, the burden of disease resulting from an unhealthy lifestyle and living environment is decreased by 30%.'*⁶ This is also emphasized in the articulation of the policy-based report *'The right care in the right place'*, which states, *'We should be thinking much more in terms of health and well-being. This also means investing in prevention, lifestyle advice, early detection and a broad assessment of what is genuinely needed.'*⁷ These policy documents stimulate the development of interventions such as the RISE intervention from a broader health care perspective and the need to address lifestyle. The RISE intervention focuses on healthy movement behaviour as part of a healthy lifestyle and may be highly valuable for secondary prevention. The RISE intervention also incorporates innovative technological applications by means of e-health and blended care. Both aspects fit the current policies: *'the essence of 'The right care in the right place' is avoiding expensive care, moving the point of care delivery closer to people's homes and replacing care delivery with other forms such as e-health.'*⁷

More than just physical capabilities

Currently, physiotherapy care focuses mostly on physical capabilities. Research, including the current studies (Chapters 2, 3, 5, and 6), shows the importance of focusing on environmental (both social and physical) and behavioural aspects to support people to reduce their sedentary behaviour.^{1,8,9} Just because someone is capable of a certain behaviour, such as standing or walking, does not automatically mean they will perform this behaviour in sufficient amounts. Therefore, there is much to gain from a complete behavioural approach that enables change throughout the day while focusing on opportunity, motivation and cognitive as well as physical capabilities. For this reason, we used the behaviour change wheel (BCW) to develop the RISE intervention (Chapters 5

and 6). This intervention development methodology takes into account all these aspects related to movement behaviour.^{10,11} It enables the indication of all factors related to capabilities, opportunities and motivation regarding the behaviour and how they should be addressed.^{10,11}

During the intervention development process, we found that the incorporation of social support is needed, which is also supported by the literature on the stroke population.^{8,12,13} This is because people's levels of sedentary behaviour are mostly driven by habits and routines, which are directly related to their social and physical environment (Chapter 5). Additionally, social support helps people stay motivated and obtain the support needed to sustainably change their behaviour.^{8,12,13} Within the RISE intervention, an extensive form of social support, participatory support, was investigated and appears to contribute to greater results. This means truly involving people from the social environment of the participant in interventions. The coaching sessions were in the home environment, allowing the physiotherapist and the participant to assess the environment. Addressing possible limitations due to stroke or other comorbidities as well as every environmental factor related to movement behaviour.

Another finding from our studies that was relevant to further exploration during the development process was the large variability in movement behaviour and within the accumulation patterns (Chapters 2 and 3). Since sedentary behaviour is often spread throughout the day and is closely related to habits and routines, it is part of mostly subconscious processes (Chapter 5). That is, being highly sedentary is not a conscious choice for most people with stroke; it highly depends on what activities people engage in and what their physical and social environment looks like. Within an intervention, a focus on creating awareness of personal movement behaviour patterns and the health risks related to these movement patterns is needed. These insights are vital to enable behavioural regulation and address daily habits and routines that increase sedentary behaviour and enable behaviour change.

Using innovative technologies to provide insight into movement behaviour

The RISE intervention development process indicated the need to develop the RISE eCoaching system. One of the things that makes the RISE eCoaching system unique is that it provides an accurate overview of 1) the amount of sedentary time with a specification of time spent in prolonged bouts (>30 min) and 2) the time spent engaged in physical activity with a specification for moderate to vigorous physical activity. Both the participant and the physiotherapist can see this overview. Second, the RISE system provides an accurate overview of each type of movement behaviour throughout the day. Both the

participant and the physiotherapist can see the daily accumulation pattern (see image 1). The availability of total amounts and accumulation patterns in real time is not found in other available monitoring systems.

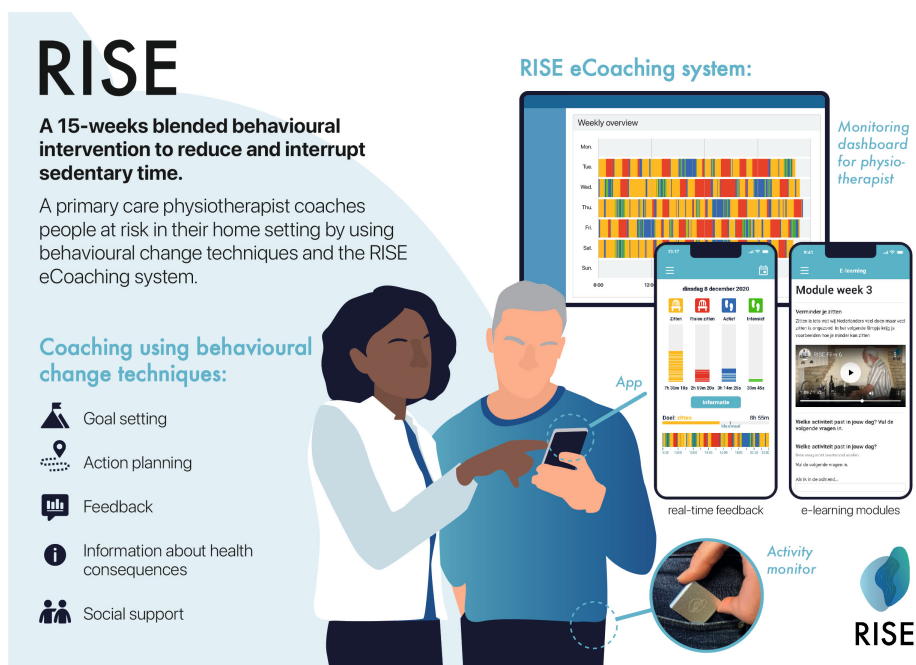


Image 1. The RISE intervention including the RISE eCoaching system

Providing this real-time feedback enables sustainable change to sedentary behaviour. These insights are needed to determine the focus of the behaviour change and to enable individualised and thorough coaching. By showing the goals and the action plan, the system provides daily support throughout the day to specifically change sedentary behaviour, which is accumulated throughout the day. The real-time feedback is also of great importance because the different types of movement behaviour and their influence on health are not independent.^{14–16} Since the system shows the integrated movement behaviour pattern throughout the day, it allows for a more integrated level of coaching.

Physiotherapist from cure to coach

The shift in focus in health care from a cure perspective and focus on (physical) capabilities to prevention and coaching in lifestyle requires a change in the regular conduct of physiotherapists. Changing movement behaviour, especially sedentary behaviour, requires behavioural interventions that address all factors related to the behaviour. Coaching and behaviour change techniques are thus becoming increasingly important in physiotherapy

care for people with stroke. As lifestyle coaching is an upcoming profession and coaches have different backgrounds, one of the questions to ask is whether a physiotherapist is needed to support movement behaviour change. Looking at the results of our lifestyle intervention review (Chapter 4), we see an indication that the involvement of physiotherapists may be relevant. Additionally, a well-supported finding from both our review and the reviews of others is that a specific focus on movement behaviour and sedentary behaviour is needed to enable change.^{17,18} Physiotherapists have expertise in regard to stroke sequelae, physical capabilities, training principles, physical activity and basic coaching skills. Therefore, they account for a large part of the skills needed to cover important aspects to support movement behaviour change, including sedentary behaviour, in people who have suffered a stroke. This makes them capable of providing a focus on movement behaviour, including sedentary behaviour, that was found to be necessary in our studies (Chapters 4 and 5) and in previous literature.^{17,18} Physiotherapists are also familiar with working with other disciplines to address the complex multifactorial aspects of stroke sequelae to provide complete care.

Expansion of these skills is necessary. To support sustainable sedentary behaviour change, a physiotherapist needs a thorough understanding of movement behaviour patterns, including sedentary behaviour, and the associated health risks to determine possible focus points for coaching. Additionally, physiotherapists need to be able to make a behavioural diagnosis to identify all factors regarding capabilities (including stroke-related factors), opportunity and motivation related to personal movement behaviour. Furthermore, they need to be able to incorporate appropriate behaviour change techniques and have sufficient communication skills to deliver the coaching in an effective manner. The promising results of the RISE intervention study (Chapter 7) show that with education and skill training, physiotherapists feel more capable of delivering advanced behaviour change techniques and appear to be able to support people with stroke in improving their movement behaviour patterns by reducing and interrupting sedentary behaviour, indicating great potential in this area. The education and training of physiotherapists in the current RISE intervention is a good starting point; however, it is not sufficiently extensive with regard to the advanced practical incorporation of all relevant behaviour change techniques and knowledge of movement behaviour to optimally support behaviour change. This conclusion is based on the evaluation of the results and specifically on the fact that physiotherapists involved in delivering the RISE intervention have stated that they need an even higher skill level to optimally support movement behaviour change. This calls for more attention to movement behaviour, including sedentary behaviour, as well as behaviour change knowledge and coaching skills in educational programmes for both newly educated physiotherapists and current professionals.

Implementation into regular care

How can an intervention such as RISE fit into regular care? When we look at the guidelines for stroke care, they all include secondary prevention aims, such as stimulating healthy movement behaviour, including sedentary behaviour in some.^{19–22} In practice, the incorporation of these secondary prevention guidelines is often part of routine cardiovascular risk checks at the general practitioner's office that mostly focus on medication regulation.²³ There is some attention to a healthy lifestyle, although this often only entails the advice to, for instance, engage in sufficient moderate to vigorous physical activity. This is the case although the literature and the findings of our study show that general advice is not sufficient to incorporate behaviour change, and sedentary behaviour warrants specific attention.^{1,17} The preliminary effect study showed that the RISE intervention seems promising, so it might be beneficial to start thinking about how it could be integrated into current secondary prevention actions if effectiveness is definitively proven. An option could be to expand regular check-ups with general practitioners to include an objective determination of movement behaviour to identify who is at risk. This would enable indicated referrals for those in need of support to a physiotherapist to participate in the RISE intervention as part of routine care. With the high costs of curative health care and the personal burden of recurrent stroke and other cardiovascular disease,^{19,24} it seems warranted to allocate budgets to these types of secondary prevention interventions.^{19–22} These interventions will also have some costs; however, it is expected that the costs will be lower than curative and long-term care costs, especially if risk identification is used.^{3–7}

Another implementation option for those receiving post-stroke rehabilitation would be to integrate RISE within regular physiotherapy care. Ideally, secondary prevention should start as soon as possible after stroke.^{19–22} Within the first year, approximately 25% of people will have another major adverse cardiovascular event (e.g., recurrent stroke, acute coronary events and cardiovascular death).²⁵ Post-stroke care is provided immediately after these major life events and often involves addressing people's daily activities from a capability perspective in the home setting. This provides the ideal situation to integrate and/or follow-up by addressing movement behaviour, including sedentary behaviour.

Methodological considerations

Due to the complexity of behaviour change, we conducted a thorough design process that included truly understanding the behaviour and determining the needs of the people for whom the intervention was designed (Chapters 2–6). To ensure that the intervention met the needs of people with stroke and other stakeholders and could be delivered as intended, it was decided not to immediately proceed to a large randomised trial with the newly developed intervention. In line with recommendations,^{26,27} the preliminary effectiveness

and feasibility were first determined (Chapter 7). To enable an accurate assessment of the preliminary effectiveness of the intervention without the need for a large sample, a randomised multiple baseline design was used.^{28–33} In these types of designs, repeated measurements are applied before, after and during the intervention with baselines of varying length, including random allocation. This allows a distinction between observed effects of the treatment and effects due to chance.^{28–34} Due to the continuous monitoring over time, the pattern of behaviour change can be determined, enabling the detection of genuine change in sedentary behaviour that can be complicated in other designs due to the large day-to-day variability of sedentary behaviour.³⁵ Therefore, this type of design is recommended for future studies with a similar aim. To account for this large variability, which was also seen in our data, we recommend including a sufficiently long baseline measurement. The previous estimation of 3–4 days³⁶ to obtain accurate averages within this design does not seem sufficient for some participants. For future research, we would recommend a minimum baseline period of at least two weeks.

The RISE intervention development process was thorough and methodical. It included several research strategies to determine what was needed within the intervention. To guide several parts of this process, the Behaviour Change Wheel methodology was used. This included obtaining the perspective of people with stroke who were highly sedentary and inactive to ensure that the intervention matched their needs as much as possible. Additionally, in the actual design phase of the RISE system, people with stroke provided valuable input. In future intervention development, we recommend increasing end-user participation even further to a level where participants are involved in the choices made regarding the trial. This would, for instance, provide information regarding the best time to start the intervention post-stroke, which we found out during the trial, varied among potential participants.

For the RISE intervention, we had a detailed intervention protocol and provided educational sessions for the physiotherapist delivering the intervention before the start of inclusion. Throughout the trial period, we held regular coaching meetings during which questions and complex cases were discussed. Nevertheless, the physiotherapist indicated after the trial that an even higher skill level was needed to provide optimal support for behavioural change. The literature on coaching and communication skills also recommends extensive and ongoing group support on this topic, including feedback.³⁷ Therefore, for future research, we recommend extending the education sessions to include more time on the topic of behavioural coaching. Additionally, monitoring the coaching sessions with participants, either live or via videos, to provide specific support and feedback to the physiotherapists could improve skill levels as well as the quality of the intervention delivery.

Clinical implications

1. With regard to influencing movement behaviour, general lifestyle interventions seem insufficient. A specific focus on movement behaviour and the parts that should change is needed to ensure behaviour change.
2. Due to the large individual variability in movement behaviour patterns in people with stroke (with regard to the levels of sedentary behaviour and accumulation), there is a need to objectively determine personal movement behaviour. This would allow the identification of people at risk within the stroke population and personalised coaching.
3. The need to look beyond physical capabilities and stroke-related factors with regard to sedentary behaviour change has been clarified further with our findings. Within clinical practice, all behavioural aspects that influence sedentary behaviour should be taken into account, including capabilities (physical and psychological), opportunities (physical and social environment) and motivations (automatic and reflective). This calls for adequate and complete behavioural diagnosis and the incorporation of matching behaviour change techniques. Examples of key techniques identified within our studies are real-time feedback, goal setting, action planning and social support. Physiotherapists must be sufficiently skilled and trained to deliver these types of interventions.
4. Since people with stroke are mostly unaware of their movement behaviour patterns, especially with regard to sedentary behaviour, and these patterns are highly dependent on habits and daily routines, it is important to provide insight into their movement behaviour throughout the day. Innovative technology such as the RISE eCoaching system can provide this crucial information via real-time feedback to both participants and therapists.
5. The current results indicate that extensive forms of social support such as participatory support seem to generate better results. This shows the possibility of extensive involvement of people from the social environment of the participants to facilitate sedentary behaviour change.

Implications for education

The necessary shift in focus to coaching on movement behaviour, including sedentary behaviour, calls for an extended educational focus in this matter. Both the experiences of the physiotherapist included in our trial and the literature³⁸ show that the current knowledge and skill levels of physiotherapists are insufficient for behavioural coaching. Education should focus on these skills, including the ability to perform a complete

behavioural diagnosis and the use of appropriate behaviour change techniques to ensure that interventions are sufficiently personalised to be effective. Another area of importance is a focus on the skills to work with other disciplines to optimise the integration of the physiotherapist in the needed multidisciplinary setting of secondary prevention after stroke.

We showed the feasibility of using monitoring and eCoaching within an intervention aimed at improving sedentary behaviour, and participants stated that they highly valued the combination. Blended care is the integration of face-to-face coaching and eCoaching by means of innovative technologies. This strategy fits the needs of the 'the right care in the right place' policy to reduce health care costs, to increase self-efficacy and self-management, and for care to be delivered in a meaningful context such as the home setting.⁷ Because we did not assess the effectiveness of the different aspects of the RISE intervention separately, we cannot definitively state that the monitoring and eCoaching were crucial parts of the intervention. However, the promising preliminary results and the necessary changes in health care seem to call for the inclusion of properly used monitoring and eCoaching within interventions as part of educational programmes for physiotherapists.

Future research

The current results show the potential of the RISE intervention to support people with stroke who are highly sedentary and inactive to reduce and interrupt their sedentary behaviour. The findings of this study have been used to make final improvements to the RISE intervention. Follow-up research is necessary to definitively prove the effectiveness of the (improved) RISE intervention to support people with stroke to sustainably reduce and interrupt their sedentary behaviour through the use of a randomised controlled trial including long-term follow-up. If a (long-term) effect on behaviour is shown, there is a need to determine whether this will lead to less recurrent cardiovascular events, as hypothesized. Furthermore, the cost effectiveness should be addressed to obtain a complete picture of the added value of the RISE intervention. Cost effectiveness and the preventive effect can be addressed within a randomised controlled trial by including long-term follow-up with outcome measurements of these aspects (e.g., quality-adjusted life years and cardiovascular events). To determine what is needed for implementation, focused analyses of the current preventive system are needed, including the needs and barriers of different stakeholders (e.g., neurologists, nurse practitioners and physician assistants, general practitioners, general practice nurses and physiotherapists). Intervention implementation can be challenging, especially when it involves multiple health care professionals and requires a change in perspectives, routines and skill levels. Therefore, a structured

methodology that incorporates the entire care spectrum is necessary. The development of an appropriate business model for the technology involved is also needed.

Within the RISE intervention, personal movement behaviour patterns were determined for each participant and used to determine the personal focus for behaviour change. Aims and recommendations were made by comparing the personal pattern with currently available information regarding healthy movement behaviour. Total amounts of time spent in each type of movement behaviour, with a special focus on total sedentary time and the interruption of sedentary time, were taken into account to maximize health benefits. This was based on currently available health recommendations for the separate types of movement behaviours in isolation and thus do not take into account interactions between the different types of movement behaviour that could influence the overall risk level. However, the different types of movement behaviour are not independent and neither is their influence on health.^{14–16,39} Recent studies show the possibility of using this interaction to provide integrated movement behaviour advice that allows for more personalised and possibly more feasible recommendations when it comes in regard to healthy movement behaviour.^{15,16} This could allow compensation between the different types of movement behaviour instead of having to meet every isolated recommendation. This is a new area of research, and insufficient information is currently available to incorporate this into interventions. Based on our findings that show a high level of individuality of combinations of the different types of movement behaviour and accumulation patterns and the dependence of the behaviour on habits and daily routines, this next step in personalisation seems valuable. Thus, research is needed that provides the necessary information to make these personalised interactive recommendations. It seems worth considering the inclusion of sleep time within these recommendations to account for the entire daytime continuum.^{15,39}

Conclusion

Within this thesis, we identified what is needed to support people with stroke who are highly sedentary and inactive to sustainably reduce and interrupt their sedentary behaviour. We found that the variability in sedentary behaviour was largely unaccounted for by physical capabilities or stroke sequelae. Our research showed that movement behaviour, including sedentary behaviour, is mainly based on personal habits and daily routines and is therefore influenced by the physical and social environment of the participant. Additionally, accumulation patterns vary, and sedentary behaviour is often accumulates in prolonged bouts. All findings were incorporated in the RISE intervention, and we have provided a first proof of concept. The RISE intervention, including participatory

support, seems promising to support people with stroke who are highly sedentary and inactive to improve their movement behaviour patterns by reducing and interrupting their sedentary time. Thus, the RISE intervention might be of added value for secondary prevention after stroke.

References

1. Saunders DH, Mead GE, Fitzsimons C, et al. Interventions for reducing sedentary behaviour in people with stroke. *Cochrane Database Syst Rev.* 2018;2018(4). doi:10.1002/14651858.CD012996
2. Perk J, De Backer G, Gohlke H, et al. European Guidelines on cardiovascular disease prevention in clinical practice (version 2012). *Eur Heart J.* 2012;33(13):1635-1701. <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365218239>.
3. RIVM. Volksgezondheid Toekomstverkenning 2018. <https://www.vtv2018.nl/>.
4. Zorg R voor de V en. Preventie van welvaartsziekten. https://www.raadrvs.nl/binaries/raadrvs/documenten/publicaties/2011/12/13/preventie-van-welvaartsziekten/Preventie_van_welvaartsziekten.pdf.
5. Ministry of Health Welfare and Sport. Intergraal Zorgakkoord 2022. <https://www.rijksoverheid.nl/documenten/rapporten/2022/09/16/integraal-zorgakkoord-samenwerken-aan-gezonde-zorg>.
6. Vilsteren van C, Gerritsen E, Pols H, et al. Knowledge and Innovation Agenda 2020-2023 health and care. <https://www.health-holland.com/sites/default/files/downloads/Knowledge-and-Innovation-Agenda-2020-2023-health-and-care.pdf>. Published 2019.
7. Dungen van den B. The right care in the right place report taskforce. [https://www.dejuistezorgopdejuisteplek.nl/uc/fcef77d2b01028d5c0000bd7ca7026baaac90942d76c900/The right care in the right place_report taskforce.pdf](https://www.dejuistezorgopdejuisteplek.nl/uc/fcef77d2b01028d5c0000bd7ca7026baaac90942d76c900/The%20right%20care%20in%20the%20right%20place_report%20taskforce.pdf).
8. Ezeugwu VE, Garga N, Manns PJ. Reducing sedentary behaviour after stroke: perspectives of ambulatory individuals with stroke. *Disabil Rehabil.* 2017;39(25):2551-2558. doi:10.1080/09638288.2016.1239764
9. Wondergem R, Veenhof C, Wouters EMJ, de Bie RA, Visser-Meily JMA, Pisters MF. Movement Behavior Patterns in People With First-Ever Stroke. *Stroke.* 2019;50(12):3553-3560. doi:10.1161/STROKEAHA.119.027013
10. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011;6(1):42. doi:10.1186/1748-5908-6-42
11. Michie S, Atkins L, West R. *The Behaviour Change Wheel, a Guide to Designing Interventions*. Silverback Publishing Great Britain; 2014.
12. Outermans J, Pool J, van de Port I, Bakers J, Wittink H. What's keeping people after stroke from walking outdoors to become physically active? A qualitative study, using an integrated biomedical and behavioral theory of functioning and disability. *BMC Neurol.* 2016;16(1):137. doi:10.1186/s12883-016-0656-6
13. Nicholson SL, Donaghy M, Johnston M, et al. A qualitative theory guided analysis of stroke survivors' perceived barriers and facilitators to physical activity. *Disabil Rehabil.* 2014;36(22):1857-1868. doi:10.3109/09638288.2013.874506
14. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet.* 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1

15. Chastin SFM, McGregor DE, Biddle SJH, et al. Striking the Right Balance: Evidence to Inform Combined Physical Activity and Sedentary Behavior Recommendations. *J Phys Act Health*. 2021;18(6):631-637. doi:10.1123/jpah.2020-0635
16. Hibbing PR, Bellettiere J, Carlson JA. Sedentary Profiles: A New Perspective on Accumulation Patterns in Sedentary Behavior. *Med Sci Sports Exerc*. 2022;54(4):696-706. doi:10.1249/MSS.0000000000002830
17. Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJH. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol Rev*. 2016;10(1):89-112. doi:10.1080/17437199.2015.1082146
18. Patterson K, Davey R, Keegan R, Kunstler B, Woodward A, Freene N. Behaviour change techniques in cardiovascular disease smartphone apps to improve physical activity and sedentary behaviour: Systematic review and meta-regression. *Int J Behav Nutr Phys Act*. 2022;19(1):81. doi:10.1186/s12966-022-01319-8
19. Feigin VL, Brainin M, Norrving B, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2022. *Int J Stroke*. 2022;17(1):18-29. doi:10.1177/17474930211065917
20. Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 Guideline for the Prevention of Stroke in Patients With Stroke and Transient Ischemic Attack: A Guideline From the American Heart Association/American Stroke Association. *Stroke*. 2021;52(7). doi:10.1161/STR.0000000000000375
21. Pennlert J, Eriksson M, Carlberg B, Wiklund P-G. Long-term risk and predictors of recurrent stroke beyond the acute phase. *Stroke*. 2014;45(6):1839-1841. doi:10.1161/STROKEAHA.114.005060
22. Koninklijk Nederlands Genootschap voor Fysiotherapie. KNGF-richtlijn Beroerte. 2017. www.kngfrichtlijnen.nl.
23. de Ruijter W. [New guideline "Stroke" from the Dutch College of General Practitioners (NHG): "wait and see" management of neurological function loss is outdated]. *Ned Tijdschr Geneesk*. 2014;158(1):A7175.
24. Cijfers hart- en vaatziekten 2022 | Hartstichting. <https://www.hartstichting.nl/hart-en-vaatziekten/cijfers-hart-en-vaatziekten>. Accessed January 13, 2023.
25. Carlsson A, Irewall A-L, Graipe A, Ulvenstam A, Moos T, Ögren J. Long-term risk of major adverse cardiovascular events following ischemic stroke or TIA. *Sci Rep*. 2023;13(1):8333. doi:10.1038/s41598-023-35601-x
26. Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ*. 2008;337:a1655. doi:10.1136/bmj.a1655
27. Bernhardt J, Hayward KS, Dancause N, et al. A stroke recovery trial development framework: Consensus-based core recommendations from the Second Stroke Recovery and Rehabilitation Roundtable. *Int J Stroke*. 2019;14(8):792-802. doi:10.1177/1747493019879657
28. Ferron J, Sentovich C. Statistical Power of Randomization Tests Used with Multiple-Baseline Designs. *J Exp Educ*. 2002;70(2):165-178. doi:10.1080/00220970209599504
29. Levin JR, Ferron JM, Gafurov BS. Additional comparisons of randomization-test procedures for single-case multiple-baseline designs: Alternative effect types. *J Sch Psychol*. 2017;63:13-34. doi:10.1016/j.jsp.2017.02.003

30. Levin JR, Ferron JM, Gafurov BS. Comparison of randomization-test procedures for single-case multiple-baseline designs. *Dev Neurorehabil.* 2018;21(5):290-311. doi:10.1080/17518423.2016.1197708
31. Hawkins NG, Sanson-Fisher RW, Shakeshaft A, D'Este C, Green LW. The Multiple Baseline Design for Evaluating Population-Based Research. *Am J Prev Med.* 2007;33(2):162-168. doi:10.1016/j.amepre.2007.03.020
32. Kratochwill TR, Levin JR. Enhancing the scientific credibility of single-case intervention research: Randomization to the rescue. *Psychol Methods.* 2010;15(2):124-144. doi:10.1037/a0017736
33. Wampold, Bruce E. Worsham NL. Randomization tests for multiple-baseline designs. - PsycNET. *Behav Assess.* 1986;8:135-143. <https://psycnet.apa.org/record/1987-09267-001>. Accessed February 21, 2020.
34. Nourbakhsh MR, Ottenbacher KJ. The statistical analysis of single-subject data: a comparative examination. *Phys Ther.* 1994;74(8):768-776. doi:10.1093/ptj/74.8.768
35. Chastin SFM, Winkler EAH, Eakin EG, et al. Sensitivity to Change of Objectively-Derived Measures of Sedentary Behavior. *Meas Phys Educ Exerc Sci.* 2015;19(3):138-147. doi:10.1080/1091367X.2015.1050592
36. Tinlin L, Fini N, Bernhardt J, Lewis LK, Olds T, English C. Best practice guidelines for the measurement of physical activity levels in stroke survivors. *Int J Rehabil Res.* 2017;41(1):1. doi:10.1097/MRR.0000000000000253
37. Miller WR, Rollnick S. *Motiverende Gespreksvoering.*; 2018.
38. Freene N, Cools S, Bissett B. Are we missing opportunities? Physiotherapy and physical activity promotion: a cross-sectional survey. *BMC Sport Sci Med Rehabil.* 2017;9:19. doi:10.1186/s13102-017-0084-y
39. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act.* 2017;14(1):75. doi:10.1186/s12966-017-0525-8



CHAPTER 9

Summary

Nederlandse samenvatting

Authors Contributions

PhD Portfolio

About the Author

Summary

Stroke affects approximately 12.2 million people around the world each year and remains the second leading cause of death and the third leading cause of disability worldwide. People who have suffered a stroke are at high risk of recurrent stroke, and secondary prevention after stroke is therefore of vital importance. As described in **Chapter 1**, healthy movement behaviour is an important part of secondary prevention guidelines. Sedentary behaviour (in addition to physical activity, an important part of movement behaviour) is defined as 'any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task while in a sitting, reclining, or lying posture'. High amounts of sedentary behaviour, especially when accumulated in prolonged bouts, increase the risk of cardiovascular disease. Approximately 78% of people who have had a stroke are highly sedentary and inactive. Therefore, improving movement behaviour by reducing and interrupting sedentary behaviour and replacing it with physical activity might help to reduce the risk of recurrent events after stroke.

Currently, care after stroke mainly focuses on people's physical and cognitive functions and abilities. Rehabilitation mostly aims to regain independence in daily living and participation. An added focus on improving movement behaviour, especially sedentary behaviour, seems warranted. This calls for effective interventions to support people with stroke who are highly sedentary and inactive in improving movement behaviour by reducing and interrupting sedentary behaviour. Currently, there are no proven effective interventions available. Therefore, the aim of this thesis was to identify what is needed to support people with stroke who are highly sedentary and inactive to sustainably change their movement behaviour patterns. This enabled the development of an intervention that aims to improve movement behaviour, by reducing and interrupting sedentary behaviour and determine the preliminary effectiveness and feasibility of the intervention.

The first step, as described in **Chapter 2**, was to identify factors associated with high sedentary time in community-dwelling people with stroke. To obtain a sufficiently large sample size to identify the demographic and stroke-related factors that are associated with high amounts of sedentary time, we conducted a data pooling study in which datasets from 9 original studies, including 274 participants from Australia, Canada and the United Kingdom, were combined. The participants spent, on average, 69% (SD 12.4) of their waking hours sedentary. Of the demographic and stroke-related factors, slower walking speed was significantly and independently associated with a higher percentage of waking hours spent sedentary ($p=0.001$) and uninterrupted sedentary bouts of >30 and >60 minutes ($p=0.001$ and $p=0.004$, respectively). Regression models explained 11-19% of the variance in total sedentary time and time in prolonged sedentary bouts. This indicates

that the variability in sedentary time among people with stroke was largely unaccounted for by demographic and stroke-related variables and suggests that behavioural and environmental factors are likely to play an important role in sedentary behaviour after stroke.

Chapter 3 shows the results of an exploration of how people with stroke accumulate their periods of sedentary behaviour. We identified which demographic and stroke-related factors influence the distribution of sedentary behaviour and whether clusters can be distinguished. We conducted data-driven clustering analyses to identify unique accumulation patterns of sedentary time across participants. This was followed by multinomial logistical regression to determine the association between the clusters and the total amount of sedentary time, age, gender, body mass index (BMI), walking speed and wake time. We found that participants in the highest quartile of total sedentary time accumulated a significantly higher proportion of their sedentary time in prolonged bouts ($p < 0.001$) compared to people with lower amounts of total sedentary time. This suggests that this part of the population would benefit most from interventions to reduce and interrupt sedentary time to mitigate their health risks. Six unique accumulation patterns were identified, all of which were characterized by high sedentary time. We found wide variability in total sedentary time and average bout duration across the clusters. Total sedentary time, age, gender, BMI and walking speed were significantly associated with the probability of a person being in a specific accumulation pattern cluster, $p < 0.001$ – $p = 0.002$. Although unique accumulation patterns were identified, there is not just one unique accumulation pattern for high sedentary time. This suggests that interventions to reduce sedentary time should be tailored to the individual and include objectively determining accumulation patterns.

To inform intervention development, Chapter 4 includes the result of a systematic review that assessed the effect of lifestyle interventions on levels of physical activity performed by people with stroke or TIA. Three databases were searched up to August 2018. We identified 11 randomised controlled trials that met the inclusion criteria. These studies compared lifestyle interventions that aim to increase the amount of physical activity completed by participants with stroke or TIA with controls. The Physiotherapy Evidence Database (PEDro) score was used to assess the quality of the articles, and the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) method was used for the best evidence synthesis. The quality of the trials was mostly high, with 8 (73%) trials scoring ≥ 6 on the PEDro scale. The overall best evidence syntheses showed moderate quality evidence that the included lifestyle interventions do not lead to significant improvements in the physical activity level of people with stroke or TIA. This indicates that general lifestyle interventions on their own seem insufficient to improve the levels of physical

activity after stroke or TIA. There is low-quality evidence that lifestyle interventions that specifically target physical activity are effective at improving the levels of physical activity of people with stroke or TIA. A specific focus on physical activity and/or adding an exercise component to a lifestyle intervention and having a physiotherapist involved in the delivery of the intervention might be beneficial. Further properly powered trials using objective physical activity measures are needed to determine the effectiveness of such interventions.

Chapter 5 shows the results of a qualitative study conducted to identify Capabilities, Opportunities and Motivational model factors influencing movement behaviour throughout the day from the perspective of people with stroke who are highly sedentary and inactive, to inform intervention development. Semi-structured interviews with people with stroke who were highly sedentary and inactive were conducted. The interview guide was based on the Capabilities, Opportunities and Motivation Behavioural model. Analyses were conducted using an iterative process using the Theoretical Domains Framework. Saturation was reached after eleven interviews. The participants reported a lack of knowledge regarding healthy movement behaviour patterns and a lack of insight into their own movement behaviour. Some experienced physical and cognitive limitations in engaging in certain physical activities. Several social and environmental elements affecting movement behaviours were mentioned, and their impact on movement behaviour varied among the participants. Movement behaviour, especially sedentary behaviour, was mostly driven by habits and daily routine, without conscious regulation. These results show that people with stroke are unaware of their own movement behaviour or of the consequences of these behaviours for their health. Since movement behaviour is, for the most part, based on daily routine and personal habits, this indicates there is a need for a behaviour change intervention. Such interventions will need to include providing information about healthy movement behaviour, feedback on the individual's movement behaviour and individualized support while taking into account the social and environmental context and personal capabilities.

Chapter 6 describes the development of the RISE intervention (*Reduce and Interrupt Sedentary behaviour using a blended behaviour intervention to Empower people at risk towards sustainable movement behaviour change*) to support highly sedentary people with stroke to sustainably reduce and interrupt sedentary behaviour by replacing it with physical activity.

To develop an effective intervention, the development process was guided by the Behaviour Change Wheel. Three stages were distinguished: Stage 1: Understanding the behaviour, Stage 2: Identify intervention functions and Stage 3: Identify behaviour change techniques and modes of delivery, after which the final intervention protocol could be drafted. The intervention and digital delivery system were co-created with people

with stroke and their relatives, physiotherapists, (inter)national behavioural, stroke and movement behaviour experts, people with previous experience developing blended interventions, hardware and software developers, and technical experts.

This extensive process resulted in the RISE intervention, a 15-week blended behavioural intervention in which a primary care physiotherapist coached participants to reduce and interrupt their sedentary time. Physiotherapists provided personalised coaching to people with a stroke in their home setting by using behaviour change techniques and the RISE eCoaching system. The RISE eCoaching system consists of 1) an activity monitor, 2) a smartphone application that provides real-time feedback and contains e-learning modules, and 3) a monitoring dashboard for the physiotherapist. The participants received participatory support from someone from their social network (e.g., partner or close friend) who joined them in the intervention.

Chapter 7 reports the results of a randomised multiple baseline study conducted to determine the preliminary effectiveness and feasibility of the RISE intervention to support community-dwelling people with stroke, who are highly sedentary, to reduce and interrupt sedentary time. Additionally, the added value of including participatory support within the RISE intervention was determined. Fourteen community-dwelling participants were randomly allocated to different durations of baseline assessment, during which repeated measurements were conducted. All received the RISE intervention, and half of the participants (randomly allocated) received participatory support from someone from their social network (e.g., partner or close friend) who joined them in the intervention. Outcome measures included total sedentary time and fragmentation (interruption) of sedentary time. Feasibility was assessed with adherence to the intervention protocol, safety and satisfaction with the intervention. The results showed that the RISE intervention appears promising for supporting people with stroke who are highly sedentary to reduce and interrupt their sedentary time. The participants significantly reduced their total sedentary time ($p=0.01$) by 1.3 hours on average and increased their fragmentation index ($p<0.01$). Twelve (85%) of the participants showed improvement for at least one outcome of sedentary behaviour. Subgroup analyses showed significant improvements in total sedentary time ($p=0.03$) and fragmentation ($p=0.03$) in the group with participatory support. Only fragmentation was significantly improved in the group without participatory support ($p=0.04$). This indicates that including participatory support provided by someone from their social network (e.g., partner or close friend) who joins the participant in the RISE intervention appears to contribute to greater results. Thirteen of 14 participants (93%) completed the intervention, and no related adverse events occurred. Moreover, the participants reported sufficient satisfaction with the intervention.

Chapter 8 presents a general discussion regarding the process of developing the blended RISE intervention and the determination of the preliminary effectiveness and feasibility of the intervention as well as the added value of participatory support. The implications of the main findings are addressed as are the methodological considerations and clinical implications. Recommendations are made for education and further research. The research conducted in this dissertation is a first step towards supporting people with stroke who are highly sedentary to reduce and interrupt their sedentary behaviour. The RISE intervention appears to be promising to support this movement behaviour change. We also found that participatory support appears to contribute to greater results. With the needed transition to an expansion of the view on health care from the perspective of merely the absence of illness and care to a broader perspective including a healthy lifestyle in everyday life, there is a strong need for effective interventions that support lifestyle change. Our results show that the RISE intervention might contribute to this overall aim in regard to people with stroke. To draw any definitive conclusions, a randomised controlled trial is necessary, including long-term follow-up. Additionally, attention is needed to identify how the RISE intervention can be implemented in current stroke care. Based on input from physiotherapists trained to deliver the RISE intervention, we recommend expanding the skill level of physiotherapists in regard to movement behaviour, behavioural diagnoses and the use of fitting behaviour change techniques and communication skills to deliver coaching in an effective manner.

Nederlandse Samenvatting

Jaarlijks worden ongeveer 12.2 miljoen mensen wereldwijd door een beroerte getroffen. Het is nog steeds de op één na belangrijkste doodsoorzaak en de derde belangrijkste oorzaak van invaliditeit ter wereld. Mensen die een beroerte hebben gehad, lopen een hoog risico op een recidief. Dit maakt secundaire preventie na een beroerte van vitaal belang. Zoals beschreven in **hoofdstuk 1** is gezond beweeggedrag een belangrijk onderdeel van de richtlijnen voor secundaire preventie. Sedentair gedrag (naast fysieke activiteit een belangrijk aspect van beweeggedrag) wordt gedefinieerd als 'elk wakend gedrag gekenmerkt door een energieverbruik van $\leq 1,5$ metabole equivalenten van de taak (MET) terwijl men zit of ligt'. Een hoge mate van sedentair gedrag, vooral als dit verzameld wordt in lange aaneengesloten periodes, verhoogt het risico op hart- en vaatziekten. Ongeveer 78% van de mensen die een beroerte hebben gehad, zijn zeer sedentair en inactief. Daarom zou het verbeteren van het beweeggedrag, door het verminderen en onderbreken van sedentair gedrag en het vervangen daarvan door fysieke activiteit, kunnen helpen het risico op een nieuwe beroerte of een ander cardiovasculair incident te verminderen.

Momenteel ligt de focus bij de zorg na een beroerte vooral op de fysieke en cognitieve functies en vaardigheden van mensen. Revalidatie is met name gericht op het herstellen van onafhankelijkheid in dagelijks functioneren en participatie. Een toegevoegde focus op het verbeteren van het beweeggedrag, en dan met name sedentair gedrag, lijkt gerechtvaardigd. Dit vraagt om effectieve interventies om mensen met een beroerte die zeer sedentair en inactief zijn te ondersteunen bij het verbeteren van hun beweeggedrag door het verminderen en onderbreken van sedentair gedrag. Momenteel zijn er geen bewezen effectieve interventies beschikbaar. Daarom was het doel van dit proefschrift om te identificeren wat nodig is om mensen met een beroerte die zeer sedentair en inactief zijn duurzaam hun sedentaire gedrag te laten veranderen. Dit om de ontwikkeling van een interventie die gericht is op het verminderen en onderbreken van sedentair gedrag mogelijk te maken en de preliminaire effectiviteit en haalbaarheid van deze interventie te bepalen.

De eerste stap, beschreven in **hoofdstuk 2**, was het identificeren van factoren die geassocieerd zijn met een hoge mate van sedentaire tijd bij mensen met een beroerte die thuis wonen. Om een voldoende grote steekproef te krijgen voor het identificeren van demografische en beroerte-gerelateerde factoren die geassocieerd zijn met veel sedentaire tijd, voerden we een data-pooling studie uit. Daarbij werden de datasets van negen oorspronkelijke studies, met in totaal 274 deelnemers uit Australië, Canada en het Verenigd Koninkrijk, gecombineerd. Ze brachten gemiddeld 69% (SD 12,4) van de tijd

dat ze wakker waren sedentair door. Van de demografische en beroerte-gerelateerde factoren was een lagere loopsnelheid significant en onafhankelijk geassocieerd met een hoger percentage wakende tijd die sedentair werd doorgebracht ($p=0,001$) en met ononderbroken sedentaire periodes van >30 en >60 minuten ($p=0,001$ en $p=0,004$, respectievelijk). Regressiemodellen verklaarden 11-19% van de variantie in totale sedentaire tijd en tijd in langdurige sedentaire periodes. Een groot deel van de variabiliteit in sedentaire tijd bij mensen met een beroerte lijkt dus niet verklaard te kunnen worden door demografische en beroerte-gerelateerde variabelen. Dit suggereert dat gedrags- en omgevingsfactoren waarschijnlijk een belangrijke rol spelen in zittend gedrag na een beroerte.

Hoofdstuk 3 toont de resultaten van een onderzoek naar hoe mensen met een beroerte hun sedentaire gedrag verzamelen gedurende de dag. We hebben geïdentificeerd welke demografische en beroerte-gerelateerde factoren de distributie van sedentair gedrag beïnvloeden en of er clusters te onderscheiden zijn. Datagestuurde clusteranalyses zijn uitgevoerd om na te gaan of er unieke accumulatiepatronen van sedentaire tijd geïdentificeerd konden worden bij de deelnemers. Dit werd gevolgd door multinomiale logistische regressie om de associatie tussen de clusters en de totale hoeveelheid sedentaire tijd, leeftijd, geslacht, Body Mass Index (BMI), loopsnelheid en waaktijd te bepalen. Deelnemers in het hoogste kwartiel van totale sedentaire tijd verzamelen een significant hoger aandeel hiervan in langdurige aaneengesloten periodes ($p<0,001$), in vergelijking met mensen met lagere hoeveelheden sedentaire tijd. Dit suggereert dat dit deel van de populatie het meeste baat zou hebben bij interventies om sedentaire tijd te verminderen en te onderbreken om hun gezondheidsrisico's te verminderen. Er werden zes unieke accumulatie patronen geïdentificeerd; allen gekenmerkt door een hoge maten van sedentaire tijd. We vonden een brede variabiliteit in de totale sedentaire tijd en de gemiddelde duur van sedentaire periodes in de verschillende clusters. De totale sedentaire tijd, leeftijd, geslacht, BMI en loopsnelheid waren significant geassocieerd met de waarschijnlijkheid dat een persoon zich in een specifiek accumulatiepatroon cluster bevindt, $p<0,001$ – $p=0,002$. Hoewel unieke accumulatiepatronen werden geïdentificeerd, is er niet slechts één uniek accumulatiepatroon voor hoge sedentaire tijd. Dit suggereert dat interventies om sedentaire tijd te verminderen afgestemd moeten worden op het individu en een objectieve bepaling van het accumulatiepatroon moeten bevatten.

Om informatie op te halen ten behoeve van interventie ontwikkeling hebben we een systematische review naar het effect van leefstijlinterventies op de hoeveelheid fysieke activiteit bij mensen met een beroerte of TIA uitgevoerd. De resultaten hiervan zijn beschreven in **hoofdstuk 4**. Drie databases werden doorzocht tot augustus 2018. We identificeerden 11 gerandomiseerde gecontroleerde studies die aan de inclusiecriteria

voldeden. Deze studies vergeleken leefstijlinterventies, met als doel het verhogen van de hoeveelheid fysieke activiteit bij mensen met een beroerte of TIA, met een controle groep. De Physiotherapy Evidence Database (PEDro) score werd gebruikt om de kwaliteit van de artikelen te beoordelen en de Grading of Recommendations, Assessment, Development and Evaluations (GRADE) methode voor de best evidence synthese. De kwaliteit van de trials was meestal hoog, acht (73%) van de trials scoorde ≥ 6 op de PEDro-schaal. De algehele best evidence synthese laat zien dat er matige kwaliteit bewijs is dat de opgenomen leefstijlinterventies niet leiden tot significante verbeteringen in de hoeveelheid fysieke activiteit bij mensen met een beroerte of TIA. Dit duidt erop dat algemene leefstijlinterventies op zichzelf niet voldoende lijken om de niveaus van fysieke activiteit na een beroerte of TIA te verbeteren. Er is lage kwaliteit bewijs dat leefstijlinterventies die zich specifiek richten op fysieke activiteit effectief zijn bij het verbeteren van de hoeveelheid fysieke activiteit bij mensen met een beroerte of TIA. Een specifieke focus op fysieke activiteit en/of het toevoegen van een oefencomponent aan een leefstijlinterventie en het betrekken van een fysiotherapeut bij de uitvoering van de interventie zou een positief effect kunnen hebben. Vervolgonderzoek met een voldoende grote steekproef en objectieve uitkomstmaten voor fysieke activiteit zijn nodig om de effectiviteit van dergelijke interventies te bepalen.

Hoofdstuk 5 toont de resultaten van een kwalitatieve studie om de factoren gerelateerd aan capaciteiten, gelegenheden en motivatie die het beweeggedrag gedurende de dag beïnvloeden te identificeren, vanuit het perspectief van mensen met een beroerte die in hoge mate sedentair en inactief zijn. Dit om de ontwikkeling van interventies mogelijk te maken. Er zijn semigestructureerde interviews gehouden met mensen met een beroerte die veelal sedentair en inactief zijn. De interviewgide was gebaseerd op het Capabilities, Opportunities and Motivation Behavioural model. Analyses werden uitgevoerd met behulp van het Theoretical Domains Framework in een iteratief proces. Na 11 interviews werd saturatie bereikt. Deelnemers gaven aan dat ze weinig kennis hadden over gezond beweeggedrag en geen inzicht hadden in hun eigen beweeggedrag. Sommigen ervaarden fysieke en/of cognitieve beperkingen om bepaalde fysieke activiteiten te ondernemen. Verschillende sociale en omgevingsfactoren die het beweeggedrag beïnvloeden werden genoemd, de invloed hiervan varieerde onder de deelnemers. Beweeggedrag, met name sedentair gedrag, werd voornamelijk bepaald door gewoonten en dagelijkse routine, zonder bewuste regulatie. Deze resultaten laten zien dat mensen met een beroerte zich niet bewust zijn van hun eigen beweeggedrag of van de gevolgen daarvan voor hun gezondheid. Aangezien het beweeggedrag grotendeels is gebaseerd op dagelijkse routines en persoonlijke gewoonten, lijken gedragsveranderingsinterventies noodzakelijk. Dergelijke interventies zullen informatie over gezond beweeggedrag, feedback over

het individuele beweeggedrag en gepersonaliseerde ondersteuning moeten bevatten, rekening houdend met de sociale en omgevingscontext en persoonlijke capaciteiten.

Hoofdstuk 6 beschrijft de ontwikkeling van de RISE-interventie (*Reduce and Interrupt Sedentary behaviour using a blended behaviour intervention to Empower people at risk towards sustainable movement behaviour change*). Deze interventie is ontwikkeld om mensen met een beroerte die in hoge mate sedentair zijn, te helpen om duurzaam hun sedentaire gedrag te verminderen en te onderbreken door het te vervangen met fysieke activiteiten. Om te komen tot een effectieve interventie hebben we het Behaviour Change Wheel gebruikt in het ontwikkelingsproces. Er werden drie fasen onderscheiden: 1) Het gedrag begrijpen, 2) Bepalen van de interventiefuncties en 3) Bepalen van de gedragsveranderingstechnieken en de leveringswijze, waarna het definitieve interventieprotocol kon worden opgesteld. De interventie en het digitale systeem werden ontwikkeld samen met mensen met een beroerte en hun naasten, fysiotherapeuten, (inter) nationale gedrags-, beroerte- en beweeggedragsexperts, mensen met ervaring in het ontwikkelen van blended interventies, hardware- en softwareontwikkelaars en technische experts. Dit uitgebreide proces resulteerde in de RISE-interventie, een 15 weken durende blended gedragsinterventie, waarbij een eerstelijns fysiotherapeut de deelnemers coachte om hun sedentaire tijd te verminderen en te onderbreken. Fysiotherapeuten boden gepersonaliseerde coaching aan, aan mensen met een beroerte in hun thuissituatie middels gedragsveranderingstechnieken en het RISE eCoaching-systeem. Dit systeem bestaat uit 1) een activiteitenmonitor, 2) een smartphone-applicatie die real-time feedback geeft en e-learningmodules bevat, 3) een monitoringdashboard voor de fysiotherapeut. Deelnemers ontvingen participatieve ondersteuning van iemand uit hun sociale netwerk (bijv. partner of goede vriend) die mee deed aan de interventie.

Hoofdstuk 7 rapporteert de resultaten van een gerandomiseerde multiple baseline studie met als doel de preliminaire effectiviteit en feasibility van de RISE-interventie te bepalen om thuiswonende mensen met een beroerte die in hoge mate sedentair zijn, te ondersteunen bij het verminderen en onderbreken van hun sedentaire gedrag. Ook werd de toegevoegde waarde van participatieve ondersteuning binnen de RISE-interventie vastgesteld. Veertien thuiswonende deelnemers, werden willekeurig toegewezen aan baseline periodes van verschillende duur, waarbinnen de herhaalde metingen werden uitgevoerd. Alle deelnemers ontvingen de RISE-interventie en de helft van hen (random toegewezen) kreeg participatieve ondersteuning van iemand uit hun sociale netwerk (bijvoorbeeld een partner of goede vriend) die mee deed aan de interventie. Uitkomstmaten waren de totale sedentaire tijd en fragmentatie (onderbreken) van sedentaire tijd. De haalbaarheid werd beoordeeld op basis van het naleven van het interventieprotocol, veiligheid en de tevredenheid met de interventie. De resultaten

toonden aan dat de RISE-interventie veelbelovend lijkt om mensen met een beroerte te ondersteunen bij het verminderen en onderbreken van hun zittende tijd. Deelnemers verminderden hun totale sedentaire tijd significant ($p=0.01$), met gemiddeld 1,3 uur en verhoogden hun fragmentatie index ($p<0.01$). Twaalf (85%) deelnemers verbeterden op ten minste één uitkomstmaat van sedentair gedrag. Subgroep analyses toonden significante verbeteringen in de totale sedentaire tijd ($p=0.03$) en de fragmentatie ($p=0.03$) in de groep met participatieve ondersteuning. De groep zonder participatieve ondersteuning verbeterde alleen de fragmentatie significant ($p=0.04$). Dit wijst erop dat het opnemen van participatieve ondersteuning, geboden door iemand uit hun sociale netwerk (bijv. partner of goede vriend) die mee doet in de interventie, in de interventie bijdraagt aan betere resultaten. Dertien van de 14 deelnemers (93%) voltooiden de interventie en er deden zich geen gerelateerde adverse events (ongewenst medisch voorvallen) voor. Deelnemers rapporteerden voldoende tevredenheid over de interventie.

Hoofdstuk 8 bevat een algemene bespreking van het ontwikkelproces van de RISE-interventie en het bepalen van de voorlopige effectiviteit en feasibility ervan, evenals de toegevoegde waarde van participatieve ondersteuning. De implicaties van de belangrijkste bevindingen worden besproken, evenals methodologische overwegingen en de klinische implicaties. Aanbevelingen worden gedaan voor onderwijs en vervolgonderzoek. Het onderzoek binnen dit proefschrift is een eerste stap om mensen met een beroerte, die in hoge mate sedentair zijn, te ondersteunen bij het verminderen en onderbreken van hun sedentaire gedrag. De RISE-interventie lijkt veelbelovend om deze beweeggedragsverandering te ondersteunen. Ook participatieve ondersteuning lijkt bij te dragen aan betere resultaten. Gezien de noodzakelijke transitie naar het bredere perspectief op gezondheid met daarin aandacht voor een gezonde leefstijl, is er een sterke behoefte aan effectieve interventies die leefstijlverandering ondersteunen. Onze resultaten laten zien dat de RISE-interventie mogelijk kan bijdragen aan dit algemene doel voor mensen met een beroerte. Om definitieve conclusies te kunnen trekken is een gerandomiseerde gecontroleerde studie nodig, inclusief lange-termijn follow-up. Ook is het nodig om te identificeren hoe de RISE-interventie kan worden geïmplementeerd in de huidige beroerte nazorg. Op basis van ervaringen van de fysiotherapeuten die getraind zijn om de RISE-interventie te geven, bevelen we aan om het vaardigheidsniveau van de fysiotherapeut op het gebied van beweeggedrag, gedragsdiagnoses en het gebruik van passende gedragsveranderingstechnieken en communicatievaardigheden uit te breiden, om op een effectieve manier te kunnen coachen.

Authors' Contributions

Chapter 2: Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies.

Data collection	WH, CD, VE, TJ, SK, NM, LP, DS, ZT, CE
Study concept and design	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE
Data analysis and interpretation	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE
Draft of Manuscript	WH
Manuscript editing and review	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE

Chapter 3: An exploration of sedentary behaviour patterns in community dwelling stroke survivors. A cluster-based analysis.

Data collection	WH, CD, VE, TJ, SK, NM, LP, DS, ZT, CE
Study concept and design	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE
Data analysis and interpretation	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE
Draft of Manuscript	WH
Manuscript editing and review	WH, CR, TA, JB, MC, SC, CD, VE, TJ, SK, NM, TM, GM, SM, LP, MP, DS, DS, ZT, OV, CE

Chapter 4: General lifestyle interventions on their own seem insufficient to improve the level of physical activity after stroke or TIA: a systematic review.

Data collection	WH, LV
Study concept and design	WH, KV, RW, CV, CE, MP
Data analysis and interpretation	WH, LV, KV, RW, CV, CE, MP
Draft of Manuscript	WH
Manuscript editing and review	WH, LV, KV, RW, CV, CE, MP

Chapter 5: It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive.

Data collection	WH
Study concept and design	WH, RW, MP, CE, JV, CV
Data analysis and interpretation	WH, RW, MP, CL, CE, JV, CV
Draft of Manuscript	WH
Manuscript editing and review	WH, RW, MP, CL, CE, JV, CV

Chapter 6: Developing RISE, a blended behavioural intervention to support people with stroke to reduce and interrupt their sedentary behaviour.

Data collection	WH, RW
Study concept and design	WH, RW, CE, JV, CV, MP
Data analysis and interpretation	WH, RW, CE, JV, CV, MP
Draft of Manuscript	WH, RW
Manuscript editing and review	WH, RW, CE, JV, CV, MP

Chapter 7: Improving movement behaviour in people after stroke with the RISE intervention – a randomised multiple baseline study.

Data collection	WH
Study concept and design	WH, RW, CV, CE, JV, MP
Data analysis and interpretation	WH, RW, CV, CE, JV, MP
Draft of Manuscript	WH
Manuscript editing and review	WH, RW, CV, CE, JV, MP

PhD Portfolio

Name of PhD student	W. (Wendy) Hendrickx
PhD period	November 2017 - October 2024
Name of PhD supervisors	C. (Cindy) Veenhof C. (Coralie) English M.F. (Martijn) Pisters R. (Roderick) Wondergem

PhD Portfolio	Year	Work-Load (ECTS)
Courses		
Introduction course PhD program Clinical and Experimental Neuroscience	2018	0.5
Basic course on Regulation and Organization for Clinical Investigators (BROK)	2019	1
Clinical and Experimental Neuroscience Summerschool 2019	2019	2
Qualitative research course	2019	0.4
Basic qualification for didactical skills (BKO), <i>Fontys university of applied sciences</i>	2020	6
Clinical and Experimental Neuroscience Summerschool 2022	2022	1
Basic qualification for examination (BKE), <i>Fontys university of applied sciences</i>	2023	6
Conference and presentation		
Wetenschapsdag fysiotherapie 2018 (Amersfoort, 21 Mar '18)	2018	-
Dag Wetenschappelijk College Fysiotherapie (Hilversum, 27 Mar '19)	2019	0.3
World Physiotherapy Congress (Geneva, 10-13 May '19) – <i>Oral presentation & Poster</i>	2019	0.9
FysioExperience (Eindhoven, 14 Jun '19) – <i>Workshop</i>	2019	0.3
Studiedag Neuromotorische Revalidatie KU & UZ Leuven 2019, "Patient empowerment", (Leuven, 19 Oct '19) – <i>Workshop</i>	2019	-
Dag van de Fysiotherapeut (Den Bosch, 16 Nov '19) – <i>Poster</i>	2019	0.3
Kennisnetwerk CVA symposium 2019 "de kracht van leren" (Utrecht, 29 Nov '19) – <i>Workshop</i>	2019	-
CVA Ketenavond Utrecht (Utrecht, 17 Nov '20) – <i>Oral presentation</i>	2020	-
World Physiotherapy Congress (Online, 9-11 Apr '21) – <i>Oral presentation</i>	2021	0.9
Community of Practice Gezond weer meedoen na CVA meeting Utrecht (Online, 31 May '21) – <i>Oral presentation</i>	2021	-
Seminar Exploring Healthy Behaviour Fontys (Online, 1 Jun '21) – <i>Oral presentation</i>	2021	-
KNGF research network meeting (Online, 13 Sept '21) – <i>Oral presentation</i>	2021	-
'Fontys opent deuren' (Eindhoven, 23 Jun '22) – <i>Walk in workshop</i>	2022	-
World Physiotherapy Congress (Dubai, 2-4 Jun '23) – <i>Oral presentation & Poster</i>	2023	0.9
Teaching and supervision		
Supervision Bachelor students thesis, research project, Fontys University of Applied Science, Eindhoven (15 students)	2019-2023	-
Lecturer Research methodology and thesis, Fontys University of Applied Science, Eindhoven	2019-2023	-
Learning process counsellor graduation phase, Fontys University of Applied Science, Eindhoven	2021-2023	-

Visiting lecturer minor Exploring Healthy Behaviour, behaviour change research; Improving movement behaviour after stroke, Fontys University of Applied Science	2020 - 2021	-
Visiting lecturer Les blended care, Lifestyle Coach, Fontys University of Applied Science, Eindhoven	2022	-
Supervising Master thesis student clinical health scientist, Utrecht University	2022- 2023	-
RISE intervention Course, Research Group Empowering Healthy Behaviour, Department of Health Innovations and Technology, Fontys University of Applied Sciences, Eindhoven	2023	-

List of peer reviewed publications included in this dissertation

Hendrickx W, Riveros C, Askim T, Bussmann JBJ, Callisaya ML, Chastin SFM, Dean CM, Ezeugwu VE, Jones TM, Kuys SS, Mahendran N, Manns TJ, Mead G, Moore SA, Paul L, Pisters MF, Saunders DH, Simpson DB, Tiegies Z, Verschuren O, English C. Identifying factors associated with sedentary time after stroke. Secondary analysis of pooled data from nine primary studies. *Top Stroke Rehabil.* 2019 Jul;26(5):327-334. doi: 10.1080/10749357.2019.1601419.

Hendrickx W, Vlietstra L, Valkenet K, Wondergem R, Veenhof C, English C, Pisters MF. General lifestyle interventions on their own seem insufficient to improve the level of physical activity after stroke or TIA: a systematic review. *BMC Neurol.* 2020 May 1;20(1):168. doi: 10.1186/s12883-020-01730-3.

Hendrickx W, Riveros C, Askim T, Bussmann JBJ, Callisaya ML, Chastin SFM, Dean C, Ezeugwu V, Jones TM, Kuys SS, Mahendran N, Manns PJ, Mead G, Moore SA, Paul L, Pisters MF, Saunders DH, Simpson DB, Tiegies Z, Verschuren O, English C. An Exploration of Sedentary Behavior Patterns in Community-Dwelling People With Stroke: A Cluster-Based Analysis. *J Neurol Phys Ther.* 2021 Jul 1;45(3):221-227. doi: 10.1097/NPT.0000000000000357.

Hendrickx W, Wondergem R, Pisters MF, Lecluse C, English C, Visser-Meily JMA, Veenhof C. It is a matter of changing habits; Factors related to high-risk movement behaviour in people with stroke who are highly sedentary and inactive. Under review 2023

Hendrickx W & Wondergem R, English C, Visser-Meily JMA, Veenhof C, Pisters MF. RISE, a blended behavioural intervention to support people to reduce and interrupt their sedentary behaviour. Under review 2023

Hendrickx W, Wondergem R, Veenhof C, English C, Visser-Meily JMA, Pisters MF. Improving movement behaviour after stroke with the RISE intervention – a randomised multiple baseline study. Submitted 2023

List of peer reviewed publications outside of this dissertation

Vlietstra L, Hendrickx W, Waters DL. Exercise interventions in healthy older adults with sarcopenia: A systematic review and meta-analysis. *Australas J Ageing.* 2018 Sep;37(3):169-183. doi: 10.1111/ajag.12521.

Hendrickx W, Wondergem R, Pisters M. De RISE-interventie. Meer bewegen na een beroerte begint bij minder zitten. *Fysiopraxis* 2021 okt

English C, Wondergem R, Hendrickx W, Pisters MF. People with Stroke Are Most Sedentary in the Afternoon and Evening. *Cerebrovasc Dis.* 2022;51(4):511-516. doi: 10.1159/000521209. Epub 2022 Jan 4.

About the Author

Wendy Hendrickx (1982) graduated as a BSc physical therapist in 2004 at Avans University of Applied Science, Breda, the Netherlands, afterwards specialising in geriatric physical therapy. After working as a physical therapist in primary care, geriatric rehabilitation and care institutions she started her MSc clinical health scientist, specifically physical therapy science, at University Utrecht, Utrecht, the Netherlands in 2015. Wendy's clinical work has allowed her to see the importance of secondary prevention and attention for movement behaviour in people with stroke. In 2017, she conducted her master thesis on sedentary behaviour in people with stroke, at the Hunter Medical Research Instituted and the University of Newcastle Australia, and graduated later that academic year. After her masters Wendy started work as a physical therapist and researcher (PhD candidate) at the Center for Physical Therapy Research and Innovation in Primary Care, a structural collaboration in innovation, education and research between Leidsche Rijn Julius Health Care Centers, Fontys University of Applied Sciences, Utrecht University of Applied Sciences and the University Medical Center Utrecht. Her research on sedentary behaviour in people with stroke is performed in close collaboration with the University of Newcastle Australia. In 2019 Wendy started working as teacher and researcher (PhD candidate) at the Research Group Empowering Healthy Behaviour, Department of Health Innovations and Technology, Fontys University of Applied Sciences, Eindhoven. She currently still works there allowing here to combine both research and teaching and integrating these two pillars.

Wendy is engaged to Martijn Pot, they live together in Rijen.

Dankwoord & Acknowledgements

Hij is af, mijn proefschrift, het is gelukt en wat was het een geweldige tijd. Ik kan het nog niet helemaal geloven dat het klaar is, maar wat ben ik dankbaar voor alle mooie ervaringen en momenten met zo veel inspirerende mensen. Wat heb ik genoten van alles wat ik heb geleerd. Zowel over bijvoorbeeld onderzoeksmethodologie, data analyses, wetenschappelijk schrijven als inhoudelijk. Ik heb me mogen verdiepen in de uitdagingen van het veranderen van gedrag, de mogelijkheden van technologie, bijvoorbeeld voor het geven van inzicht in bewegen.

Ook van de mensen die deelgenomen hebben aan de studies heb ik veel geleerd en ze hebben me verrast door hun openheid, betrokkenheid en scherpe inzichten. Ik heb mogen ervaren wat ik eigenlijk al wist, hun perspectief is echt onmisbaar. Ook als persoon heb ik mij mogen ontwikkelen. Ik ben enorm dankbaar dat ik deze uitdaging aan mocht gaan. En dat allemaal dankzij alle mensen die mij hebben begeleid, ondersteund en aangemoedigd, dank jullie wel!

Allereerst mijn promotieteam

Beste Cindy, dank voor jouw open en benaderbare houding. Ondanks dat je enorm druk bent, heb ik toch steeds het gevoel gehad dat ik altijd bij jou terecht kon als het nodig was. Dank voor de nuchtere houding en kritische blik die je hebt gebracht binnen mijn promotie traject. Je hebt mij gestimuleerd om mezelf te ontwikkelen en altijd scherp te blijven. Daarnaast heb je mij geïnspireerd met jouw visie op de gezondheidszorg, alle taken die jij combineert en de aandacht en interesse die je hebt voor de personen met wie jij samenwerkt.

Dear Coralie, I can't believe I've made it... You probably knew all along. I still don't know how I won your confidence in my abilities when we met, but you were always there to support and guide me. I don't think I could have made it this far without you believing in me. You supported and encouraged me to make well-argued choices within our research projects. Also, you thought me so much when it comes to scientific writing by letting me do it and showing me how to improve by example without taking over. It has meant the world to me that you thought I could do it all and understood that I sometimes didn't believe I could do it. Your open and welcoming spirit made my time in Newcastle amazing. Deciding not to stay, but to pursue a chance to work with you from the Netherlands, was probably one of the hardest choices I ever had to make. Even from across the world you kept supporting me and was there when I needed advice not just as a supervisor but as a mentor and friend. It has made all the difference, thank you for being there!

Beste Martijn, dankjewel voor alle kansen die jij mij gegeven hebt. Het contact met Coralie, wat heeft geleid tot een fantastische periode in Australia, waarin ik met zo veel geweldige mensen heb mogen samenwerken binnen het STARS project. Mijn onderzoekstage binnen het RISE project, ook daar heb ik zo veel geleerd van jou en Roderick. Ik had nooit verwacht dat dit alles zou leiden tot waar ik nu sta, dat ik dit zou bereiken. Dat was ook nooit gelukt zonder het vertrouwen wat jij mij hebt gegund. Ik heb enorm veel van je geleerd en daarvoor ben ik je ontzettend dankbaar. Je hebt me geleerd kansen te zien en groter en strategischer te denken. En ja, je had gelijk het onderwijs was misschien toch wel iets voor mij.

Roderick, onze samenwerking begon in een bewogen periode voor jou en ik heb heel veel respect voor de open manier waarop je hierin stond. Daarbij bleef je ook altijd oog houden voor de personen met wie je samenwerkte, dat bewonder ik enorm. Je hielp mij om te relativiseren en beter in balans te komen als ik me weer eens veel te druk maakte. Jouw kritische vragen en feedback hebben mij altijd gestimuleerd om alles wat ik deed goed te overdenken en te onderbouwen. Dank daarvoor!

Beste Anne, ook al was je officieel geen onderdeel van mijn promotie team, in de praktijk voelde dat vaak wel zo. Jouw betrokkenheid en kritische blik heeft mij verder gebracht en altijd geprikkeld om na te denken en keuzes goed te onderbouwen. Je doortastendheid, behulpzaamheid en enthousiasme heb ik enorm gewaardeerd. Ook van de manier waarop jij altijd de vertaalslag maakte naar de praktijk en de mensen met een beroerte heb ik veel geleerd.

Graag bedank ik de Beoordelingscommissie: prof. dr. F.H. Rutten, prof. dr. O.H. Franco Duran, prof. dr. L.J. Kappelle, prof. dr. R. Crutzen, prof. dr. F. van Wijck. Hartelijk dank dat jullie de tijd namen om mijn proefschrift te lezen en te beoordelen.

Dank aan alle mensen die deelgenomen hebben aan de onderzoeken in dit proefschrift, de mensen die zo open verteld hebben over hun leven, activiteiten, zitten en bewegen. De mensen die meegedaan hebben aan de multiple baseline studie, met alle metingen en vragen. Ik was welkom bij jullie thuis en ik heb jullie medewerking, openheid en hartelijkheid enorm gewaardeerd. Het gaat jullie goed!

Ook alle medewerkers van de deelnemende ziekenhuizen bedankt, zonder jullie inzet was het nooit gelukt om alle mensen voor de multiple baseline studie te rekruteren. Jullie hebben steeds met ons meegedacht en dat was enorm waardevol.

Consortium partners, bedankt voor jullie inzet voor het RISE project. Jullie kennis en expertise was van onschatbare waarde en heeft er voor gezorgd dat de RISE interventie een succes is geworden. In het bijzonder Coen, Michel, Guido en Thomas bedankt voor al jullie inzichten, meedenken en werk aan de RISE monitor en app. Jullie waren er als wij vragen hadden en kwamen met constructieve oplossingen.

Dear co-authors, thank you for working with me on the chapters of this thesis, you have been an inspiration! A special thanks to the STARS collaboration for all your availability, support and kindness during the time we worked together from all over the world, I learned a lot from all of you. A special thanks to Seb Chastin, I still remember the first time we spoke online. Straight of you asked me a well-argued critical question about influencing sedentary behaviour in the current environment. I was almost surprised I was able to answer the question that quick at that early stage, it put me on my toes in a great way. You have been an inspiration and I learned a lot from you, through your sharp viewpoints and kind support!

I want to thank Gary Crowfoot (Hunter Medical Research Institute, Newcastle Australia), Gillian Mason (Hunter Medical Research Institute, Newcastle Australia) and Dawn Simpson (University of Newcastle, Newcastle Australia) for their input regarding text editing for Chapter 4 and 7.

Heidi, dankjewel voor jouw geduld en meedenken als ik weer eens een onmogelijk planningsverzoek had. Zonder jou waren al die intercontinentale overleggen nooit gelukt.

Lieve collega's van Fontys en team EHB, Eveline, Céline, Jaron, Noëlle, Els, Forra, Lea, Marcel, Angela, Patrick, Verena, Sandra, Thom en alle anderen, dank voor al jullie positieve energie, creativiteit, enthousiasme, gezelligheid en betrokkenheid. Jullie maken werken voor Fontys echt fantastisch. Céline, bedankt voor jouw hulp bij het analyseren van de data van de interviews en het delen van jouw heldere inzichten.

Beste (oud) collega's van LRJG en de Academische Werkplaats Fysiotherapie, dank voor de fijne samenwerking gedurende de 5 jaar dat ik bij LRJG gewerkt heb. Het was mooi om samen met jullie goede zorg te leveren voor de mensen in Leidsche Rijn. Een extra dank aan de collega's van het expertteam 'gezond ouder worden en chronische ziekten' en locatie Terwijde voor al jullie oprechte interesse, meedenken en de gezellige momenten.

Team Fysiotherapiewetenschap, dank voor alle inspiratie die jullie mij gegeven hebben. Er was altijd wel iemand die raad wist of mee wilde denken. Dank ook voor de gezelligheid tijdens de WCPT bezoeken! Een speciale dank aan Merel Timmer voor het delen van haar inzichten in data analyses bij multiple baseline onderzoek.

Els, Suze, Remco, Mark en Sander, dank voor de leuke momenten op de vrijdagen, het was fijn om mensen te hebben om mee te sparren. Tjarco dank voor jouw rust, relativerend vermogen en nuchterheid, het hielp me om dingen weer in perspectief te zien.

Naast Martijn zijn er nog 2 leden van het RISE team die ik wil bedanken. Camille, het was zo leuk om met jou het afgelopen jaar te werken om de RISE interventie nog beter te maken. Dank voor al jouw enthousiasme, optimisme en spontaniteit het maakt je een fijn persoon om mee samen te werken. Ik heb heel veel bewondering voor hoe jij het afgelopen jaar alle werkzaamheden in het project hebt opgepakt. Hoe spannend je het ook vond, jij stond er en maakte het tot een succes. Heerlijk hoe perfectionistisch, zelfkritisch, volhardend en een klein beetje positief naïef jij soms ook kan zijn (it takes one to know one)! Yvonne, in de relatief korte tijd dat we nu samenwerken heb ik waardering gekregen voor de rust en constructiviteit waarmee jij zaken aanpakt en dit ook uitstraalt naar anderen. Dank voor de tijd die je vrij maakt en de interesse die je hebt in de persoon tegenover je.

Lord Björn, knight in shining armour, dankjewel voor al jouw tijd waarin je mij hebt geholpen om de data voor te bereiden en later met de analyses voor hoofdstuk 7. Zonder het 'Knitter' programma wat jij speciaal geschreven hebt om de enorme hoeveelheid data samen te voegen zou ik de analyses niet zo gedegen en robuust uit hebben kunnen voeren. En hoeveel mensen kunnen nu zeggen dat er een softwareprogramma voor hen ontwikkeld is? Het was erg leuk en ik heb veel geleerd. Daar hoort ook een extra bedankje bij voor al je geduld bij mijn domme vragen en acties. Ik beloof nogmaals dat ik nooit meer een update zal uitvoeren mid-project!

Lieve vrienden, bedankt voor de leuke momenten en gezellige etentjes en drankjes, het was heerlijk om soms ook even niet bezig te zijn met mijn promotie. Maar ook voor het aanhoren van mijn ongetwijfeld vaak saaie verhalen al die jaren.

Petra, al bijna 20 jaar mijn lieve vriendinnetje die er altijd is voor anderen, enthousiast, open en behulpzaam. Jij ziet altijd het mooie in anderen. Karen, naast alle gezellige momenten ook dank voor jou hulp om mijn VWO wiskunde binnen te halen zodat ik aan mijn master kon beginnen. Miranda, dank voor alle gezellige wijntjes op de vrijdagavond. Het was fijn om over alles en niets te kunnen kletsen, lekker nuchter, logisch en met humor. En natuurlijk Marleen en Jony, altijd gezellig en betrokken.

Neeltje en Roos mijn vriendinnen uit mijn tienertijd, jullie hebben me altijd het idee gegeven dat ik alles kon bereiken. Ik had toen niet verwacht dit te kunnen, maar jullie vertrouwen heeft er aan bijgedragen dat ik hier gekomen ben.

Lieve Judith, altijd enthousiast, nuchter, positief, begripvol en coachend. Je hebt altijd ondersteunende woorden en durft kritisch en spiegelend te zijn. Dat heeft me zeker geholpen tijdens dit project. Het is altijd fijn om weer even bij te kletsen en gezellig een kop thee te drinken en een Bossche bol te eten.

Lieve Maaïke, jij bent er altijd voor mij als ik je nodig heb, heerlijk nuchter, relativerend en logisch. Bij jou kon ik altijd mijn verhaal kwijt en je had advies als ik dat nodig had. Jij begrijpt mij vaak al met een half woord. We weten na onze scriptie fysiotherapie dat samenwerken aan een stuk tekst geen goed idee is maar daar kunnen we nu om lachen. Je hebt me in dit proces vaak geholpen om dingen op een rijtje te zetten en de chaos van mijn eigen gedachten te ordenen. Dankjewel voor jouw vriendschap en ik ben blij dat jij als paranimf naast mij wilt staan als ik mijn proefschrift mag verdedigen.

Familie Pot bedankt voor de gezellige momenten. Irma dank voor al het lekkere eten dat regelmatig onze kant op komt als we weer eens laat thuis zijn.

Lieve pap en mam, bedankt voor alles! Alle tijd die jullie voor me vrij hebben gemaakt, altijd een luisterend oor en praktische hulp waar nodig. Dank voor jullie steun bij al mijn ambities en in het bijzonder bij mijn tijd in Australië. Jullie hebben me aangemoedigd om uitdagingen aan te gaan, dingen goed uit te denken en lekker nuchter met beide voeten op de grond te blijven. Zonder jullie was ik nooit zo ver gekomen!

Lieve oma Hendrickx, van jou heb ik geleerd om mensen te waarderen om wie ze zijn en altijd het mooie te zien in anderen, juist ook de gekke dingen en eigenaardigheden. Dit heeft me geleerd dat het belangrijk is om te luisteren naar mensen en dat heeft mij een beter persoon en een betere onderzoeker gemaakt. Je was altijd zo trots.

Broertjes, ook al zijn jullie ruim een kop groter dan ik, dankjewel dat jullie er altijd voor me zijn! Jullie humor, praktische insteek en steun. Vero, dank voor jou betrokkenheid, je altijd oprechte interesse in waar ik mee bezig ben, jouw humor en sarcasme. Gemma, dank voor het maken van het mooie figuur in hoofdstuk 5 en natuurlijk de afbeelding op de voorkant van dit boekje, je hebt mijn favoriete kleuren combinatie gecreëerd op basis van een half woord.

Lieve Martijn, jij bent ergens net na het begin van dit gekke en tijdrovende proces ingestapt. Je hebt me aangemoedigd en begrip gehad voor de investeringen die ik deed om dit promotie traject te volbrengen. Je hebt en me weer laten zien dat er meer is dan alleen werken. Dankjewel voor het vertrouwen dat je altijd hebt in mij en alle steun die je me biedt. Niet alleen voor al je hulp bij de praktische dingen maar ook de ruimte die je me hebt gegeven. Jouw relativerende reflecties en kritische vragen hebben me veel geleerd en hebben me sterker gemaakt. Samen hebben we genoten van heel veel mooie momenten en ik ben heel blij dat jij naast me staat in dit proces en straks bij mijn verdediging als paranimf.

