Stroke in urban Suriname and the feasibility of a home-based physiotherapy program

AMEERANI JARBANDHAN

KU Leuven
Biomedical Sciences Group
Faculty of Movement- and Rehabilitation Sciences
Department of Rehabilitation Sciences

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Ameerani JARBANDHAN

Promotor	:	Prof. dr. Em. Luc Vanhees
Co-promotors	:	Prof. dr. DirkJan H.E.J. Veeger
		Dr. Roselien Buys
Chair	:	Prof. dr. Hilde Feys
Members	:	Prof. dr. Dirk Cambier
		Prof. dr. Thierry Troosters
		Prof. dr. Yves Vanlandewijck
		Prof. dr. Geert Verheyden

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To my patients…
your perseverance inspires me…

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List of abbreviations

6MWD	Six Minute Walk Distance
6MWT	Six Minute Walk Test
ADL	Activities of Daily Living
AHA	American Heart Association
ANOVA	Analysis Of Variance
BBS	Berg Balance Scale
BMI	Body Mass Index
BP	Blood Pressure
B-PAD	Barriers to Physical Activity and Disability
CG	Control Group
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
DASH	Disabilities of the Arm, Shoulder and Hand
DM	Diabetes Mellitus
EE	Energy Expenditure
ESES	Exercise Self-Efficacy Scale
FAC	Functional Ambulation Category
HeliSur	Healthy life in Suriname
HIC	High Income Countries
HT	Hypertension
HGS	Handgrip Strength
ICF	International Classification of Functioning, Disability and Health
IG	Intervention Group
LE	Lower Extremity
LMIC	Low- and Middle-Income Countries
MMSE	Mini Mental Scale Examination
MMT	Manual Muscle Testing
NP	Non-Paretic
OR	Odds Ratio
P	Paretic
PA	Physical Activity
PF	Physical Fitness
PNF	Proprioceptive Neuromuscular Techniques
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomized Controlled Trial
SCI	Spinal Cord Injury
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
SRD	Surinamese Dollars
STEPS	STEPwise approach to Surveillance
STROBE	Strengthening the Reporting of Observational studies in Epidemiology
TIA	Transient Ischemic Attack
UE	Upper Extremity
VG	VolksGezondheid
W/H Ratio	Waist Hip Ratio
WHO	World Health Organization
WHR	Waist-Hip Ratio
YD	Yamax Digiwalker

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Dankwoord

Atma namaskar ….

First of all, I want to thank God for giving me this opportunity…
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Ohm shanti, shanti, shanti…

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Chapter 1

General Introduction

1.1 Definition and aetiology

Stroke is one of the leading causes of death globally [1] and also the leading cause of long term disability in adults [2]. According to the American Stroke Association (AHA) the updated definition of a stroke is "rapidly developing clinical signs of focal or global disturbance to cerebral function, with symptoms lasting 24 hours or longer, or leading to death, with no apparent cause other than of vascular origin and includes cerebral infarction, intracerebral haemorrhage and subarachnoid hemorrhage" [3]. There is a difference with a Transient Ischemic Attack (TIA), which is defined as "a transient episode of neurologic dysfunction caused by focal brain, spinal cord or retinal ischemia without acute infarction" [3]. A stroke can be due to ischemia (lack of blood supply) caused by thrombosis or embolism, or due to a haemorrhage [3]. Stroke as a result of ischemia is seen more frequently (87%) as opposed to haemorrhage (13%) [4]. Cerebral infarction is a consequence of the atherosclerotic occlusion of large cervical and cerebral arteries, with ischemia in the area supplied by the occluded artery [5,6] mostly associated to chronic hypertension [5,6]. Intracerebral haemorrhages are mostly a consequence of coagulation disorders, cerebral vascular deformity and modifiable risk factors such as abnormal blood cholesterol levels and hypertension [5-7]. Other modifiable risk factors are cigarette smoking, alcohol abuse and low physical activity levels [5,6]. Stroke risk factors are high and increasing in low- and middle-income countries such as Suriname [8,9], and the burden of stroke is projected to rise unless proper actions are introduced [10].

1.2 Epidemiology

Following a report of the American Heart Association, the worldwide prevalence of stroke was 80.1 million in women and 39.0 million in men [11]. The global burden of stroke differs between countries. High-income countries (HIC) have experienced a substantial decrease, whilst low- and middle-income countries (LMIC) show an increase in stroke cases [10]. It has been estimated that 52.2% prevalent strokes and 70.9% stroke deaths have occurred in LMIC [12]. For Suriname, a middle-income country, no prevalence data are available, whilst cardiovascular diseases are known to be a major cause of death in Suriname, with stroke as the primary cause of death [13]. Additionally, local studies indicate that stroke risk factors such as hypertension [8], diabetes [9] and metabolic disorders [14] are rising. One of the aims of this dissertation is to report on the prevalence of stroke in the capital of Suriname, as a first step to identify part of the burden of the disease stroke.

According to a study (2019) from another middle-income country, modifiable risk factors such as obesity and low education were associated to increased ischemic stroke in urban areas compared to rural areas [15]. Furthermore, the prevalence of alcoholism, dyslipidaemia and diabetes were higher in urban areas compared to rural areas [15], in addition to the increased prevalence of stroke with age [16]. Therefore, the consequences of living in an urban area and increased life expectancy are considerable. The lifestyle of Surinamese endorses chronic disease such as stroke due to an increase of the life expectancy of Surinamese people [17], a transition towards urbanization [18], a high prevalence of diabetes [9], hypertension [8], metabolic disorders [14] and unhealthy dietary habits [19]. Conclusively, variables such as age, sex and traditional stroke risk factors modify the prevalence of stroke. Hence, we expect to find a high prevalence of stroke in the capital of Suriname, a middle-income country. Furthermore, we expect to find a high prevalence of stroke risk factors amongst post-stroke survivors. As we stated earlier, the burden of stroke also depends on ethnic origin. In some groups the risk for stroke is higher, i.e., the prevalence of stroke is higher for Hispanics in the USA compared to Caucasians [20]. In this dissertation ethnic background is included as a risk factor and study variable as Suriname is known for its multi-ethnic population [14,21].

1.3 Stroke and ethnic background

Studies have already assessed the association between stroke and hypertension [22], diabetes [23] and metabolic disorders [24]. Ethnicity is already categorised as a biological risk factor for several chronic disorders [8,9,14,25,26] i.e., people from South-Asia show a higher risk for diabetes mellitus and coronary artery disease compared to other ethnicities [25,26]. However, limited data is available for ethnicity as a risk factor for stroke. So far, studies from HIC show increased stroke prevalence amongst Hispanics compared to Caucasians [20], more than 200% excess stroke mortality for Blacks compared to Caucasians and a greater stroke risk for ethnic minorities (Pacific, Māori and Asian people) compared to people from European origin [10]. However, the association of ethnicity with stroke has not been assessed in detail, especially in multi-cultural developing countries. One of the aims of this dissertation is to report the relationship between stroke and ethnicity adjusted for traditional risk factors. In this thesis we used the following definition for ethnic background: "characteristic, distinctive cultural or sub-cultural traits that set one group off from others"[27]. Another risk factor after stroke is low level of physical activity (PA).

1.4 Physical activity as a post-stroke risk factor

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure [28]. The concept of evaluating and modifying PA, as a component to improve our understanding and insight on strategies to improve mobility, rose from an advanced understanding of the International Classification of Functioning, Disability and Health (ICF) model (figure 1) [29].

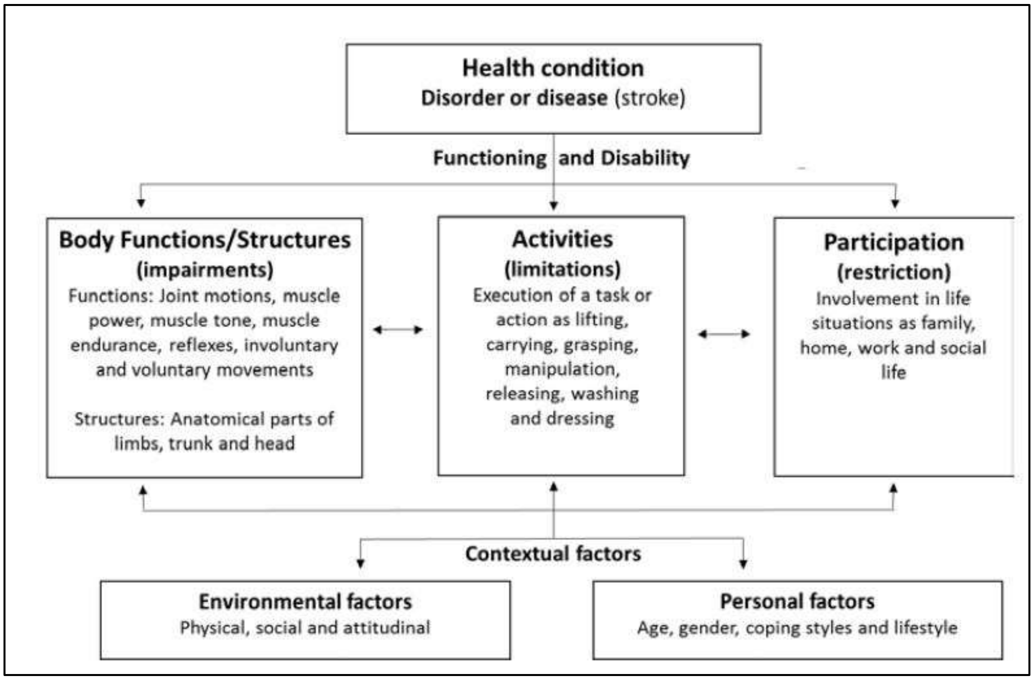

Figure 1. The ICF-Framework with a biopsychosocial view (from: http://icfeducation.org/what-is-icf)[30]

As reported by public health guidelines, stroke survivors would benefit greatly from an active lifestyle [31]. However, chronic stroke survivors are not active enough and generally reach much fewer of the recommended 8,000 steps/day [31]. Even in high-functioning subjects after stroke, the risk for recurrent stroke is increased, due to the low physical activity (PA) levels [32,33] in these subjects. As a result, this adds to a sedentary lifestyle and a low functional walking capacity level among stroke survivors [34]. This makes the group of people after stroke more prone to recurrent stroke or other cardiovascular diseases [31]. Reasons for this are diverse and seem to vary in different countries [35-37]. Marked differences between as well as within high- [32] and middle-income countries [35-37] for factors associated with physical activity have been reported. In addition to stroke related impairments, the low PA can be related to low income level, low education level, single marital status [13] and perceived exercise barriers [38]. The latter two may vary among countries and depend on different sociocultural factors. Environmental and facility barriers including costly exercise programs, transportation availability, poor local infrastructure and weather conditions are reported in both HIC and LMIC as determinants for low participation in structured PA programs [35,39]. On the other hand, a Nigerian study [13] reports personal exercise barriers are due to cultural perceptions, such as the notion that people in exercise clothes look funny or being too embarrassed to exercise. This differs from an American study which reports a lack of interest in addition to concerns that exercise might worsen their condition, as the reason for personal exercise barriers [15]. In addition, lack of information, accessibility and availability were identified as shortcomings in a low resource setting regarding stroke care for promotion of PA after hospital discharge [28,40]. From these abovementioned studies, we conclude that generalization of findings requires caution. Barriers within stroke rehabilitation, especially barriers to exercise, need to be identified in Suriname for stroke survivors in order to test successful exercise interventions. Therefore, it seems important to add the study of potential factors associated with low post-stroke PA levels and barriers to exercise as one of the aims of this dissertation.

1.5 Post-stroke mobility

Mobility is a broad term and mainly includes walking ability and other mobility-related activities such as mobility during rising to stand, sitting down and transferring [41]. In more than 80% of all stroke cases mobility is disturbed [42]. Physical therapy focuses on improvement of mobility which is in line with improvement of activities according to the ICF [43]. Hence, for the purpose of developing and evaluating an effect of a physiotherapy intervention to promote post-stroke mobility, with less implementation problems in a low financial resource setting, we had to choose a feasible functional walking test. In post stroke survivors, the six-minute walk test (6MWT) is a frequently used measure of functional walking capacity, which can be defined as the extent to which increased intensities of walking capacity can be maintained to perform activities of daily living (ADL) [44,45]. This test is considered as a valid, reliable and feasible tool to measure functional walking capacity in post-stroke patients [44] and is well tolerated by patients, easy to use and it better reflects ADL than other walking tests [44,46,47]. The 6MWT is also an independent predictor for community ambulation [48] and an indicator for post-stroke balance confidence [49]. However, this test embraces a complex interaction with several stroke related factors [46]. So far, it is known that it is influenced by several stroke-related impairments such as energy cost of walking [50], gait asymmetry [51] and balance impairments [49,52,53].

Growing evidence suggest that the upper extremity (UE) function affects the walking capacity in stroke patients. Stroke survivors suffer frequently from disabilities, like motor deficits in the extremities, which impedes proper community ambulation [54] which refers to the ability of a person to walk in their own community and this is often disturbed after stroke [54]. In this dissertation UE function is defined as the capacity to perform activities with the UE [55]. The cyclic motion of the UE serves to reduce energy cost during bipedal human gait [56]. In addition, it was suggested that arm cycling improved grip strength and the neurological connection between the arms and the legs [57]. Additionally, a coordination between the upper and contralateral lower limb during walking is suggested in post-stroke survivors [58]. Moreover, immobilization of the UE induces negative changes in spatial gait parameters [59]. And the handgrip strength (part of UE function) was associated to walking in elderly [60] and patients with lumbar stenosis [61]. Since these studies suggest that the UE function affects the walking capacity, we expect that the UE function might also affect the 6MWT. So far, only one study [62] that reported a moderate correlation between the 6MWT and the SIS hand function domain in 30 chronic stroke survivors was found.

Therefore, one of the aims of this dissertation was to assess the association between UE function and the 6MWT adjusted for balance control and gait asymmetry. Findings from this study will improve insight about the factors that might affect the outcome of the 6MWT and facilitate the development of the feasibility study. We expect a positive relationship between UE function and the 6MWT, because of the previous findings from Muren et al. (2008).

1.5 A home-based semi-supervised feasibility study to promote post-stroke mobility

1.5.1 Post-stroke rehabilitation

Post-stroke risk factors are often co-occurring, are interconnected and demand combined educational, behavioural and medical interventions (figure 2) [7]. High-income countries show enhancements in prevention, acute treatment and neuro-rehabilitation, which led to an overall decrease in burden of disease. It is well established that stroke survivors need rigorous rehabilitation in order to achieve maximum chance of functional recovery after stroke [41]. Functional recovery is defined as "improvement in mobility and activities of daily living" which can be influenced by rehabilitation [16,63]. However, in a group with chronic stroke, it is not evident to expect changes based on neuroplasticity. The focus was on remaining central and peripheral neuromuscular adaptations with respect to a limited process of neural repair and the residual movement ability in the chronic phase after stroke. Whilst, outpatient care is defined as care after hospital discharge during the post-acute and chronic phase after stroke [64,65]. In the United States and in Western Europe outpatient care includes rehabilitation and follow-up care that is provided according to the needs of patients and after formal assessments by a rehabilitation team [41,66]. The rehabilitation team consists of a neurologist, skilled nurse, physiotherapist, speech therapist and occupational therapist. In Western European hospitals, nursing homes and rehabilitation centres are organized in a care chain and work closely together to offer high quality care to stroke patients [66,67]. Approximately 3-4% of total health care expenditures in Western Europe are spent on stroke and the lifetime cost of a stroke per person in the United States is estimated at $140,048 [10]. Hence, it is to be expected that high costs of stroke and an increase in the prevalence of stroke risk factors place a huge burden on LMIC [10]. Given the fact that cost of an exercise program or transportation to an exercise facility might create a problem in a middle income country setting [36,40], home-based and semi-supervised programs might be more (cost)effective [68].

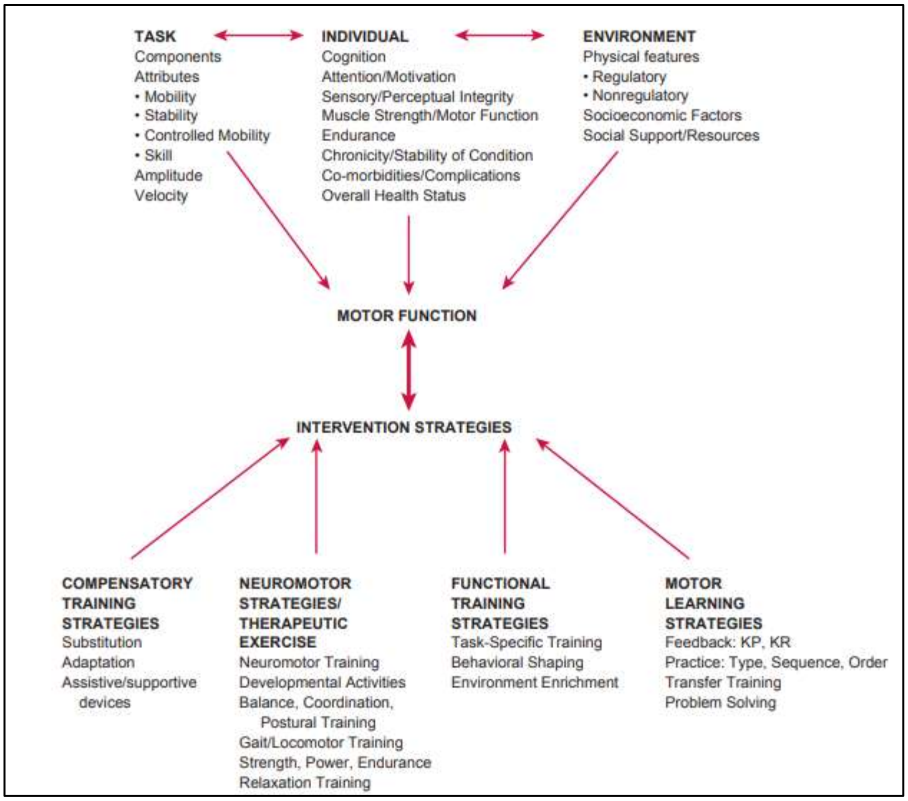

Figure 2. Interaction of several levels for improvement of post-stroke motor function (from: O'Sullivan, 2007, p.488[7])

1.5.2 Home-based semi-supervised rehabilitation

Home-based rehabilitation has demonstrated better outcome and better performance of activities of daily living (ADL) in an intervention group compared to a control group [69]. Similarly, a review suggests that home-based rehabilitation decreases the odds for poor outcome and increases independency of the patient at home [70]. However, this review was based on heterogeneous interventions, illustrating that the nature, content and most effective way of providing home-based rehabilitation still needs to be determined. What is clear is that a patient-centred culturally sensitive rehabilitation intervention as well as a less costly form of rehabilitation is of high importance [71]. Building on that, interventions at home are tailored e.g., home-based interventions are also provided in the form of semi-supervised programs. According to the literature [41,72] these programs appear to become an accepted alternative to the physical presence of the therapist for adults after stroke. Authors from this review suggested tele-neurology and phone-based interventions as a promising avenue for future stroke research in LMIC (Sub-Saharan Africa, China, Ghana, Brazil), due to shortage of skilled personnel, financial resources infrastructural and transportation problems. They concluded that all studies up till now were limited by their small sample size, but offer important implications for places where there is paucity in socioeconomic resources. Ideally, rehabilitation and follow-up care should be available as long as needed, but these specialised neuro-rehabilitation services are generally not in place for those who need long term care [73,74] especially in a LMIC, such as Suriname.

1.5.2 Stroke care in Suriname

Suriname is hampered by inaccessibility of some of the rural (and some of the urban) areas as well as lack of infrastructure [75]. The country experienced an economic crisis in 2010 [9,75-77], which deepened in 2016. Health care has been hit particularly hard by this crisis [78,79]. In 2014 an all-inclusive healthcare law was passed that guaranteed healthcare access for those under 16 and over 60, while those between 16-60 years were insured through their employers' health insurance programs [80]. Under the current rules and epidemiologic trends, costs are projected to outrun government expenses. Furthermore, as a middle-income country, the stroke care chain for stroke survivors experiences several problems such as poor communication between care professionals and lack of financial resources [81]. Due to lack of financial resources and the lack of full coverage by health insurers, patients generally cannot afford the high costs of outpatient rehabilitation, contributing to suboptimal use of local rehabilitation possibilities [81]. Moreover, there is a lack of physiotherapy guidelines for outpatient stroke care in Suriname, even though physiotherapy makes up for a substantial amount of therapy time during rehabilitation.

1.5.3 Developing an intervention program to promote post-stroke mobility

Several guidelines have been developed for physiotherapeutic management of post stroke disabilities [82]. These guidelines are used during clinical decision-making and assessment of the functional improvement after treatment [82]. However, they include several functional tests that require special professional skills by the physiotherapist and infrastructural facilities to be in place [82]. The availability of these requirements may vary per country. Studies from developed countries have reported factors such as 'changing routines', 'time investment', financial compensation' that prevent the use of functional tests amongst physiotherapists [83]. In contrast to this, developing countries report other factors such as 'lack of human and structural resources', therapists are not aware and therefore not routinely using functional tests', and 'very little or no resources for rehabilitation research' [84]. On the other hand, several facilitators have been studied. High income countries have reported factors such as 'positive attitude towards functional tests', 'acquaintance with functional tests' as facilitators [83]. But, concerning facilitators for the use of functional tests in LMIC, especially for Suriname, there is no information provided [84]. As physiotherapy makes up for 40-90% of the therapy time for stroke patients [41], we developed our own intervention program tailored to the local setting of Suriname, but based on empirical evidence of RCT's, systematic reviews and behavioral theories e.g. exercise self-efficacy (a main component often used during treatment by helping patients set realistic small goals [85]) with a main objective to test feasibility of a program that promotes physical activity.

Today, no structural home-based or tele-physiotherapy program is available for chronic stroke survivors in Suriname. Currently, reimbursed therapy sessions at the rehabilitation centre in the capital of Suriname are offered for a maximum of ten sessions in one year. Suriname is contextually unique: socio-economic barriers, cultural barriers, uncoordinated care, underdiagnoses, low awareness, lack of research, etc. limit the capacity to develop successful strategies 5 against the rising burden of disease27. From this point of view, the SunRISe (Stroke Rehabilitation In Suriname) project was initiated, in which we developed an 8-week home-based semi-supervised physiotherapy program to improve functioning of chronic stroke survivors in the urban area of Suriname. The aim of this pilot study was to assess the feasibility and safety of this program. Additionally, the clinical efficacy of this approach was explored. We hypothesize that this program will be feasible in a low-income setting and will induce a clinically important improvement. Furthermore, this study will generate efficacy estimates to inform sample size calculation and best primary outcome measures for designing a properly powered randomized controlled trial in the future.

Aims and outline of PhD research

The main objective of this dissertation is to assess the feasibility of a tailored PA intervention [86] for the reason that PA is normally reduced in post-stroke survivors [87]. To structurally frame the development of and to facilitate this program, three cross-sectional studies are conducted (chapter 2-4).

In **Chapter 2** we describe the prevalence of stroke in Paramaribo and assess the relationship between stroke and ethnic background adjusted for traditional risk factors such diabetes, hypertension, dyslipidaemia and smoking. We expect a relatively high prevalence due to urbanization and increased life expectancy. Secondly, we expect a higher prevalence of stroke in Hindustani compared to other ethnic groups when adjusted for traditional risk factors. The focus of **chapter 3** is to examine the association between functional walking capacity and UE function in chronic stroke survivors. We expect a decreased 6MWT performance to correlate moderately with UE function. Findings from this study will improve our insight about factors that might affect the performance of the 6MWT. This facilitates the use of the 6MWT when it is to be used to measure an intervention effect.

The aim of **chapter 4** is to explore possible factors associated with low PA levels in chronic stroke patients by also describing the PA-barriers. The converging lines of evidence let us expect low PA levels in our study population. Additionally, this study will enable us to identify PA barriers in order to improve our insight on how to customize our PA programs specifically for the Surinamese stroke population.

In **chapter 5** we describe a home-based semi-supervised physiotherapeutic program of eight weeks designed for the middle-income country setting of Suriname and report on its feasibility for chronic stroke survivors. In this regard, a pilot randomized controlled clinical trial was conducted with thirty chronic stroke survivors, all able to walk at least 10m with or without supervision. We hypothesized that this program would be feasible, as well as beneficial for improving the patient' mobility, in terms of functional walking capacity and functionality.

A systematic review of the literature on test-retest reliability, internal validity and accuracy of PA monitors, including accelerometers and pedometers, solely for chronic stroke survivors is added to this thesis to have an indication of which PA monitors are valid in this patient group (**addendum I**).

In the final chapter, **chapter 6**, the main results and conclusions from the different studies are discussed and recommendations for future research are presented.

In the following table (table 1), information on methodology, patients and statistical analysis of the different chapters is provided. In figure 3 the place of residence according to the districts they fall into is presented on a Surinamese map for all participants from this dissertation.

Table 1. Overview of the methodology and relevance of the different chapters

Title	Methodology	Knowledge Gap	Number of patients	Statistical analysis
Chapter 2: Prevalence of self-reported stroke in association with ethnic background within a multi-ethnic population in Paramaribo, Suriname: results from the HeliSur study	cross-sectional study; House-hold based sample design	Prevalence of stroke in Suriname is unknown. Association between ethnic background and stroke (in Suriname) is suggested but never documented.	N=1478	Multiple imputations; multivariate regression analysis
Chapter 3: A cross-sectional study to assess an association between upper extremity function and functional walking capacity in chronic stroke survivors.	Cross-sectional study; association between outcome measures	It is suggested that arm cycling training improved grip strength and the neurological connection between the arms and the legs. Yet, no study documented the direct relationship between arm function and functional walking ability. If the 6MWT is to be used to assess performance of a post-stroke patient over time (for example, in response to an intervention) it might be important to know whether UE function assessment is necessary.	N=50	The spearman rho and point biserial tests; linear regression analysis

Title	Methodology	Knowledge Gap	Number of patients	Statistical analysis
Chapter 4: A description of factors associated with reduced physical activity and barriers for exercise in chronic stroke survivors from a multi-ethnic society: a cross-sectional study	Cross-sectional study; association between outcome measures	Low- and middle-income countries as well as multi-ethnic populations, might face different socio-economic challenges compared to high-income countries. Generalization of study findings requires caution. It is relevant to further explore factors associated with low PA in stroke survivors in diverse populations, in order to be able to build effective interventions to increase PA. Suriname has less developed care for people after stroke, less resources and ethnically diverse groups.	N=44	Univariate and multivariate regression analysis
Chapter 5: Feasibility of a home-based physiotherapy intervention to promote post-stroke mobility: a randomized controlled pilot study	Longitudinal (feasibility pilot) study; randomized controlled trial design.	No structural home-based or tele-physiotherapy program is available for chronic stroke survivors. Suriname is contextually unique: socio-economic barriers, cultural barriers, uncoordinated care, under-diagnosis, low awareness, lack of research, etc. limit the capacity to develop successful strategies against the rising burden of disease.	N=30 (subsample of abovementioned study group)	Mixed design ANOVA
Chapter 6: General discussion	---	Elaboration on the aims of chapter 2-5 followed by methodological considerations, the impact of this dissertation and finally recommendations for future stroke research	---	---
Addendum 1: A systematic review of the validity, reliability and accuracy of physical activity monitors in chronic stroke patients	Systematic review according to PRISMA guidelines; quality methodology by STROBE guidelines for reporting observational studies	Inquiry on new evidence of validity, accuracy and reliability of physical activity monitors for chronic stroke survivors in literature	7 papers included representing 193 participants	Descriptive statistics only

Figure 3. The districts related to the place of residence of all the study participants.

References

1. Mendis S, Puska P, Norrving B. Global atlas on cardiovascular disease prevention and control: World Health Organization; 2011.
2. Adamson J, Beswick A, Ebrahim S. Is stroke the most common cause of disability? Journal of stroke and cerebrovascular diseases : the official journal of National Stroke Association 2004;13:171-7.
3. Sacco RL, Kasner SE, Broderick JP, et al. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2013;44:2064-89.
4. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics--2015 update: a report from the American Heart Association. Circulation 2015;131:e29-322.
5. Pikija S, Trkulja V, Malojcic B, Mutzenbach JS, Sellner J. A High Burden of Ischemic Stroke in Regions of Eastern/Central Europe is Largely Due to Modifiable Risk Factors. Curr Neurovasc Res 2015;12:341-52.
6. Truthmann J, Busch MA, Scheidt-Nave C, et al. Modifiable cardiovascular risk factors in adults aged 40-79 years in Germany with and without prior coronary heart disease or stroke. BMC Public Health 2015;15:701.
7. Susan B. O'Sullivan tJS. Physical Rehabilitation. 5th ed: F.A.DAVIS COMPANY; 2007.
8. Krishnadath IS, Jaddoe VW, Nahar-van Venrooij LM, Toelsie JR. Ethnic differences in prevalence and risk factors for hypertension in the Suriname Health Study: a cross sectional population study. Popul Health Metr 2016;14:33.
9. Krishnadath IS, Nahar-van Venrooij LM, Jaddoe VW, Toelsie JR. Ethnic differences in prediabetes and diabetes in the Suriname Health Study. BMJ Open Diabetes Res Care 2016;4:e000186.

10. Katan M, Luft A. Global Burden of Stroke. Semin Neurol 2018;38:208-11.
11. Collaborators GBDS. Global, regional, and national burden of stroke, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol 2019;18:439-58.
12. National Stroke Registry Programme. Indian Council of Medical Research, 2017. (Accessed 29-01-2017, 2017, at http://ncdirindia.org/stroke/BS_FactSheet_Stroke.aspx.)
13. Punwasi W. Doodsoorzaken in Suriname 2010-2011. In: Epidemiology, ed. Suriname: Bureau of Public Health; 2012:11-7.
14. Krishnadath IS, Toelsie JR, Hofman A, Jaddoe VW. Ethnic disparities in the prevalence of metabolic syndrome and its risk factors in the Suriname Health Study: a cross-sectional population study. BMJ Open 2016;6:e013183.
15. Yang Li XZ, Hui Sang, Xiaoyuan Niu, Tingting Liu, Weidong Liu,, Li J. Urban-rural differences in risk factors for ischemic stroke in northern China. Medicine 2019;98:e15782.
16. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. Lancet Neurol 2009;8:741-54.
17. UNDP. Human Development for Everyone, Briefing note for countries on the 2016 Human Development Report: UNDP; 2016.
18. Factbook CW. Suriname Urbanization. 30-06-2015 ed2014.
19. Nahar-van Venrooij LMW, Marhe E, Antonius-Smits C, Krishnadath IS. Adequate and excessive food consumption in Suriname: a multiethnic middle-income country. Int J Public Health 2018;63:1059-69.
20. White H, Boden-Albala B, Wang C, et al. Ischemic stroke subtype incidence among whites, blacks, and Hispanics: the Northern Manhattan Study. Circulation 2005;111:1327-31.
21. Baldew SS, Krishnadath IS, Smits CC, Toelsie JR, Vanhees L, Cornelissen V. Self-reported physical activity behavior of a multi-ethnic adult population within the urban and rural setting in Suriname. BMC Public Health 2015;15:485.
22. Pistoia F, Sacco S, Degan D, Tiseo C, Ornello R, Carolei A. Hypertension and Stroke: Epidemiological Aspects and Clinical Evaluation. High Blood Press Cardiovasc Prev 2016;23:9-18.
23. Hill MD. Stroke and diabetes mellitus. Handb Clin Neurol 2014;126:167-74.
24. Arenillas JF, Moro MA, Davalos A. The metabolic syndrome and stroke: potential treatment approaches. Stroke 2007;38:2196-203.
25. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet 1991;337:382-6.
26. Enas EA, Yusuf S, Mehta JL. Prevalence of coronary artery disease in Asian Indians. The American journal of cardiology 1992;70:945-9.
27. Lewis L. Ethnicity And Nation-building: the Surinamese Experience. Caribbean Quarterly 1994;40:72-83.
28. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985;100:126-31.
29. Bilbao A, Kennedy C, Chatterji S, Ustun B, Barquero JL, Barth JT. The ICF: Applications of the WHO model of functioning, disability and health to brain injury rehabilitation. NeuroRehabilitation 2003;18:239-50.
30. ICF education. WHO-FIC Collaborating Centre, 2017. (Accessed 13-feb-2020, 2020, at http://icfeducation.org.)
31. Tudor-Locke C, Craig CL, Aoyagi Y, et al. How many steps/day are enough? For older adults and special populations. Int J Behav Nutr Phys Act 2011;8:80.
32. M.J. Field NG, T.S. Sundaram, S. Nicholson, G. Mead. Physical activity after stroke: a systematic review and meta-analysis. ISRN Stroke 2013;2013:13.
33. Sarah L. Galea M-JL, , Coralie English, Louise Ada. Sedentary versus active behavior in people after stroke. physical therapy reviews 2014;20:1-7.
34. 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;97:707-17.

35. Rimmer JH, Wang E, Smith D. Barriers associated with exercise and community access for individuals with stroke. J Rehabil Res Dev 2008;45:315-22.
36. Idowu OA, Adeniyi AF, Ogwumike OO, Fawole HO, Akinrolie O. Perceived barriers to physical activity among Nigerian stroke survivors. Pan Afr Med J 2015;21:274.
37. Adeniyi A, Idowu O, Ogwumike O, Adeniyi C. Comparative influence of self-efficacy, social support and perceived barriers on low physical activity development in patients with type 2 diabetes, hypertension or stroke. Ethiop J Health Sci 2012;22:113-9.
38. Nicholson S, Sniehotta FF, van Wijck F, et al. A systematic review of perceived barriers and motivators to physical activity after stroke. Int J Stroke 2013;8:357-64.
39. Mohammad Usman Akhtar SA, Man Mohan Mehndiratta. Barriers associated with community access by stroke patients in Indian population. Indian Journal of Physiotherapy and Occupational Therapy An International Journal 2012;7.
40. Kamalakannan S, Gudlavalleti Venkata M, Prost A, et al. Rehabilitation Needs of Stroke Survivors After Discharge From Hospital in India. Arch Phys Med Rehabil 2016;97:1526-32 e9.
41. Winstein CJ, Stein J, Arena R, et al. Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke 2016;47:e98-e169.
42. Duncan PW, Zorowitz R, Bates B, et al. Management of Adult Stroke Rehabilitation Care: a clinical practice guideline. Stroke 2005;36:e100-43.
43. J.M. Veerbeek EEHvW, R.P.S. van Peppen, H.J.M. Hendriks, M.B. Rietberg, Ph.J. van der Wees, K. Heijblom,, A.A.G. GoosI WOH, B.C. Harmeling-van der We, L.D. de Jong, J.F. Kamphuis, M.M. Noom, R. van der Schaft,, C.J. Smeets TPMMV, D.R.B. Vijsma, C.M. Vollmar, G. Kwakkel. KNGF-richtlijn Beroerte. Tertius - Redactie en organisatie, Houten2014 2014.
44. van Bloemendaal M, van de Water AT, van de Port IG. Walking tests for stroke survivors: a systematic review of their measurement properties. Disabil Rehabil 2012;34:2207-21.
45. Kim DK, Oh DW. Repeated Use of 6-min Walk Test with Immediate Knowledge of Results for Walking Capacity in Chronic Stroke: Clinical Trial of Fast versus Slow Walkers. J Stroke Cerebrovasc Dis 2019;28:104337.
46. Dunn A, Marsden DL, Nugent E, et al. Protocol variations and six-minute walk test performance in stroke survivors: a systematic review with meta-analysis. Stroke Res Treat 2015;2015:484813.
47. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest 2001;119:256-70.
48. Fulk GD, He Y, Boyne P, Dunning K. Predicting Home and Community Walking Activity Poststroke. Stroke 2017;48:406-11.
49. Regan E, Middleton A, Stewart JC, Wilcox S, Pearson JL, Fritz S. The six-minute walk test as a fall risk screening tool in community programs for persons with stroke: a cross-sectional analysis. Top Stroke Rehabil 2020;27:118-26.
50. Eng JJ, Dawson AS, Chu KS. Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil 2004;85:113-8.
51. Sibley KM, Tang A, Patterson KK, Brooks D, McIlroy WE. Changes in spatiotemporal gait variables over time during a test of functional capacity after stroke. J Neuroeng Rehabil 2009;6:27.
52. Pohl PS, Duncan PW, Perera S, et al. Influence of stroke-related impairments on performance in 6-minute walk test. J Rehabil Res Dev 2002;39:439-44.
53. Marco Y.C.Pang JJE, Andrew S.Dawson. Relationship Between Ambulatory Capacity and Cardiorespiratory Fitness in Chronic Stroke. Chest 2005;127:495-501.
54. Sall J, Eapen BC, Tran JE, Bowles AO, Bursaw A, Rodgers ME. The Management of Stroke Rehabilitation: A Synopsis of the 2019 U.S. Department of Veterans Affairs and U.S. Department of Defense Clinical Practice Guideline. Ann Intern Med 2019;171:916-24.

55. Catherine E. Lang MDB, Ryan R. Bailey, Y. Schaefer, Rebecca L. Birkenmeier. Assessment of upper extremity impairment, function, and activity following stroke: foundations for clinical decision making. J Hand Ther 2013;26:104-15.
56. Meyns P, Bruijn SM, Duysens J. The how and why of arm swing during human walking. Gait Posture 2013;38:555-62.
57. Kaupp C, Pearcey GEP, Klarner T, et al. Rhythmic arm cycling training improves walking and neurophysiological integrity in chronic stroke: the arms can give legs a helping hand in rehabilitation. J Neurophysiol 2018;119:1095-112.
58. Bovonsunthonchai S, Hiengkaew V, Vachalathiti R, Vongsirinavarat M, Tretriluxana J. Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke. Kaohsiung J Med Sci 2012;28:667-72.
59. Hong SH, Jung SY, Oh HK, Lee SH, Woo YK. Effects of the Immobilization of the Upper Extremities on Spatiotemporal Gait Parameters during Walking in Stroke Patients: A Preliminary Study. Biomed Res Int 2020;2020:6157231.
60. Savino E, Martini E, Lauretani F, et al. Handgrip strength predicts persistent walking recovery after hip fracture surgery. Am J Med 2013;126:1068-75 e1.
61. Inoue H, Watanabe H, Okami H, Shiraishi Y, Kimura A, Takeshita K. Handgrip strength correlates with walking in lumbar spinal stenosis. Eur Spine J 2020;29:2198-204.
62. Muren MA, Hutler M, Hooper J. Functional capacity and health-related quality of life in individuals post stroke. Top Stroke Rehabil 2008;15:51-8.
63. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet 2011;377:1693-702.
64. Teasell R, Salbach NM, Foley N, et al. Canadian Stroke Best Practice Recommendations: Rehabilitation, Recovery, and Community Participation following Stroke. Part One: Rehabilitation and Recovery Following Stroke; 6th Edition Update 2019. Int J Stroke 2020;15:763-88.
65. Diermayr G, Schomberg M, Greisberger A, Elsner B, Gronwald M, Salbach NM. Task-Oriented Circuit Training for Mobility in Outpatient Stroke Rehabilitation in Germany and Austria: A Contextual Transferability Analysis. Phys Ther 2020;100:1307-22.
66. Tuinman MP. Is de uitkomst van CVA-patienten opgenomen buiten kantooruren minstens even goed vergeleken met CVA-patienten opgenomen binnen kantooruren? [Verslag]. Enschede: Medisch Spectrum Twente; 2013.
67. Arnao V, Popovic N, Caso V. How is stroke care organised in Europe? Presse Med 2016;45:e399-e408.
68. Keith RA, Wilson DB, Gutierrez P. Acute and subacute rehabilitation for stroke: a comparison. Arch Phys Med Rehabil 1995;76:495-500.
69. Iuly Treger CL, Eitana Tabacaru, Leonid Kalichman. Influence of home-based exercises on walking ability and function of post-stroke individuals. International Journal of Therapy and Rehabilitation 2014;21.
70. Group CS. Therapy-based rehabilitation services for stroke patients at home. Cochrane Database of Reviews 2003.
71. Calvin Moorley SC, Nova Corcoran. Stroke among African-Caribbean women: lay beliefs of risks and causes. J Clin Nurs 2016;25:403-11.
72. Sarfo FS UU, Opare-Sem OK, Ovbiagele B. Tele-Rehabilitation after Stroke: An Updated Systematic Review of the Literature. J Stroke Cerebrovasc Dis 2018;27:2306-18.
73. Feigenson JS. Stroke rehabilitation. Outcome studies and guidelines for alternative levels of care. Stroke 1981;12:372-5.
74. Eichler R. Suriname Health Sector Assessment: Inter-American Development Bank (IDB); 1999 August 1999.
75. Suriname's Economic Crisis. the Center for Strategic and International Studies, 2017. (Accessed 12 september 2017, 2017, at https://www.csis.org/analysis/surinames-economic-crisis.)

76. Bertrand AM, Fournier K, Wick Brasey MG, Kaiser ML, Frischknecht R, Diserens K. Reliability of maximal grip strength measurements and grip strength recovery following a stroke. J Hand Ther 2015;28:356-62; quiz 63.
77. The World Data Bank in Suriname: Overview. The World Data Bank, 2017. (Accessed 12-09-2017, 2017, at http://www.worldbank.org/en/country/suriname/overview.)
78. Peplow D, Augustine S. Public health programs as surrogates for social action in Suriname, South America. Public Underst Sci 2015;24:53-68.
79. Peplow D, Augustine S. Intervention mapping to address social and economic factors impacting indigenous people's health in Suriname's interior region. Global Health 2017;13:11.
80. Biasin L, Sage MD, Brunton K, et al. Integrating aerobic training within subacute stroke rehabilitation: a feasibility study. Phys Ther 2014;94:1796-806.
81. M. van Dijk EvdS, H. van Vlaardingen, E. Vollebregt. Minor beyond borders: Ketenzorg in Suriname bij een CVA. Suriname: Revalidatiecentrum Paramaribo, Hogeschool Rotterdam, Instituut voor Gezondheidszorg; 2019 Januari 2019.
82. Platz T. Evidence-based guidelines and clinical pathways in Stroke Rehabilitation - An international perspective. Frontiers in Neurology 2019;10.
83. Van Peppen RP, Maissan FJ, Van Genderen FR, Van Dolder R, Van Meeteren NL. Outcome measures in physiotherapy management of patients with stroke: a survey into self-reported use, and barriers to and facilitators for use. Physiother Res Int 2008;13:255-70.
84. Schoonraad N. Outcome measures validated for use in stroke rehabilitation in low- and middle-income countries: A systematic review. South Africa: Stellenbosch University; 2020.
85. Bailey RR. Lifestyle Modification for Secondary Stroke Prevention. Am J Lifestyle Med 2018;12:140-7.
86. Kringle EA, Barone Gibbs B, Campbell G, et al. Influence of Interventions on Daily Physical Activity and Sedentary Behavior after Stroke: A Systematic Review. PM R 2020;12:186-201.
87. Aguiar LT, Nadeau S, Martins JC, Teixeira-Salmela LF, Britto RR, Faria C. Efficacy of interventions aimed at improving physical activity in individuals with stroke: a systematic review. Disabil Rehabil 2020;42:902-17.

Chapter 2

Prevalence of self-reported stroke in association with ethnic background within a multi-ethic population in Paramaribo, Suriname: results from the HeliSur study.

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Abstract

Background. Suriname is a middle-income country with a multi-ethnic population. Urbanization and ethnic background are generally associated with an increase in cerebrovascular disease, but so far this has not been documented for Suriname. The objective of this study was, therefore, to examine the prevalence of stroke in the capital of Suriname and its association with ethnic background.

Methods. Using the self-reported data from the 'Healthy life in Suriname' (HeliSur) study, we determined the prevalence of stroke in 1478 subjects. The odds for having suffered from stroke in Javanese, Maroons and Creoles were separately compared to the odds in Hindustani. Odds ratios were adjusted for traditional risk factors including age, sex, diabetes, hypertension, dyslipidemia, and smoking, by use of multiple logistic regression analysis.

Results. The overall prevalence of stroke in urban Suriname is 3.2%. Hindustani reported the highest prevalence of stroke (4.1%) compared to the Javanese (2.0%, 95% CI 0.14 to 1.68), Creoles (3.6%, 95% CI 0.48 to 2.03) and Maroons (1.8%, 95% CI 0.38 to 2.32). Adjusted odds ratios showed no significant association between ethnic background and stroke.

Conclusions. Stroke is significant for part of the burden of disease in urban Suriname and ethnic differences in its prevalence seem to be present. However, with and without adjustments for traditional risk factors no significant association between stroke and ethnic background could be shown. Further studies should incorporate other risk factors to indicate whether customized prevention programs targeted at ethnic groups are necessary.

Keywords: ethnicity, stroke, cardiovascular risk, epidemiology

Introduction

Stroke is one of the leading causes of death globally (1). It is expected that the occurrence of stroke will increase in low- and middle-income countries (LMICs), along with an increase in life expectancy, an increase in sedentary lifestyle and consumption of high energy density food as a consequence of urbanization (2, 3). In Suriname, stroke is the leading cause of death (4, 5) and Surinamese in the Netherlands show higher rates for stroke compared to other populations (6). Suriname is a middle-income country (7) situated in the north-east of South America with a population around 0.5 million people (8). The country has gone through a strong transition toward urbanization in the last decades (9). A major part of the population (49%) now lives in the capital Paramaribo (10). Identifying risk factors can aid in the global endeavour for the application of personalized medicine and reduce stroke occurrence. However, detailed knowledge of the prevalence of stroke and stroke risk factors in Suriname is not available.

Paramaribo has a multi-ethnic population of which the largest groups are from South Asian descent (Hindustani), African descent (Creoles, Maroons) and Javanese descent (Javanese) (10). Stroke affects every ethnic group(2), but ethnic disparities remain, supposedly because of variations in risk factor burden (2) (11). However, studies show ethnic differences in stroke prevalence despite variation in risk burden, suggesting further attention for differences in genetic, behavioral and psychological risk factors (12). It is known that despite the presence of conventional risk factors, Hindustani show a higher risk for diabetes mellitus and stroke compared to other ethnicities (13, 14). It is proposed that Hindustani may have an underlying state of insulin resistance (14) and are ethnically susceptible to atherosclerosis due to endothelial dysfunction (15), diabetes mellitus and obesity (16) which all might amplify the risk of stroke in comparison to other ethnic groups (12, 17). The Bureau of Public Health of Suriname documented a high mortality due to stroke in Suriname, with a higher mortality rate due to stroke among Hindustani (18). However, the overall prevalence of stroke in Paramaribo has not been documented yet. We hypothesize that the prevalence of stroke will be higher among Hindustani in Paramaribo compared to other ethnic groups and that there is a positive association between ethnic background and stroke after controlling for conventional risk factors. Therefore, the aim of the present cross-sectional study was to document the prevalence of stroke in the multi-ethnic population of Paramaribo and its association to ethnic background adjusted for traditional cardiovascular risk factors.

Methods

Study design and study population

This secondary study uses part of the data collected from The Healthy life in Suriname (HeliSur) study which was designed as a primary study to assess cardiovascular health of the multi-ethnic population living in Paramaribo (19). Non-institutionalized citizens living in Paramaribo, aged between 18 and 70 years old were eligible for inclusion (approximately 168000 subjects (10)). People above 70 years were excluded because of the total life expectancy of 71.6 years in Suriname (20). By law, Suriname is divided into 10 districts and 62 blocks, which are subdivisions at a district level. Each block is divided into enumeration areas. In cooperation with the General Bureau of Statistics 18 enumeration areas were randomly selected from 1200 enumeration areas in Paramaribo. A cluster househould sampling method was used and trained interviewers were sent out for home visits to include all household members of every house until they had reached 100 subjects for one area. According to Lwanga et al., the minimum necessary representative sample size was calculated to be 1092 participants to arrive at a relatively precise estimate of the true prevalence (19, 21).

The interviewers were instructed to begin randomly at a house to collect information. To minimize inclusion bias, interviewers went back to the subject's home for a maximum of three times if they were not at home. Subjects had the opportunity to reject participation to the study or to stop at any moment during data collection.

The medical ethical committee of the Ministry of Health in Suriname approved the study (dated October 10th, 2012). The study was conducted in accordance with the declaration of Helsinki (59th WMA General Assembly, Seoul, October 2008). Data was obtained between April 2013 and August 2013.

Outcomes

The primary outcome measure was the history of stroke. The diagnosis of stroke was determined with a positive response to the question whether the participant was ever diagnosed with having had a stroke by a general practitioner, or medical specialist (neurologist) (22).

Ethnicity

Ethnicity was based on self-identification. Subjects could choose whether they considered themselves to be Hindustani, Creole, Javanese, Maroon, Chinese, Amer-indian, Caucasian, mixed, other or unknown. People from South Asian origin are referred to as Hindustani (23, 24). People from Indonesian origin are classified as Javanese. Creoles are defined as people from African origin who after the period of slavery remained in the city (23, 24), whereas people from African origin who escaped into the hinterland during the slavery period are referred to as Maroons. The distinction between these groups is important because of different living conditions in the hinterland, different lifestyle and less genetic admixture.

Demographic characteristics and cardiovascular risk factors

Age, gender and marital status were assessed by interview. For the analyses age was divided into three age groups: 18-30, 31-50 and 51-70 years (25). Marital status was indicated as: married; couple living together; single; divorced; widow(er).

A history of Transient Ischemic Attack (TIA), diabetes mellitus (DM), high blood pressure (HT), dyslipidemia and smoking habits were selected as potential confounders for the association between ethnicity and stroke (26). For each risk factor, except for smoking habits, the subject was asked if they were ever diagnosed by a general practitioner (or medical specialist) for having the disease. To assess their smoking habits subjects could choose between: yes, I smoke; no, I do not smoke right now but I did in the past; No, I have never smoked.

Statistical analysis

Descriptive analyses were used to describe prevalence of stroke and demographic characteristics. Because of low number of participants (< 150) for certain ethnic groups, statistical analyses were performed only for the four largest ethnic groups in the sample, which were Hindustani, Creoles, Maroons and Javanese (N=1478). To correct for disproportional frequency of ethnic groups in the overall population compared to the study population, all cases were weighted for ethnic background (27). For Hindustani the weighting factor was 0.76, for Creole 1.18, for Maroon 0.72 and for Javanese 1.25. As a consequence, the study group for statistical analysis changed to N=1344.

The missing value analysis option for multiple imputations in SPSS was used to prevent any bias which could have been introduced by incomplete data. In case of incomplete data above 5%, multiple imputations were performed to restore data of subjects as much as possible (28, 29).

Fisher's exact tests were used to determine whether potential risk factors for stroke were associated with both ethnicity and stroke. Subsequently, logistic regression analyses were used to determine the association between ethnic background and stroke. For the categorical predictor ethnicity, Creole, Maroon or Javanese participants were compared to Hindustani. Hindustani were chosen to be the reference group in this study (2) because of a higher number of participants in this ethnic group (18). Multiple logistic regression analysis was used to adjust the crude Odds Ratio's (ORs) and their 95% confidence intervals for the bias caused by confounding variables. Confounding variables were identified as variables that changed the regression coefficients of ethnic background with more than 10% when they were included in the regression model. Correlation coefficients between all confounders and ethnicity were determined to prevent multicollinearity in the final regression model. All analyses were conducted using IBM SPSS Statistics software version 21 (IBM SPSS, Inc., Chicago, IL, USA). Results were considered significant when $p<0.05$.

Results

Participants

Out of 240.924 people living in Paramaribo, approximately 70% was considered eligible for participation in the study (10). In total, 1808 citizens were approached to participate in the study of which eventually 1786 subjects agreed to participate. The distribution of these participants over the ethnical groups is presented in table 1. After selecting the four largest ethnic groups, data of 1478 subjects were included for further statistical analyses (figure 1). Of the 1478 participants, 63% were female and 37% were male (table 2). The mean age for the women was 40.1 (SD 14.0) years and the mean age of the men was 40.8 (SD 14.5) years.

Table 1: Overview of ethnic groups in the total study population.

Ethnic groups (n)	Total (n=1786)
Hindustani	544 (30.5 %)
Creole	388 (21.7 %)
Maroon	396 (22.2 %)
Javanese	150 (8.4 %)
Caucasian	4 (0.2 %)
Chinese	2 (0.1 %)
Mixed	266 (14.9 %)
Amer-Indian	26 (1.5 %)
Unknown	10 (0.5 %)

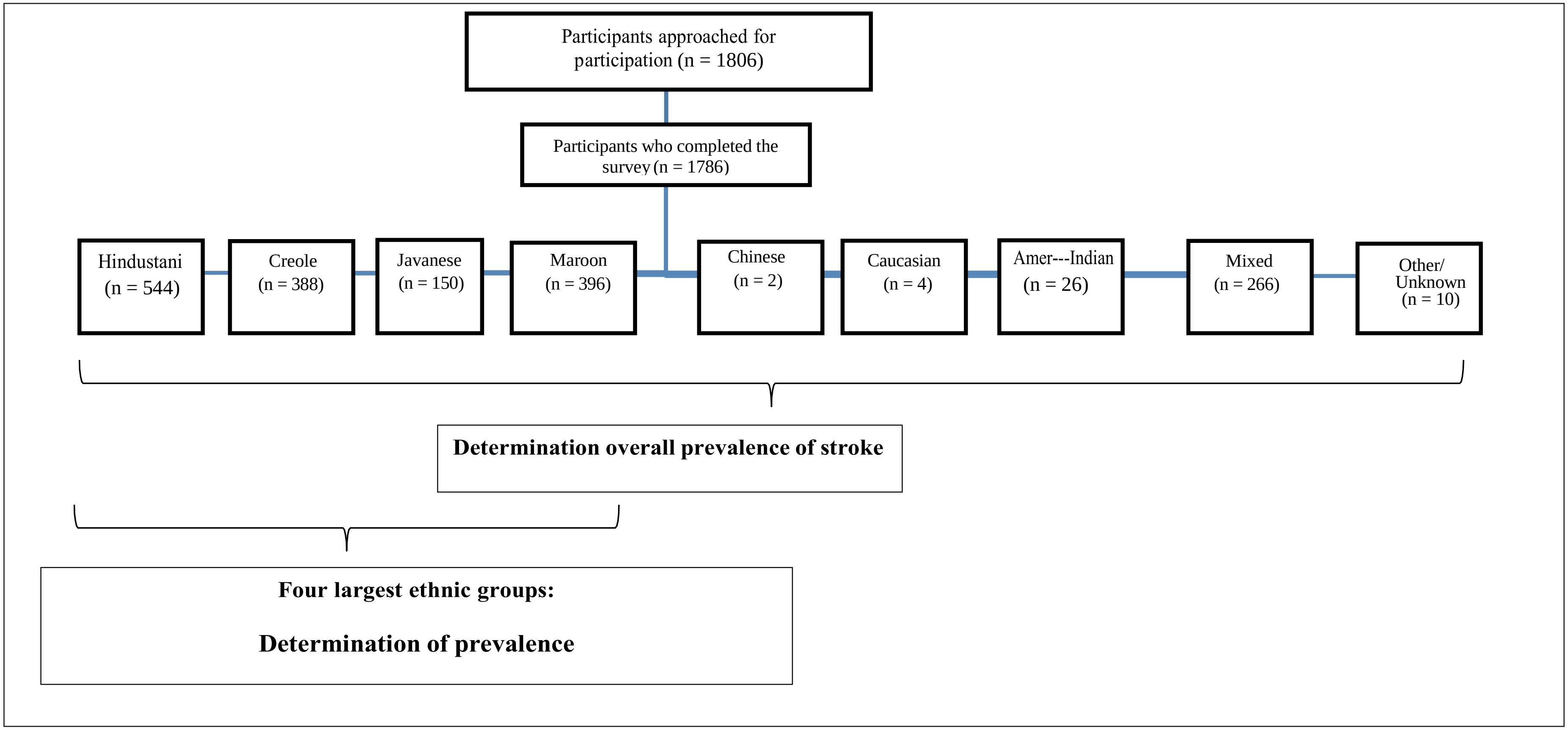

Figure 1. Study flowchart

Missing value analysis
Missing value analysis showed that 17% of the data were incomplete. For diabetes mellitus 51% of the data were missing and 32% missing cases were observed for dyslipidaemia. The deletion of cases decreases the power of the study especially when variable selection is difficult when different variables are missing on different cases. Therefore, multiple (automatic) imputations in SPSS were applied, which is considered the best option for dealing with missing data (30, 31) in cardiovascular health studies. After implying (automatic) multiple imputations on weighted cases, conclusions of the pooled data were presented for the sample of this study.

Table 2: Demographic and clinical characteristics of the study population

	Hindustani (n=544)	**Creole (n=388)**	**Maroon (n=396)**	**Javanese (n=150)**	**Total (n=1478)**
Gender (n, %)					
Male	226 (41.5%)	151 (38.9%)	121 (30.6%)	54 (36.0%)	552 (37.3%)
Female	318 (58.5%)	237 (61.1%)	275 (69.4%)	96 (64.0%)	926 (62.7%)
Age groups (n, %)					
18-30 years	151 (27.8%)	115 (29.6%)	182 (46.0%)	27 (18.0%)	475 (32.1%)
31-50 years	243 (44.7%)	163 (42.0%)	150 (37.9%)	78 (52.0%)	634 (42.9%)
51-70 years	150 (27.5%)	110 (28.4%)	64 (16.1%)	45 (30.0%)	369 (25.0%)
Marital status (n, %)					
Married/couple	356 (65.4%)	154 (39.7%)	168 (42.4%)	101 (67.3%)	779 (52.7%)
Single	106 (19.5%)	191 (49.2%)	211 (53.3%)	31 (20.7%)	539 (36.5%)
Divorced	39 (7.2%)	26 (6.7%)	6 (1.5%)	10 (6.7%)	81 (5.5%)
Widow/widower	43 (7.9%)	17 (4.4%)	11 (2.8%)	8 (5.3%)	79 (5.3%)
Prevalence (n, %)					
Diabetes	131 (24.1%)	51 (13.1%)	46 (11.7%)	26 (17.3%)	254 (17.2%)
High blood pressure	108 (19.9%)	81 (20.9%)	55 (13.9%)	30 (20.0%)	274 (18.5%)
Dyslipidemia	96 (17.6%)	56 (14.4%)	48 (12.1%)	17 (11.3%)	217 (14.7%)
Smoking	164 (30.1%)	149 (38.4%)	62 (15.7%)	54 (36.0%)	429 (29.0%)

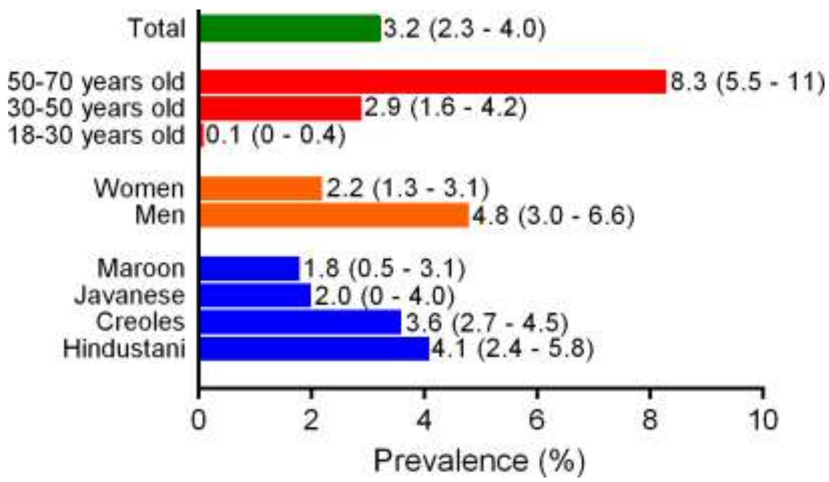

Figure 2. Prevalence of Stroke (%) for 1478 participants including the four largest ethnic groups

The prevalence of stroke

Overall, prevalence of stroke was 3200 per 100.000 people (figure 2). In the subsample with the four largest ethnic groups, stroke was reported by 3100 per 100.000 (n=46) of the respondents. Significantly more men than women reported stroke ($p<0.01$) (figure 2). A statistically significant difference between age groups was found in which the prevalence of stroke was higher for the oldest age group ($P<0.01$) (figure 2). Hindustani reported the highest prevalence of stroke (4100 per 100.000) with a difference of more than 0.5% compared to the other ethnic groups (figure 2). However, this difference was not statistically significant.

Association between ethnic background and stroke

Simple logistic regression showed that Hindustani tend to have a higher risk of stroke (table 3) as compared to Creole, Javanese and Maroon residents. However, none of the crude ORs for stroke were significant (table 3). Age, diabetes and smoking were considered confounding variables in the association between ethnic background and stroke. The multiple logistic regression analyses showed no significant ORs after adjusting for these confounding variables (table 3).

Table 3: Crude and adjusted odds ratio's (OR) and 95% confidence intervals (CI) for ethnic background in association with stroke adjusted for diabetes, smoking and age groups

STROKE	Crude OR [95% CI]	Adjusted OR [95% CI]
Ethnicity (N=1478)		
Hindustani	1	1
Creole	0.89 [0.45-1.76]	0.99 [0.48-2.03]
Javanese	0.49 [0.14-1.67]	0.48 [0.14-1.68]
Maroon	0.43 [0.18-1.02]	0.93 [0.38-2.32]

The prevalence of traditional cardiovascular risk factors

The overall prevalence for the traditional cardiovascular risk factors was the highest for smoking (29.0%), followed by high blood pressure (18.5%), diabetes (17.2%) and dyslipidaemia (14.7%) (table 2). Hindustani reported more diabetes and dyslipidaemia in comparison to other ethnic groups ($p<0.001$ for diabetes, $p=0.04$ for dyslipidaemia). Creoles reported the highest numbers for smoking ($p<0.001$) together with high blood pressure, but the difference between ethnic groups for self-reported high blood pressure was not statistically significant ($p=0.092$).

Discussion

This study is the first to document the prevalence of stroke in Paramaribo, overall and by ethnicity.

Our study documented an overall prevalence of 3200 per 100.000 for stroke, however no differences in prevalence was present between the investigated ethnic groups even after adjusting for the confounding effect of risk factors.

Overall prevalence of stroke in Paramaribo

The overall stroke prevalence we now obtained for Suriname is higher compared to prevalence in France (1600/100.000) (32), urban Jakarta (800/100.000%) (33), Africa (1000/100.000%) (34), and Central Spain (500/100.000) (35), but less when compared to Northern England (4700/100.000), urban Spain (8500/100.000) (36), Hong Kong (5100/100.000) (37), Colombia (5600/100.000) (38), and Peru (6200/100.000) . Observed differences between studies might be explained by variation in lifestyles and cultures, the presence of cardiovascular risk factors within ethnic groups, the urban/rural setting and the type of data collection (39). It should be noted that disease prevalence is also the difference between incidence and mortality which might also explain the observed differences compared to prevalence in other countries. Nevertheless, stroke is a concerning cause for mortality in Suriname (9.4%), and the high prevalence of self-reported stroke in this study seems to be in line with that (18).

Association between ethnic background and stroke

Hindustani and Creole are known for higher rates of stroke (6, 25) and higher rates for stroke risk factors compared to other ethnic groups (6, 11, 24). There are multiple explanations for this higher risk for stroke such as presence of genetic differences predisposing to disease, differences in socio-economic factors and living environments. The study by Agyemang (6) compared Hindustani and Creole to Ethnic Dutch people in the Netherlands and found higher rates of hypertension, obesity, diabetes and smoking, but this could not explain the difference in stroke prevalence they found between Moroccan, and Chinese in comparison to aforementioned ethnic groups. Other studies show genetic predisposition for endothelial dysfunction in Hindustani, which might underlie a predisposition for stroke (40, 41). To our knowledge, hereditary factors for endothelial dysfunction in Creoles and Javanese have not been studied and stroke heritability in general is still only scarcely investigated (42). However, despite our hypothesis and despite the differences in cardiovascular risk factors between ethnic groups, we could not document an association between ethnic background and stroke. Either common or different genetic risk factors for each group could contribute to these findings. As the pathogenesis of stroke is multifactorial this study further emphasizes on the importance of traditional risk factors even in genetically diverse populations.

Preliminary recommendations for preventive strategies

The high prevalence of stroke reported in this study should be taken into account when preventive strategies are taken. A cornerstone in the prevention of cardiovascular diseases such as stroke is physical activity therefore strategies to promote physical activity in daily life seem warranted (43). Additionally, psychological stress, high intake of energy-dense foods and a sedentary lifestyle appear to contribute to a higher risk for stroke (24). This study offers data on the prevalence of stroke in genetically diverse populations as apart from sociocultural differences, genetic factors may eventually also play a role in the personalized approach in the prevention and treatment of stroke (43, 44).

Strengths and limitations of the study

Some limitations in this study should be mentioned. First, assessing prevalence is a challenge because it requires a large population survey and is accompanied by the difficulty of knowing whether for instance the stroke really occurred and what type it was. For feasibility reasons, we chose to use self-reported data which might imply that data are less accurate due to recall bias and there is lack of information on the accuracy of a self-report of stroke in Suriname. Nonetheless, self-reports have been shown to be valid and cost-effective.(45-47). It needs to be noted that a trend of rather underreporting than over reporting of stroke events is reported in studies with self-reported data.(48, 49).

Second, socio-economic inequalities are important to consider in ethnic minorities (50). Such data were not available in this study, but could have affected the association between ethnic background and stroke. Additionally, limitations include lack of corroborative information from medical records or clinical assessment; missing data for some risk factors (e.g. diabetes mellitus and dyslipidemia) requiring imputation; missing data on refusals and no data of people above 70 years.

Third, our study population was primarily recruited to examine cardiovascular health in Paramaribo (19). In order to study the association between ethnic background and stroke there was a necessity for calculation of the statistical power based on ethnic background rather than cardiovascular risk factors. Weighted factors were applied in order to obtain statistical power for our analyses, but true ethnically designed studies with a sufficient sample size are necessary to show inter-ethnic differences to further investigate the association between genetic/ethnic burden and stroke.

Conclusion

Our study shows a substantial prevalence of stroke in urban Suriname. The risk for stroke tends to be higher among Hindustani compared to Creole, Maroon and Javanese. However, with and without controlling for traditional cardiovascular risk factors there was no statistical difference in risk for stroke between ethnic groups. This indicates that identification of other cardiovascular risk factors, socio-cultural and socio-economic aspects within this high risk population is warranted and that notification of ethnic background is not necessarily a condition. To confirm and extend our results, further research with larger study samples and objective assessments are indicated.

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Conflict of Interest: None

References

1. Mendis S, Puska P, Norrving B. Global atlas on cardiovascular disease prevention and control: World Health Organization; 2011.
2. Yusuf S, Reddy S, Ounpuu S, Anand S. Global burden of cardiovascular diseases: Part II: variations in cardiovascular disease by specific ethnic groups and geographic regions and prevention strategies. Circulation. 2001;104(23):2855-64.
3. Sodjinou R, Agueh V, Fayomi B, Delisle H. Obesity and cardio-metabolic risk factors in urban adults of Benin: relationship with socio-economic status, urbanisation, and lifestyle patterns. BMC public health. 2008;8:84.
4. de Fatima Marinho de Souza M, Gawryszewski VP, Ordunez P, Sanhueza A, Espinal MA. Cardiovascular disease mortality in the Americas: current trends and disparities. Heart. 2012;98(16):1207-12.
5. Mungra A, van Kanten RW, Kanhai HH, van Roosmalen J. Nationwide maternal mortality in Surinam. British journal of obstetrics and gynaecology. 1999;106(1):55-9.
6. Agyemang C, van Oeffelen AA, Norredam M, Kappelle LJ, Klijn CJ, Bots ML, et al. Ethnic disparities in ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage incidence in the Netherlands. Stroke; a journal of cerebral circulation. 2014;45(11):3236-42.
7. The World Bank Group. Suriname [Internet]. 2015 [cited 26th january 2015]. Available from: http://data.worldbank.org/country/suriname.
8. Statistics GBo. 8th General Population and housing census in Suriname. In: Statistics GBo, editor. Suriname2012.
9. Factbook CW. 2014.
10. Voorlopige resultaten uit de 8ste volks- en woningtelling in Suriname. In: Suriname GBfSi, editor. Paramaribo, Suriname: General Bureau for Statistics in Suriname; 2012.
11. Gezmu T, Schneider D, Demissie K, Lin Y, Gizzi MS. Risk factors for acute stroke among South Asians compared to other racial/ethnic groups. PloS one. 2014;9(9):e108901.
12. Stewart JA, Dundas R, Howard RS, Rudd AG, Wolfe CD. Ethnic differences in incidence of stroke: prospective study with stroke register. Bmj. 1999;318(7189):967-71.
13. Enas EA, Yusuf S, Mehta JL. Prevalence of coronary artery disease in Asian Indians. The American journal of cardiology. 1992;70(9):945-9.
14. McKeigue PM, Miller GJ, Marmot MG. Coronary heart disease in south Asians overseas: a review. Journal of clinical epidemiology. 1989;42(7):597-609.
15. Boon MR, Karamali NS, de Groot CJ, van Steijn L, Kanhai HH, van der Bent C, et al. E-selectin is elevated in cord blood of South Asian neonates compared with Caucasian neonates. The Journal of pediatrics. 2012;160(5):844-8 e1.
16. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet. 1991;337(8738):382-6.
17. Markus HS, Khan U, Birns J, Evans A, Kalra L, Rudd AG, et al. Differences in stroke subtypes between black and white patients with stroke: the South London Ethnicity and Stroke Study. Circulation. 2007;116(19):2157-64.
18. Punwasi W. Doodsoorzaken in Suriname 2010-2011. In: Epidemiology, editor. Suriname: Bureau of Public Health; 2012. p. 11-7.

19. Diemer FS, Aartman JQ, Karamat FA, Baldew SM, Jarbandhan AV, van Montfrans GA, et al. Exploring cardiovascular health: the Healthy Life in Suriname (HELISUR) study. A protocol of a cross-sectional study. BMJ open. 2014;4(12):e006380.
20. World Life Expectancy 2016 [Available from: http://www.worldlifeexpectancy.com/country-health-profile/suriname.
21. Lwanga SK, Lemeshow S. Sample size determination in health studies : a practical manual. Geneva: World Health Organization; 1991. viii, 80 p. p.
22. Geddes JM, Fear J, Tennant A, Pickering A, Hillman M, Chamberlain MA. Prevalence of self reported stroke in a population in northern England. Journal of epidemiology and community health. 1996;50(2):140-3.
23. Stronks K, Snijder MB, Peters RJ, Prins M, Schene AH, Zwinderman AH. Unravelling the impact of ethnicity on health in Europe: the HELIUS study. BMC public health. 2013;13:402.
24. Agyemang C, Oudeman E, Zijlmans W, Wendte J, Stronks K. Blood pressure and body mass index in an ethnically diverse sample of adolescents in Paramaribo, Suriname. BMC cardiovascular disorders. 2009;9:19.
25. Tillin T, Hughes AD, Mayet J, Whincup P, Sattar N, Forouhi NG, et al. The relationship between metabolic risk factors and incident cardiovascular disease in Europeans, South Asians, and African Caribbeans: SABRE (Southall and Brent Revisited) -- a prospective population-based study. Journal of the American College of Cardiology. 2013;61(17):1777-86.
26. Anderson KM, Odell PM, Wilson PW, Kannel WB. Cardiovascular disease risk profiles. American heart journal. 1991;121(1 Pt 2):293-8.
27. table 5s. ressort by vraag 08. etnische groep-parwan. Paramaribo, Suriname: General Bureau of Statistics in Suriname; 2012.
28. van Buuren S, Boshuizen HC, Knook DL. Multiple imputation of missing blood pressure covariates in survival analysis. Statistics in medicine. 1999;18(6):681-94.
29. Burton A, Billingham LJ, Bryan S. Cost-effectiveness in clinical trials: using multiple imputation to deal with incomplete cost data. Clinical trials. 2007;4(2):154-61.
30. Shrive FM, Stuart H, Quan H, Ghali WA. Dealing with missing data in a multi-question depression scale: a comparison of imputation methods. BMC medical research methodology. 2006;6:57.
31. Arnold AM, Kronmal RA. Multiple imputation of baseline data in the cardiovascular health study. American journal of epidemiology. 2003;157(1):74-84.
32. Schnitzler A, Woimant F, Tuppin P, de Peretti C. Prevalence of self-reported stroke and disability in the French adult population: a transversal study. PloS one. 2014;9(12):e115375.
33. Kusuma Y, Venketasubramanian N, Kiemas LS, Misbach J. Burden of stroke in Indonesia. International journal of stroke : official journal of the International Stroke Society. 2009;4(5):379-80.
34. Owolabi MO, Akarolo-Anthony S, Akinyemi R, Arnett D, Gebregziabher M, Jenkins C, et al. The burden of stroke in Africa: a glance at the present and a glimpse into the future. Cardiovascular journal of Africa. 2015;26(2 Suppl 1):S27-38.

35. Martinez-Salio A, Benito-Leon J, Diaz-Guzman J, Bermejo-Pareja F. Cerebrovascular disease incidence in central Spain (NEDICES): a population-based prospective study. Journal of the neurological sciences. 2010;298(1-2):85-90.
36. Bermejo F, Vega S, Morales JM, Diaz J, Lopez L, Parra D, et al. Prevalence of stroke in two samples (rural and urban) of old people in Spain. A pilot door-to-door study carried out by health professionals. Neurologia. 1997;12(4):157-61.
37. Woo J, Chau PP. Aging in Hong Kong: the institutional population. Journal of the American Medical Directors Association. 2009;10(7):478-85.
38. Saposnik G, Del Brutto OH, Iberoamerican Society of Cerebrovascular D. Stroke in South America: a systematic review of incidence, prevalence, and stroke subtypes. Stroke; a journal of cerebral circulation. 2003;34(9):2103-7.
39. Nakagawa K, Koenig MA, Asai SM, Chang CW, Seto TB. Disparities among Asians and native Hawaiians and Pacific Islanders with ischemic stroke. Neurology. 2013;80(9):839-43.
40. Huo Y, Qin X, Wang J, Sun N, Zeng Q, Xu X, et al. Efficacy of folic acid supplementation in stroke prevention: new insight from a meta-analysis. International journal of clinical practice. 2012;66(6):544-51.
41. Webster AL, Yan MS, Marsden PA. Epigenetics and cardiovascular disease. The Canadian journal of cardiology. 2013;29(1):46-57.
42. Fornage M. Genetics of stroke. Current atherosclerosis reports. 2009;11(3):167-74.
43. Baldew SS, Krishnadath IS, Smits CC, Toelsie JR, Vanhees L, Cornelissen V. Self-reported physical activity behavior of a multi-ethnic adult population within the urban and rural setting in Suriname. BMC public health. 2015;15:485.
44. Celis-Morales CA, Ghouri N, Bailey ME, Sattar N, Gill JM. Should physical activity recommendations be ethnicity-specific? Evidence from a cross-sectional study of South Asian and European men. PloS one. 2013;8(12):e82568.
45. Engstad T, Bonaa KH, Viitanen M. Validity of self-reported stroke : The Tromso Study. Stroke; a journal of cerebral circulation. 2000;31(7):1602-7.
46. Okura Y, Urban LH, Mahoney DW, Jacobsen SJ, Rodeheffer RJ. Agreement between self-report questionnaires and medical record data was substantial for diabetes, hypertension, myocardial infarction and stroke but not for heart failure. Journal of clinical epidemiology. 2004;57(10):1096-103.
47. O'Mahony PG, Dobson R, Rodgers H, James OF, Thomson RG. Validation of a population screening questionnaire to assess prevalence of stroke. Stroke; a journal of cerebral circulation. 1995;26(8):1334-7.
48. O'Mahony PG, Thomson RG, Dobson R, Rodgers H, James OF. The prevalence of stroke and associated disability. Journal of public health medicine. 1999;21(2):166-71.
49. Reitz C, Schupf N, Luchsinger JA, Brickman AM, Manly JJ, Andrews H, et al. Validity of self-reported stroke in elderly African Americans, Caribbean Hispanics, and Whites. Archives of neurology. 2009;66(7):834-40.
50. Agyemang C, van Oeffelen AA, Norredam M, Kappelle LJ, Klijn CJ, Bots ML, et al. Socioeconomic inequalities in stroke incidence among migrant groups: analysis of nationwide data. Stroke; a journal of cerebral circulation. 2014;45(8):2397-403.

Chapter 3

A cross-sectional study to assess an association between upper extremity function and functional walking capacity in chronic stroke survivors.

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Abstract

Background. The Six-Minute Walk Test (6MWT) predicts community ambulation in stroke patients. These patients frequently face several disabilities, including upper extremity dysfunction. Since upper extremity (UE) dysfunction is related to walking disability we expect that the UE function affects the 6MWT. So far, no study has investigated the association between UE function and the 6MWTdirectly.

Aims. To examine the association between UE function and the 6MWT in stroke survivors adjusted for balance and gait problems.

Methods. Subjects were recruited from the general population and the Academic Hospital Paramaribo. UE function was measured using the handgrip strength (HGS) test together with the Disabilities of the Arm Shoulder and Hand (DASH) and Stroke Impact Scale (SIS) survey. Functional walking capacity was measured by the 6MWT. Functional balance was measured using the Berg Balance Scale (BBS). Step length ratio (SLR) and step width (SW) were used to assess gait. The median (range) or mean±SD are presented.

Results. In fifty subjects with a mean age of 58.2±9.5 years, we demonstrated that the mean 6MWT (297.9±19.8m) correlated with the mean paretic HGS (19.1±14.9kg, r=0.77, p<0.001) and non-paretic HGS (31.1±9.7kg, r=0.41, p=0.003), but not with the DASH and SIS surveys. The 6MWT correlated with the BBS (55.0(30.0-56.0), r=0.51, p<0.001), SLR (0.9(1.0-2.0), r= -0.29, p=0.044), but did not correlate with SW. After adjusting for BBS and SLR, paretic HGS explained 62% of the variance in 6MWT. The relationship between non-paretic HGS and 6MWT was influenced by the BBS and SLR ($p<0.05$, $R^2=0.39$).

Conclusions. Paretic handgrip strength predicts 6MWT performance after adjusting for balance and gait asymmetry. The 6MWT is limited by stroke-related impairments such as handgrip strength, balance control and gait asymmetry. Further studies are warranted for assessment of causal effects between these variables.

Keywords: upper extremity; six-minute walk test; cerebrovascular stroke; handgrip strength

Introduction

In post stroke survivors, the six-minute walk test (6MWT) is a frequently used measure of functional walking capacity, which can be defined as the extent to which increased intensities of walking capacity can be maintained to perform activities of daily living (ADL) [1,2]. This test is considered as a valid, reliable and feasible tool to measure functional walking capacity in post-stroke patients [1] and is well tolerated by patients, easy to use and it better reflects ADL than other walking tests [1,3,4]. The 6MWT is also an independent predictor for community ambulation [5] and an indicator for post-stroke balance confidence [6]. However, this test embraces a complex interaction with several stroke related factors [3]. So far, it is known that it is influenced by several stroke-related impairments such as energy cost of walking [7], gait asymmetry [8] and balance impairments [6,9,10].

Growing evidence suggest that the upper extremity (UE) function affects the walking capacity in stroke patients. Stroke survivors suffer frequently from disabilities, like motor deficits in the extremities, which impedes proper community ambulation [11]. Community ambulation refers to the ability of a person to walk in their own community and this is often disturbed after stroke [11]. The cycling motion of the UE serves to reduce energy cost during bipedal human gait [12]. In addition, arm cycling trainingimproved post-stroke walking ability and a coordination between the upper and contralateral lower limb during walking is suggested in post-stroke survivors [13]. Moreover, immobilization of the UE induces negative changes in spatial gait parameters [14] and the handgrip strength (part of UE function) was associated to walking in elderly [15] and patients with lumbar stenosis [16]. Since these studies suggest that the UE function affects the walking capacity, we expect that the UE function might also affect the 6MWT. So far, only one study [17] that reported a moderate correlation between the 6MWT and the SIS hand function domain in 30 chronic stroke survivors was found.

Therefore, this study aimed to assess the association between UE function, as assessed by objective and patient-reported outcome measures, and the 6MWT after adjustment for balance control and gait asymmetry. We hypothesize that there is a positive association between UE function and the 6MWT performance.

Material and methods

This study employed a number of measuring tools, namely, the Disability of the Arm, Shoulder and Hand (DASH) questionnaire, the Stroke Impact Scale (SIS) questionnaire, and a self-constructed survey for demographic data. Physical tests in this study included Handgrip Strength (HGS) tests, the Berg Balance Scale (BBS), functional gait analysis, and the Six-Minute Walk Test (6MWT).

Participants

Participants were recruited from the database of the Academic Hospital of Paramaribo and also included were respondents from the general population, in the period of April 2016 to April 2017. The participants had to meet the following criteria of respective assessment tools in order to participate in this study: (i) able to give informed consent and understand simple instructions (Mini Mental Scale Examination >24 [18]); (ii) had a stroke at least six months prior; (iii) able to walk at least 10m independently or without supervision (Functional Ambulation Category score ≥ 3), (iv) age above twenty-five years; and (v) living at home. Stroke patients who had (i) a serious cardiac condition, (ii) other serious end organ damage, (iii) other neurological deficits or (iv) uncontrolled blood pressure (systolic pressure >140 mmHg, diastolic pressure >90 mmHg), were excluded. All participants gave informed consent, and approval was received from the Institutional Review Board (CMWO: Commissie Mensgebonden Wetenschappelijk Onderzoek) at the Government of Suriname's, Ministry of Health (reference number: VG-023-15).

Anthropometric and sociodemographic data

Demographic (sex; age; ethnicity), anthropometric (Body Mass Index (BMI)) and clinical (type of stroke; recurrent stroke; time since stroke; affected side, hand dominance) data were recorded. Ethnicity was self-reported and further divided into Asian (Hindustani and/or Javanese), African (Creole and/or Maroon) and other. BMI was calculated based on weight and height (kg/m^2).

Upper extremity function

Handgrip strength was measured using a hand dynamometer with an adjustable handle (Suahan Digital, Korea). The upper arm was supported next to the body, with the elbow in 90 degrees of flexion, forearm in neutral and wrist in slight extension [19]. The test for maximum handgrip strength was then performed three times for each hand alternating between the non-paretic (HGNP) and paretic hand (HGP) with resting periods of 30 seconds. The highest value for each hand was used for analysis.

The DASH questionnaire [20] is a 30-item self-report questionnaire, with a score 0 (no disability) to 100. Its main objective is to assess physical function, symptoms, social indicators and therefore encompasses the entire UE. Higher DASH scores indicate an increase in the severity of a disability.

The SIS version 3.0 [21] is a stroke-specific questionnaire used to evaluate stroke outcomes in eight domains. This study used the hand function domain only. The questions ascertained the level of exertion or difficulty to carry heavy objects, turning a doorknob, opening a can or jar, tying a shoelace, and picking up a dime. The scoring method is rated using a 5-point ordinal scale (1-5) for each item: 1 = an inability to complete the item; 5 = no difficulty at all. Domain scores range from 0-100.

Functional walking capacity

The 6MWT participants were instructed to walk continuously at the fastest pace for 6 minutes on a ellipsoid (30-meter) pathway, as far as they could [3]. All participants received the same standardized instructions and encouragement and were allowed to use assistive devices such as a cane [3]. The maximum distance covered in six minutes was recorded in meters [3].

Gait Analysis

Spatial gait parameters such as step length and step width were determined using a double 2-D functional gait assessment. Participant's movements were video recorded while walking with their preferred walking velocity on a 10-meter pathway. Two cameras (Sony and Panasonic Hand-Held Camcorder) were strategically placed for ventral/dorsal and lateral view. All the participants walked back and forth twice. Kinovea 8.15, was used to extract frames and coordinates from these videos [22] and three extracted frames were used to calculate step length and step width. Step width was measured using frames with a dorsal view, during the double stance phase. Step length was measured using the average of three frames from the lateral view [22], during the subject's double stance phase, from the heel of the non-paretic foot to the heel of the paretic foot. In case one heel was not in contact with the ground (e.g., drop foot), the measure was done from the head of the first metatarsal of the paretic foot to the head of the first metatarsal of the non-paretic foot. Data from the step length were used to assess step length asymmetry (or gait asymmetry).

Gait asymmetry was referred to as the Step Length Ratio (SLR) which was calculated as the ratio of the paretic step length relative to the non-paretic step length [23]. Step Width (SW) was measured as the distance between the left and right heel at mid stance. To correct for depth error in our video analysis a normalization procedure was performed for each subject in which step width and step length were corrected for the visible width of the walkway.

Balance assessment

The *Berg Balance Scale* (BBS) was used to evaluate balance and consists of 14 items in which the participant has to maintain different functional static positions, be able to move the Center of Mass and change the base of support without losing balance. The scoring method is a 5-point ordinal scale (0-4) for each item, with the total score ranging from 0-56 [24]. A total BBS score lower than 29 indicates that the person is at risk for falls, whereas a score above 30 indicates functional balance [25]. The test-retest agreements for use of the BBS in chronic stroke patients is high (ICC 2,1: BBS = 0.98), indicating excellent agreement from a relative perspective [24].

Statistical analysis

All statistical analyses were performed using IBM SPSS version 23.0. The Z-score and boxplot were used to test normal distribution of data. The spearman rho test was used to study the association of UE function variables and functional walking capacity. Linear regression was used to assess associations between UE function and the 6MWT (the dependent variable) with models that adjusted for sex and age and subsequently, for balance control and gait problems known to be associated to the 6MWT. For all statistical analyses the level of significance was set at $p < 0.05$. We considered an $r \leq 0.3$ a weak correlation, an r between 0.4 and 0.6 as a moderate correlation and high when $r \geq 0.7$ [26].

Results

Participants

Figure 1 shows the participant flow. From 777 contact details the telephone numbers of only 530 patients were in use. From these patients sixty-seven refused participation, 413 did not meet the criteria, therefore, fifty participants were included in this study. Participants or their physicians were called in order to evaluate eligibility for the 6MWT according to the inclusion and exclusion criteria. The characteristics of these 50 participants can be found in table 1.

Table 1. Sociodemographic, anthropometric and clinical characteristics of all participants (median, range)

Variables (n=50 participants)	
Age (years, mean ± SD)	58.2 ± 9.5
Sex (males) (N)	24.0
Time since stroke (years)	2.6 (0.5-16.6)
Recurrent stroke (N, yes)	12.0
Type of Stroke (N, ischemic)	46.0
Dominant side affected (N, yes)	23.0
Location stroke (N, right hemisphere)	27.0
BMI (kg/m²)	26.4 (19.6-39.6)
Ethnicity (N) Asian descent African descent Other	 28.0 16.0 6.0

**BMI: Body Mass Index.*

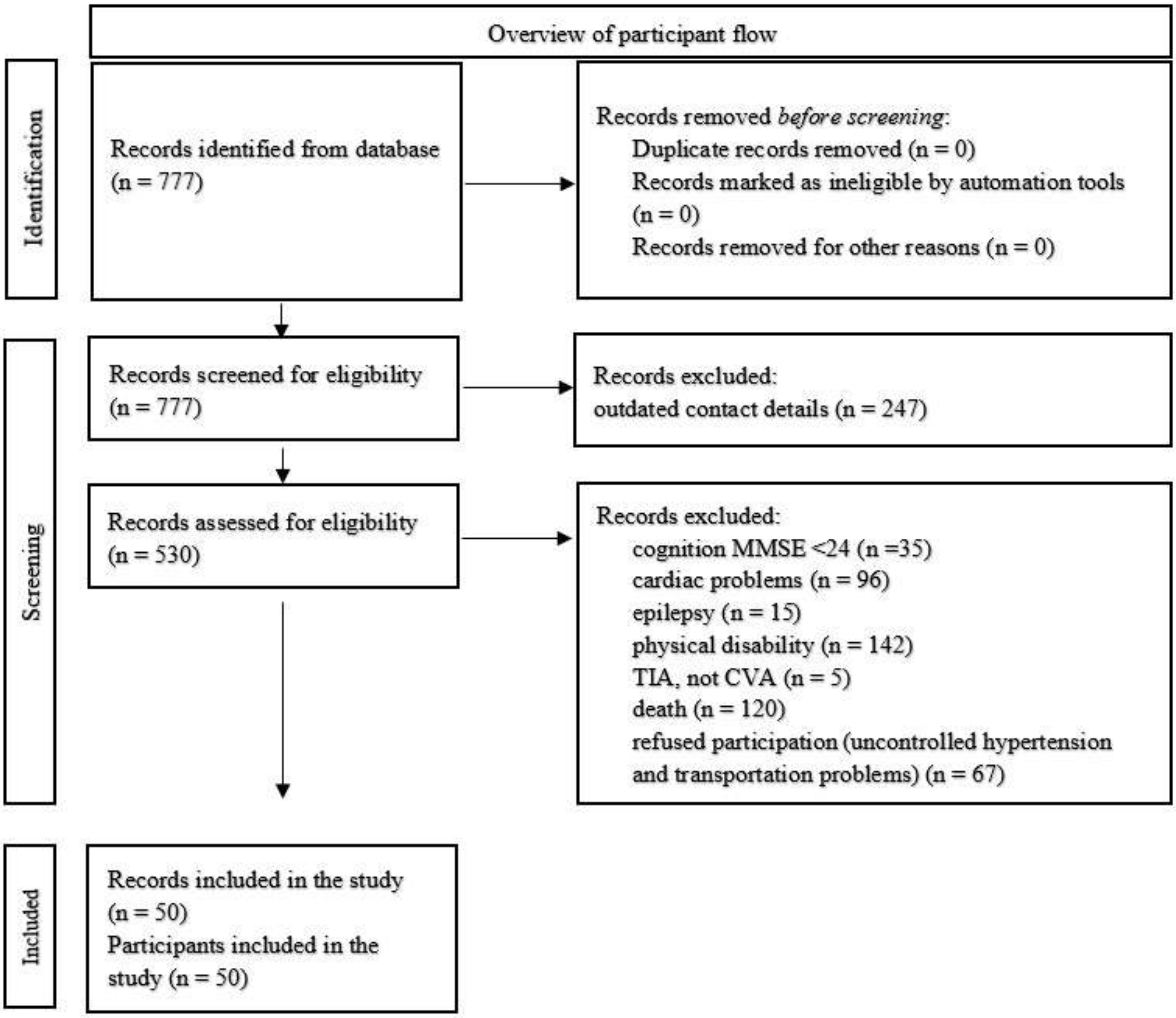

Figure 1. Overview of participant flow.
CVA: CerebroVascular Accident; MMSE: Mini Mental State Examination; TIA: Transient Ischemic Attack
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Data for the 6MWT show a normal distribution. The mean ± SD 6MWT was 297 ± 19.8 m. Table 2 shows the correlation between the 6MWT and the UE function parameters as well as the BBS and gait parameters. The 6MWT correlated with paretic and non-paretic handgrip strength (figure 2). The strongest correlation is with paretic handgrip strength (r=0.77) followed by a moderate correlation with the non- paretic handgrip strength (r=0.41) (figure 2). The scores from the two UE function surveys, DASH and SIS (hand function domain), did not correlate with the 6MWT. Moreover, the BBS and SLR correlated with the 6MWT, but SW did not.
HGP explained 62% of the variance in 6MWT without significant contribution of the BBS and SLR (table 3). The BBS and SLR significantly influenced the relationship between HGNP and the 6MWT and these parameters explained 39% of the variance in the 6MWT (table 3).

Table 2. Correlation with functional walking capacity (6MWT, N=50)

UE function parameters	Mean (SE)	Correlation coefficient (r)	p-value (two-tailed)
HGP (kg)^	19.1 (2.1)	0.76	0.000
HGNP (kg)	31.1 (1.3)	0.41	0.003
DASH score (0-100)	32.9 (3.8)	-0.26	0.062
SIS (hand function domain) score (0-100)	54 (3.8)	0.24	0.085
Balance and gait parameters			
BBS**	52.30 (0.87)	0.51	0.000
SLR	1.02 (0.03)	-0.28	0.044
SW	13.42 (0.78)	-0.27	0.057

**6MWT: Six-minute walking test; BBS: Berg Balance Scale; DASH: Disabilities of the Arm, Shoulder and Hand; HGNP: Handgrip Strength Non-Paretic; HGP: Handgrip Strength Paretic; SIS: Stroke Impact Scale; SLR: Step Length Ratio; SW: Step Width.*
***BBS is correlated with SW (r=-0.291, p=0.041);*
^HGP is correlated with HGNP (r=0.54, p=0.000), DASH (r=-0.41, p=0.003) and SIS hand function domain (r=0.45, p=0.001).

Table 3. Regression analysis between functional walking capacity and handgrip strength

	HGP(kg)			
Functional walking capacity	Unstandardized coefficients	Standard error	p-value	R-square
Model 1: (constant)	147.8	93.0	0.119	0.59
HGP	7.2	0.9	0.000	
Sex	2.5	27.7	0.927	
Age	0.1	1.4	0.911	
Model 2: (constant)	66.1	135.6	0.628	0.62
HGP	6.3	0.9	0.000	
BBS	3.5	2.2	0.120	
SLR	-73.3	58.0	0.213	
	HGNP(kg)			
Model 1: (constant)	218.5	140.9	0.128	0.21
HGNP	6.2	2.1	0.005	
Sex	-1.8	1.9	0.331	
Age	-9.7	40.6	0.811	
Model 2: (constant)	-38.2	172.5	0.826	0.39
HGNP	5.7	1.7	0.001	
BBS	-177.3	72.6	0.019	
SLR	6.4	2.7	0.022	

**BBS: Berg Balance Scale; HGNP: Handgrip Strength Non-Paretic; HGP: Handgrip Strength Paretic; SLR: StepLength Ratio.*

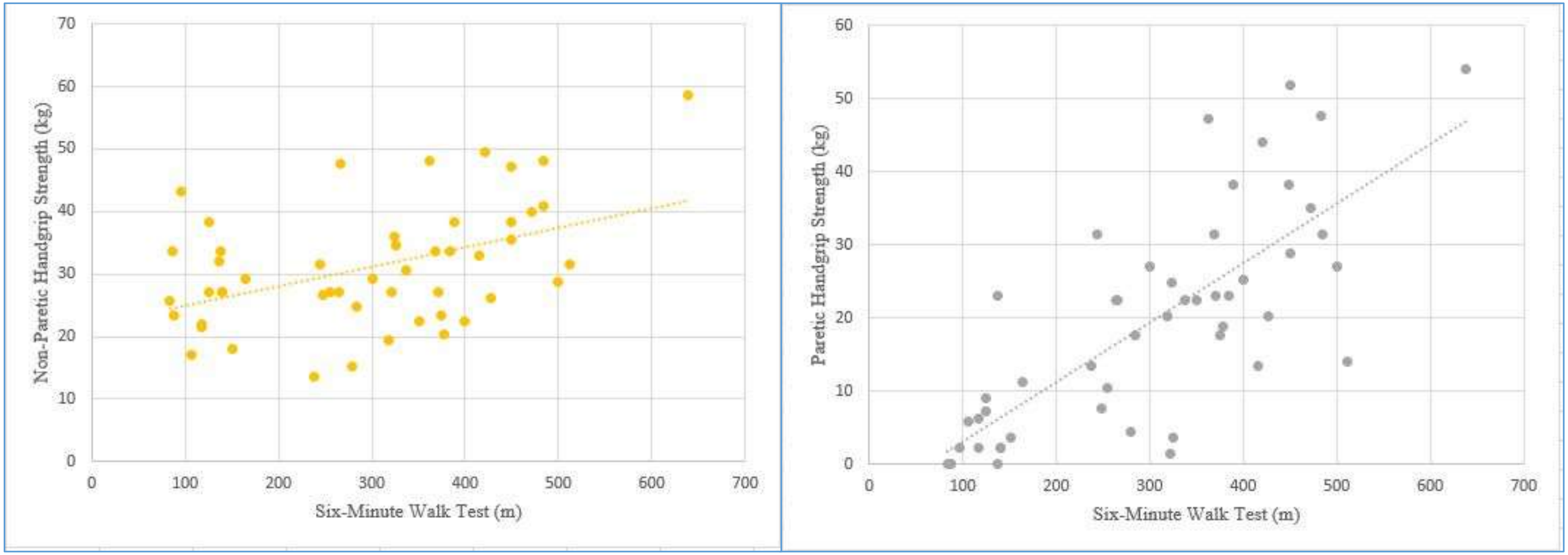

Figure 2. Scatterplots of UE function related to functional walking capacity

Discussion

We examined the association between UE function and the 6MWT in chronic stroke survivors adjusted for balance impairment and gait problems. HGP and HGNP correlated with the 6MWT. In contrast, no association was found with the DASH and the SIS (hand function domain). HGP independently explained 62% of the variance in the 6MWT, whereas the relationship between HGNP and the 6MWT was influenced by the BBS and SLR.

The observed relationship between handgrip strength and the 6MWT in elderly and lumbar stenosis patients is now also observed in stroke patients, despite their overall loss of muscular strength after a stroke [27]. However compared to older adults our study population showed an overall lower level of 6MWT and handgrip strength [28]. While the HGS is a form of isometric contraction, the 6MWT is more appealing to concentric and eccentric forms of muscle contraction over a relatively longer period of time compared to the HGS test. However, both appear to be associated to other muscle groups of the body [29-31]. It might therefore be argued that both represent overall muscle strength of the body, which is often decreased after stroke [27]. This might be an explanation for the correlation that we showed between paretic HGS and reduced 6MWT performance after adjusting for the BBS and SLR, however it does not explain the relationship between non-paretic handgrip strength and the 6MWT. Due to the variety in the level of non-paretic handgrip strength in our study population it cannot be assumed that the relationship with the 6MWT is due to common aetiology of stroke.

Hemiparetic gait is usually characterized by several compensation strategies [32] that serve to, not only guarantee safe ambulation [33], but also reduce increased mechanical cost of gait after stroke. These compensation strategies (i.e., excessive arm swing during increased walking speed [34], gait asymmetry or stepwidth) may differ in various situations. For example, during the 6MWT, in which walking speed is self-paced but exertion of maximum effort is encouraged for a relatively prolonged period, it is demonstrated that stroke-related impairments, such as balance control and lower limb motor score, limit the outcome measure in post-stroke survivors [8]. This might also explain why the relationship between the non-paretic HGS, associated to the ipsilateral muscle strength in post-stroke survivors [35], and the 6MWT was influenced by the BBS and SLR. Consequently, it might be argued that compensation strategies are reflected by the handgrip strength, balance control and gait asymmetry during the performance of the 6MWT due to (neuro)muscular fatigue mechanisms [8,9,36]. Moreover, we also demonstrated a relationship between paretic and non-paretic HGS, therefore, it might be suggested that the non-paretic HGS is indeed important to compensate for the affected upper limb [35] during bi-manual activities as well as forward movement of the body [13].

Furthermore, we demonstrated no association between functional walking capacity and paretic UE function quantified by the DASH and the SIS (hand function domain). We did not expect this, but a possible explanation might be that compared to handgrip tests, these surveys take more items such as fine UE motor skills, environmental and social items into account [20,21]. In contrast to our study, the study by Muren et al. (2008) [17] in stroke survivors showed a positive correlation between the SIS (hand function domain) and the 6MWT. Compared to our study, the variation in sample size, BMI score and level of functional walking capacity are factors that might be responsible for these discrepancies. Additionally, we found a correlation between the paretic HGS, the DASH and the SIS (hand function domain) in our study population, which can be explained by the fact the handgrip strength reflects ADL [37] as well as the general muscle fitness [29-31] of a stroke patient during performance of the test. Similarly, in another study handgrip strength was negatively correlated to the DASH in cardiac patients [38].

Limitations

It should be noted that all tests were conducted in the laboratory instead of the field or home-based setting [39]. The external environment has a significant impact on the quality of gait metrics [39], and is considered more representative to real-life situations. It is advisable that the performance of the 6MWT is researched in a patient's home or a home-based setting. In our study we did not include a practice walk before executing the 6MWT. It is generally advised to have a practice walk before the real measurement of functional walking capacity to prevent a practice effect, but a study in sub-acute and chronic stroke survivors indicates that a practice walk is not needed [40]. So, we do not expect any bias due to the absence of a practice walk. All our participants were able to finish a 6MWT, which suggests that the results of the present study cannot be generalized to all individuals with stroke. The general stroke population might be less fit or severely impaired compared to our study sample. In addition, we also needed to take into account that patient-reported outcome measures are prone to social desirability bias. In addition, there is a lack of studies (solely two studies) [41,42] validating the use of the DASH questionnaire for UE function in post-stroke patients. However, an effect is excluded most likely due to the fact that we found a correlation between the HGP, the DASH and the SIS scores. The fact that we observed low levels of the paretic UE function and the 6MWT might also have resulted from our multi-ethnic population, as most of our study population was from an Asian background, however due to imbalance in the ethnic groups an adequate adjustment for this variable was not possible [43-45]. Future studies should try to study the effects of multi-ethnic backgrounds in the relationship between these variables.

In conclusion, the association between paretic hand strength and functional walking capacity is stronger than the associations of non-paretic handgrip strength, sex, age, balance control, gait asymmetry and functional walking capacity. Further investigation is needed to assess whether handgrip strength can be used as a tool for intervention in order to improve walking capacity. .

Highlights of the study

- Paretic handgrip strength is associated to the 6MWT after adjusting for balance control and gait asymmetry.
- The relationship between non-paretic handgrip strength and the 6MWT is influenced by balance control and gait asymmetry.
- No association was found between patient-reported (paretic) UE function and the 6MWT.

References

1. van Bloemendaal M, van de Water AT, van de Port IG. Walking tests for stroke survivors: a systematic review of their measurement properties. Disabil Rehabil 2012;34:2207-21.
2. Kim DK, Oh DW. Repeated Use of 6-min Walk Test with Immediate Knowledge of Results for Walking Capacity in Chronic Stroke: Clinical Trial of Fast versus Slow Walkers. J Stroke Cerebrovasc Dis 2019;28:104337.
3. Dunn A, Marsden DL, Nugent E, et al. Protocol variations and six-minute walk test performance in stroke survivors: a systematic review with meta-analysis. Stroke Res Treat 2015;2015:484813.
4. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest 2001;119:256-70.
5. Fulk GD, He Y, Boyne P, Dunning K. Predicting Home and Community Walking Activity Poststroke. Stroke 2017;48:406-11.
6. Regan E, Middleton A, Stewart JC, Wilcox S, Pearson JL, Fritz S. The six-minute walk test as a fall risk screening tool in community programs for persons with stroke: a cross-sectional analysis. Top Stroke Rehabil 2020;27:118-26.
7. Eng JJ, Dawson AS, Chu KS. Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil 2004;85:113-8.
8. Sibley KM, Tang A, Patterson KK, Brooks D, McIlroy WE. Changes in spatiotemporal gait variables over time during a test of functional capacity after stroke. J Neuroeng Rehabil 2009;6:27.
9. Pohl PS, Duncan PW, Perera S, et al. Influence of stroke-related impairments on performance in 6-minute walk test. J Rehabil Res Dev 2002;39:439-44.
10. Marco Y.C.Pang JJE, Andrew S.Dawson. Relationship Between Ambulatory Capacity and Cardiorespiratory Fitness in Chronic Stroke. Chest 2005;127:495-501.
11. Sall J, Eapen BC, Tran JE, Bowles AO, Bursaw A, Rodgers ME. The Management of Stroke Rehabilitation: A Synopsis of the 2019 U.S. Department of Veterans Affairs and U.S. Department of Defense Clinical Practice Guideline. Ann Intern Med 2019;171:916-24.
12. Meyns P, Bruijn SM, Duysens J. The how and why of arm swing during human walking. Gait Posture 2013;38:555-62.
13. Bovonsunthonchai S, Hiengkaew V, Vachalathiti R, Vongsirinavarat M, Tretriluxana J. Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke. Kaohsiung J Med Sci 2012;28:667-72.
14. Hong SH, Jung SY, Oh HK, Lee SH, Woo YK. Effects of the Immobilization of the Upper Extremities on Spatiotemporal Gait Parameters during Walking in Stroke Patients: A Preliminary Study. Biomed Res Int 2020;2020:6157231.
15. Savino E, Martini E, Lauretani F, et al. Handgrip strength predicts persistent walking recovery after hip fracture surgery. Am J Med 2013;126:1068-75 e1.
16. Inoue H, Watanabe H, Okami H, Shiraishi Y, Kimura A, Takeshita K. Handgrip strength correlates with walking in lumbar spinal stenosis. Eur Spine J 2020;29:2198-204.
17. Muren MA, Hutler M, Hooper J. Functional capacity and health-related quality of life in individuals post stroke. Top Stroke Rehabil 2008;15:51-8.
18. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189-98.
19. Schmidt RT, Toews JV. Grip strength as measured by the Jamar dynamometer. Arch Phys Med Rehabil 1970;51:321-7.

20. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996;29:602-8.
21. Margit Alt Murphy CR, Peter Feys, Ilse Lamers. An overview of systematic reviews on upper extremity outcome measuers after stroke. BMC Neurology 2015;15.
22. Stricker M, Hinde D, Rolland A, Salzman N, Watson A, Almonroeder TG. Quantifying step length using two-dimensional video in individuals with Parkinson's disease. Physiother Theory Pract 2019:1-4.
23. Patterson KK, Gage WH, Brooks D, Black SE, McIlroy WE. Evaluation of gait symmetry after stroke: a comparison of current methods and recommendations for standardization. Gait Posture 2010;31:241-6.
24. Liaw LJ, Hsieh CL, Lo SK, Chen HM, Lee S, Lin JH. The relative and absolute reliability of two balance performance measures in chronic stroke patients. Disabil Rehabil 2008;30:656-61.
25. Maeda N, Kato J, Shimada T. Predicting the probability for fall incidence in stroke patients using the Berg Balance Scale. J Int Med Res 2009;37:697-704.
26. Akoglu H. User's guide to correlation coefficients. Turk J Emerg Med 2018;18:91-3.
27. English C, McLennan H, Thoirs K, Coates A, Bernhardt J. Loss of skeletal muscle mass after stroke: a systematic review. Int J Stroke 2010;5:395-402.
28. Zhang Q, Lu H, Pan S, Lin Y, Zhou K, Wang L. 6MWT Performance and its Correlations with VO(2) and Handgrip Strength in Home-Dwelling Mid-Aged and Older Chinese. Int J Environ Res Public Health 2017;14.
29. Rausch-Osthoff AK, Kohler M, Sievi NA, Clarenbach CF, van Gestel AJ. Association between peripheral muscle strength, exercise performance, and physical activity in daily life in patients with Chronic Obstructive Pulmonary Disease. Multidiscip Respir Med 2014;9:37.
30. Park JG, Lee KW, Kim SB, Lee JH, Kim YH. Effect of Decreased Skeletal Muscle Index and Hand Grip Strength on Functional Recovery in Subacute Ambulatory Stroke Patients. Ann Rehabil Med 2019;43:535-43.
31. Shin HI, Kim DK, Seo KM, Kang SH, Lee SY, Son S. Relation Between Respiratory Muscle Strength and Skeletal Muscle Mass and Hand Grip Strength in the Healthy Elderly. Ann Rehabil Med 2017;41:686-92.
32. Chen G, Patten C, Kothari DH, Zajac FE. Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture 2005;22:51-6.
33. Souissi H, Zory R, Boudarham J, Pradon D, Roche N, Gerus P. Muscle force strategies for poststroke hemiparetic patients during gait. Top Stroke Rehabil 2019;26:58-65.
34. Azarbayjani RYMHSHSFFMA. Effect of excessive Arm Swing on Speed and Cadence of walking. Journal of Men s Health 2020;4:1-5.
35. Takahashi J, Nishiyama T, Matsushima Y. Does grip strength on the unaffected side of patients with hemiparetic stroke reflect the strength of other ipsilateral muscles? J Phys Ther Sci 2017;29:64-6.
36. Patterson KK, Gage, W.H., Brooks, D., Black. S.E., Mcllroy, W.E. Changes in gait symmetry and velocity after stroke: a cross sectional study from weeks to years after stroke. Neurorehabil Neural Repair 2010;24:783-90.
37. Dehno NS, Sarvestani; Fahimeh Kamalib; Shariat, Abdolhamid; Jaberzadeh, Shapoure. Relationship of hand strength with paretic upper extremity function and activities of daily living performance in patients with subacute stroke. Physiotherapy Practice and Research 2020;41:69-77.
38. Izawa KP, Kasahara Y, Hiraki K, Hirano Y, Oka K, Watanabe S. Longitudinal Changes of Handgrip, Knee Extensor Muscle Strength, and the Disability of the Arm,

Shoulder and Hand Score in Cardiac Patients During Phase II Cardiac Rehabilitation. Diseases 2019;7.
39. Patterson MR, Whelan D, Reginatto B, et al. Does external walking environment affect gait patterns? Conf Proc IEEE Eng Med Biol Soc 2014;2014:2981-4.
40. Liu J, Drutz C, Kumar R, et al. Use of the six-minute walk test poststroke: is there a practice effect? Arch Phys Med Rehabil 2008;89:1686-92.
41. Dalton E, Lannin NA, Laver K, et al. Validity, reliability and ease of use of the disabilities of arm, shoulder and hand questionnaire in adults following stroke. Disabil Rehabil 2017;39:2504-11.
42. Baker K, Barrett L, Playford ED, Aspden T, Riazi A, Hobart J. Measuring arm function early after stroke: is the DASH good enough? J Neurol Neurosurg Psychiatry 2016;87:604-10.
43. Pratama IK SS. Correlation between hand grip strength and functional mobility in elderly patients. In: Publishing I, ed. The 2nd Physics and Technologies in Medicne and Dentistry Symposium: IOP Publishing 2018.
44. Dourado VZ. Reference equations for the 6-minute walk test in healthy individuals. Arq Bras Cardiol 2011;96:128-38.
45. Alain G Bertoni MB, Lenore Crago, Haiying Chen, R G Barr, Benjamin Smith, Sanjiv J Shah. Abstract P151: Race/ethnic Differences in Six Minute Walk Distance Among Older Adults: The Multi-ethnic Study of Atherosclerosis. In: Association AH, ed. AHA Epidemiology and Prevention–Lifestyle and Cardiometabolic Health 2020 Scientific Sessions2020.
46. Potempa K, Lopez M, Braun LT, Szidon JP, Fogg L, Tincknell T. Physiological outcomes of aerobic exercise training in hemiparetic stroke patients. Stroke 1995;26:101-5.

Chapter 4

A description of factors associated with reduced physical activity and barriers for exercise in chronic stroke survivors from a multi-ethnic society: a cross-sectional study.

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Abstract

Objectives**:** Physical activity (PA) levels and participation in structured PA programs are at low levels among stroke survivors, despite being strongly recommended. These survivors face different socio-economic challenges in countries with low- and middle-income and multi-ethnic populations. We therefore aimed to explore factors associated with reduced PA levels in chronic stroke patients living in a low-middle income country with a multi-ethnic population, Suriname. Secondly, we explored barriers that prevent to participation in structured PA programs.

Design**:** Subjects were recruited from the general population and the Academic Hospital Paramaribo. We used energy expenditure (EE) and daily step count, measured with the GARMIN Forerunner 225 for seven consecutive days to evaluate PA. Exercise barriers were obtained using the Barriers to Physical Activity and Disability (BPAD) questionnaire. Demographic and socio-economic characteristics were obtained and included sex, age, income level, education level, marital status and self-reported ethnic background. Univariate and multivariate regression analyses were performed to establish associations with reduced levels of PA. Descriptive analyses was used to assess exercise barriers based on socio-economic diversity.

Results**:** Our study population (N=44, 48% males, mean age 58.2 ± 10.0 years) showed low PA levels (EE: 24.2 (16.1-53.7) Cal/kg/day; 3165.5(1093.0-9727.00) steps/day, median (min-max)). . Results show that reduced PA levels were not explained by demographic or socio-economic variables. Between ethnic groups, personal exercise barriers were distinct, but environmental/facility exercise barriers were common. The most common patient-reported environmental exercise barriers were (1) "cost of the program" (45%) followed by (2) "lack of transportation" (34%). The most reported personal barriers were (1) "feeling that an exercise instructor is incapable to set up an exercise program to meet their needs" (88%), (2) "not willing to spend money" (40%), (3) "don't know a fitness center" (38%), (4) "never exercised regularly (25%), (5) "lack of personal care attendant who help for exercise" (20%).

Conclusions: High-ambulating chronic stroke patients show reduced PA levels, which were not explained by demographic and socio-economic variables. These participants reported several exercise barriers. Future research should not only evaluate other factors related to reduced PA levels, but also evaluate feasibility and (cost-) effectiveness of tailored PA programs as well as education of exercise instructors for post-stroke exercise and include policy-making bodies to tackle environmental barriers

Keywords**:** physical activity, ethnicity, stroke, exercise barriers

Introduction

The risk for recurrent stroke increases, even in highly active subjects suffering from an initial stroke [1,2]. Suriname is a middle-income country (LMIC) where the prevalence of stroke varies between ethnic groups ranging from 1.8 to 4.1%[3]. Like in most LMIC's, chronic patient care is less developed and resources are not readily available compared to high-income countries (HIC)[4]. PA is a simple and modifiable tool for improvement of post-stroke mobility[5,6] and adherence to health enhancing structured PA programs is therefore strongly encouraged by leading current guidelines for stroke patient management[5]. Notwithstanding this, healthy Surinamese show insufficient PA and this varies along ethnic lines[7]. PA is low in chronic stroke survivors as well [1,8]. In addition to stroke related impairments, low PA can be related to income level, education level, marital status[9] and perceived exercise barriers and motivators[10]. The latter two may vary among countries and populations and depend on different sociocultural factors.

To date, most of the studies on factors associated with lower PA levels show data from HICs. These studies[1,11,12] include diverse determinants of decreased exercise participation after stroke when compared to middle-income countries[9,13,14]. However, environmental and facility barriers including costly exercise programs, transportation unavailability, bad local infrastructure and weather conditions are reported in both HIC and LMIC as barriers for exercise[15,16]. On the other hand, a Nigerian study[13] reports personal exercise barriers such as the notion that people in exercise clothes look funny and being embarrassed to exercise. This shows that cultural aspects may also influence PA behavior. Furthermore, a USA study reports lack of interest in PA programs and concerns that exercise might worsen their condition[15]. From the abovementioned reports, it can be concluded that generalization of study findings requires caution and that it is relevant to further explore factors associated with low PA levels as well as exercise barriers in stroke survivors from diverse ethnic populations, in order to be able to advise effective interventions to increase post-stroke PA in the future. As exercise is, by definition, planned structured, repetitive and intentional movement to improve or maintain physical fitness (PF), low PA levels might result in decreased physical fitness levels. This study enabled us to identify the role of demographic and socio-economic factors in reduced PA levels and to identify exercise barriers in a multi-ethnic stroke population from a LMIC setting.

Methods

Participants

From April 2016 to April 2017, we recruited participants from the database of the Rehabilitation Center Paramaribo and from the local community. Inclusion criteria were: being able to understand simple instructions (Mini Mental Scale Examination >24[17]), living at home, being in the chronic stage after stroke (last stroke >6 months ago), walk independent or with supervision (Functional Ambulation Category score ≥ 3), not presenting any serious cardiac condition[18] or other neurological deficits or uncontrolled blood pressure (systolic pressure >140 mmHg, diastolic pressure >90 mmHg)[18] and willingness to provide written informed consent. Approval for conducting this study was received from the Institutional Review Board at the Ministry of Health of Suriname (reference number: VG-023-15).

Baseline Characteristics and Cardiovascular Risk Factors

A questionnaire was administered to obtain demographic and socio-economic characteristics including sex, age, self-reported ethnicity (Asian, African or other)[19], education level (less than high school or high school and higher), monthly income level (≤1000SRD or >1000SRD)[20], and marital status (married or single). Weight and height were measured using an electronic scale (Seca 750) and a stadiometer (Seca 213). Type of stroke (ischemic or hemorrhagic) and the time post stroke were noted from medical records.

We used the daily steps and energy expenditure (EE) measured by the Garmin forerunner 225 to obtain data on PA level. The watch was worn on the non-paretic wrist for 7 consecutive days. It collected daily step counts and energy expenditure per day. PA measurement was considered valid when the watch was worn for at least 22 hours on at least five days, including the weekend, of the measurement week. For invalid measurements, missing data was completed using missing value analysis by SPSS. No registration of PA data resulted in exclusion from further data analysis.

To collect information on exercise barriers, a Dutch translation of the Barriers to Physical Activity and Disability (B-PAD) questionnaire was used[15]. Forward and backward translation was performed by a professional translator and reviewed by two researchers. To assess clarity and readability, the usefulness of the translated questionnaire was piloted in five healthy Surinamese Dutch speaking individuals before being used in the study.

The SCI Exercise Self-Efficacy Scale (ESES Dutch version) was used to obtain information on the participants' level of confidence with regard to carrying out regular physical activities[21]. The ESES consists of 10 items to be scored on a 4-point Likert scale; the total score can range from 10 to 40. The higher the total score the higher the exercise self-efficacy[22].

Statistical analysis

Data were assessed for normality using the Shapiro-Wilk statistic. Data and survey responses were summarized descriptively (for continuous variables, mean and standard deviation were provided; median and range when not normally distributed, categorical variables were described by frequency and percentages). To study significant differences of the PA outcome measures compared to the global PA recommendations, a one-sample T-test was performed for parametric data. Independent students' T-test were used to compare outcomes between sex and ethnic groups. Pearson's correlation was used to study correlation within continuous data. Univariate regression analysis was used to study the factors associated with low PA, quantified as average calories/kg/day (energy expenditure, EE) and average steps/day (the dependent variables).

Independent variables were sex, age, education level, income level, marital status, ethnicity, self-efficacy. Multivariate regression analysis was used to study which variables were independent predictors of PA. Hereby, the stepwise method was used in order to prevent multicollinearity. The difference between perceived exercise barriers according to education level, income level, marital status and ethnic background were completed using descriptive analyses. Statistical analyses were undertaken using IBM SPSS Statistics version 21.1. Statistical significance was set at $p < 0.05$.

Results

Baseline characteristics and PA

Fifty participants (48% males, mean age 58.2 ± 9.5 years) in the chronic phase after stroke (93.2% ischemic stroke and 46% left hemisphere affected) were included. Collection of the data regarding EE and steps/day of 3 participants was incomplete and added using missing value analysis. The data of 6 participants was not registered and therefore excluded from further analysis ultimately resulting in a total study group of 44 (table 1). Most of the 44 participants were Asian (N=25, 56.8%) followed by African (N=13, 29.5%) and Other ethnic backgrounds (N=6, 13.6%). The latter two were regrouped together as Non-Asians (N=19, 43.2%) to prevent defragmentation in ethnic groups. Twenty-one participants had a monthly income lower than 1000SRD (47.7%), and most of the participants had an educational degree lower than high school (68.2%) and were single (N=13, 29.5%). Median time post-stroke was 2.5 (range 0.5-16.6) years. Hypertension (N=37, 84.1%) and diabetes (N=23, 52.3%) were the most common comorbidities. Most of the participants had a lesion in the right hemisphere (N=23, 52.3%).

Table 1. Characteristics of all participants included in data analysis (N=44)

Age (years, mean ± SD)	58.2 ± 10.0
Sex (N, female)	23.0
Weight (kg, mean ± SD)	72.1 ± 13.4
PA level	
EE (calories / kg / day, median (min-max))	24.2 (16.1-53.7)
Steps / day (median, min-max)	3165.5 (1093.0-9727.0)

EE: Energy Expenditure; PA: Physical Activity; SD: Standard Deviation.

Factors associated with low physical activity

An a-priori correction was done for weight in the data of EE/day and this data did not show a normal distribution (p=0.000). Data from steps/day showed a normal distribution after transformation with the Ln function (p=0.006). Moreover, education level was associated to income level (r=0.457, p=0.002).

A univariate regression analysis was run to predict physical activity (steps/day) from age, sex, education level, income level, marital status, exercise self-efficacy and ethnicity (table 2). Furthermore, PA was not explained by these variables (table 3), therefore no multivariate regression analysis is conducted with these variables. No association was found between energy expenditure and steps/day (r = 0.027, p =0.863).

Table 2. Univariate regression analysis between PA measures and independent variables

		PA level			
Independent variables	Total, N=44	Average steps /day		Average EE	
		p-value	r-square	p-value	r-square
Sex (N, females)	23	0.93	0.00	0.24	0.03
Age (years, mean ± SD)	58.2 ± 10.0	0.97	0.00	0.34	0.02
Marital status (N, single)	13	0.47	0.12	0.19	0.03
Education level (N, lower than high school)	30	0.32	0.02	0.84	0.00
Income level (N, lower than 1000SRD)	21	0.77	0.00	0.99	0.00
Ethnicity (N, Asian/ Non-Asian)	25/19	0.25	0.03	0.18	0.41
Exercise Self-Efficacy score (median (min-max))	35 (10-40)	0.56	0.32	0.98	0.15

** EE: Energy Expenditure; Max: Maximum; Min: Minimum; PA: Physical Activity; R-square: percentage of variance explained by independent variable; SRD: Surinamese Dollar*

BPAD questionnaire

Barriers to exercise can be found in table 2. One participant (2.3%) was enrolled in a structured exercise program. About 9% of the participants stopped exercise due to health problems. Another 11.4% had an injury after participating in an exercise program. Most participants were interested in (re)starting an exercise program (81.8%) and felt that exercise would help their condition (93%). The most common patient-reported environmental exercise barriers were (1) “cost of the program” (45%) followed by (2) “lack of transportation” (34%). The most reported personal barriers were (1) “feeling that an exercise instructor is incapable to set up an exercise program to meet their needs” (88%), (2) “not willing to spend money” (40%), (3) “don’t know a fitness center” (38%), (4) “never exercised regularly (25%), (5) “lack of personal care attendant who help for exercise” (20%) (table 2). On average, each participant reported 7 exercise barriers.

Table 3. Exercise Barriers (N=44)

BARRIERS to exercise	N, yes
lack of transport facilities	15
lack of time	7
lack of energy	3
lack of motivation	5
lack of family and friends support*	2
Ever afraid to leave your home*	6
costly exercise program	20
lack of interest in exercise	1
lack of personal care attendant who will help with exercise	9
lack of accessible fitness center	4
exercise is monotonic and dull	0
exercise will not improve my condition	1
exercise will worsen my health	1
exercise is too difficult	3
not knowing how to exercise	8
not knowing where to exercise	5
health concerns prevent from exercise	4
pain prevents exercise	4
too old for exercise	0
feeling uncomfortable and self-conscious in a fitness center	3
injury due to exercise	5
any concerns about exercising in a fitness center	5

had a bad experience in a fitness center	4
satisfied with physical appearance and does not need to exercise	7
family responsibilities prevent to exercise	2
work prevents to exercise	5
feeling that exercise instructor is incapable to set up an exercise program to meet your needs	39
know a fitness center where you could exercise	27
willing to pay for exercise program	26
would like to start exercise program	36
feel that an exercise program could help	41
doctor advised exercise	27

EE: Energy Expenditure; BPAD: Barriers to Physical Activity and Disability

Within group analysis of the BPAD results

There were no significant differences found in the number of exercise barriers between participants with low and high education level (p=0.765). This was also the case for groups with low- and high-income level (p=0.644), people with single and married status (p=0.290) and people from different ethnic backgrounds (p=0.388).

Figure 1 to 3 show the most common reported exercise barriers for every ethnic group, marital status group, education- and income level group. Three of the top five barriers are common between low education, low income and single marital status group and included “not exercised regularly” and “don’t know how to exercise”. Furthermore, environmental exercise barriers were a commonality across all groups. Both, the high and low education group, reported that they did not know a fitness center where they could go to and that they thought that the cost of the program was an issue. This was also the case for people from the low- and high-income groups. Moreover, both income level groups identified “not willing to spend money for a PA program”, as a barrier for execise. All the top five barriers between the single and married marital status group were identical and included “feeling that the exercise instructor is incapable of to help”, “doesn’t know a fitness center” and “lack of transportation”. The least common reported exercise barriers were: 1) exercise will worsen my health; 2) exercise will not improve my condition; 3) lack of interest; 4) exercise is too difficult and 5) lack of support from family and friends.

Comparison between ethnic groups: self-reported exercise barriers

Ethno-specific descriptive analysis between two ethnic groups showed that primarily the Asians were not willing to pay for an exercise program (60%), "didn't know how to exercise (24%)" and feel that the fitness instructor was incapable to set up an exercise program to meet their needs (100%) compared to the other ethnic group. More people from Asian descent reported to have a lack of transport facilities (40%) and lack of time (20%). Asians (20%) and non-Asians (21.1%) both reported the lack of personal care to help during exercise as an exercise barrier. Compared to Asians, people from the non-Asian group primarily reported "being injured from exercising" as an exercise barrier (21.1%).

Discussion

In this study factors associated with low PA levels were explored and barriers to exercise were described in chronic stroke survivors from a LMIC country with a multi-ethnic background. Results show that reduced PA levels were not explained by demographic or socio-economic variables. Between ethnic groups, personal exercise barriers were distinct, but environmental/facility exercise barriers were common. The most common reported environmental exercise barriers were (1) "cost of the program" followed by "lack of transportation". The most common reported personal barrier was "feeling that an exercise instructor is incapable to set up an exercise program to meet their needs".

Overall, PA levels were low compared to other stroke studies [1,23]. Lower median steps/day and lower median values for EE were seen in our cohort, which might be explained by the difference in age (21 to 96 years) and PA monitoring tools (accelorometers and pedometers) in the heterogeneous designed studies reviewed by Fini et al. (2017) [23] and Field et al. (2013) [1]. Moreover, demographic and socio-economic variables did not explain these low levels of PA in our study population. Conflicting results have been shown in other studies [24,25] before and suggest research in other potential factors limiting post-stroke PA. Perhaps, stroke-related impairments play a role here. Previous studies have highlighted influential factors on post-stroke PA level such as poor walking ability, sensorimotor dysfunction and low mood [1,26]. On the other hand, balance and degree of physical fitness (PF) were positively associated with higher PA levels [26]. A minimum level of PF is a prerequisite for maintenance of a physically active lifestyle, while at the same time PA is important for improving and maintaining adequate levels of PF [5,27], so both PA and PF need attention. PF is stimulated by participation in structured PA programs [1,5,27]. Stroke survivors might not participate enough due to high-perceived exercise barriers.

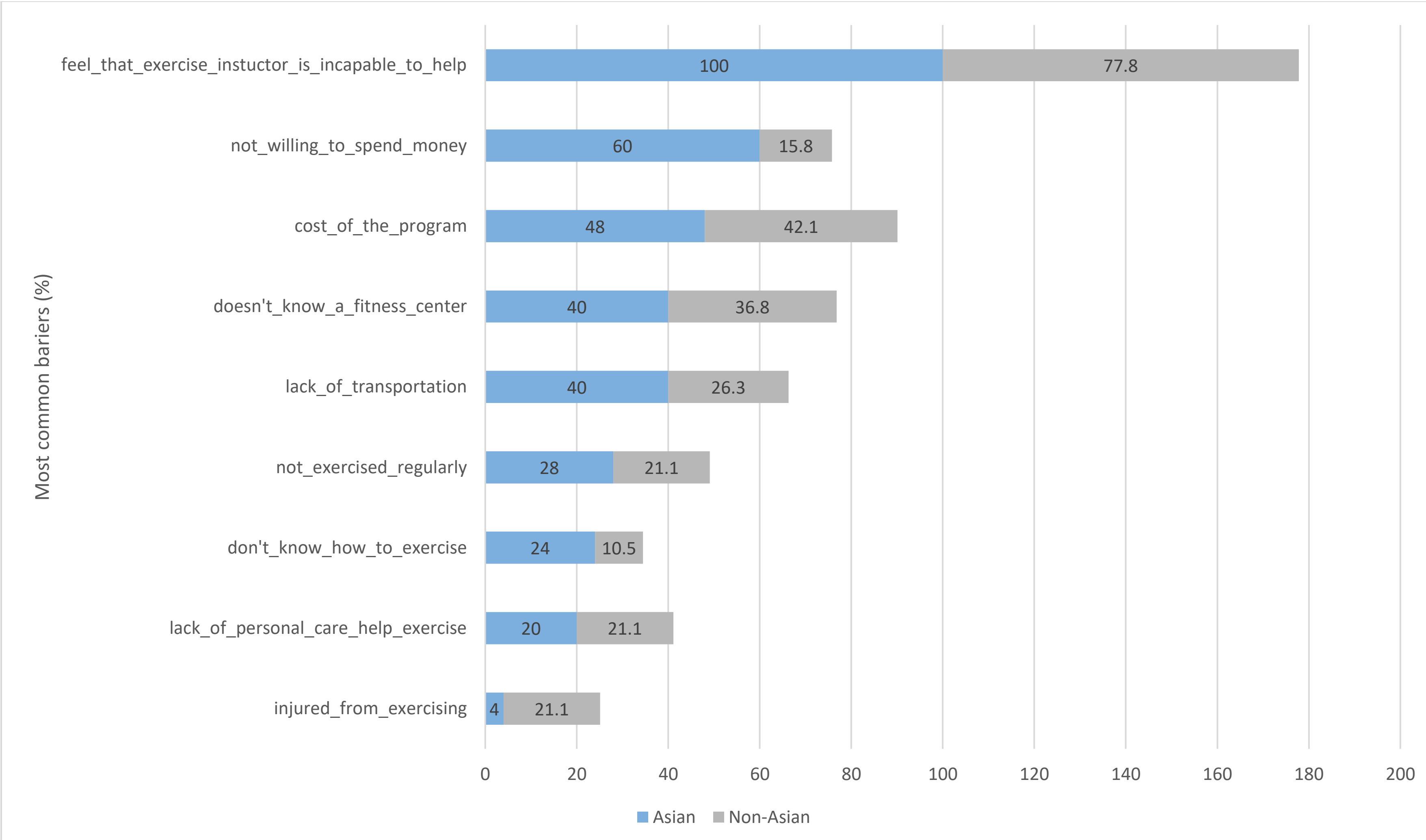

Figure 1. The most common reported PA-barriers across ethnic groups

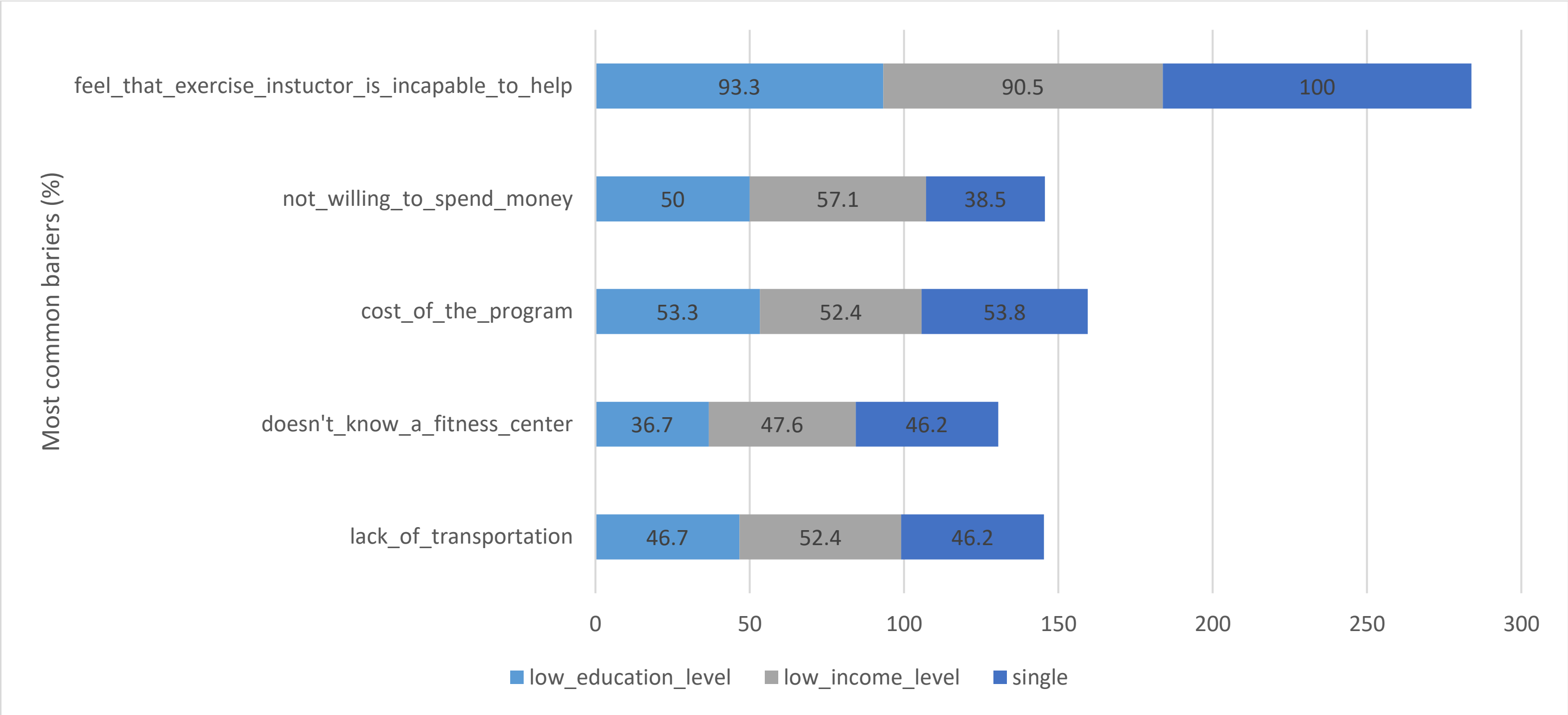

Figure 2. The most common PA barriers in the group with low education, low income and single marital status

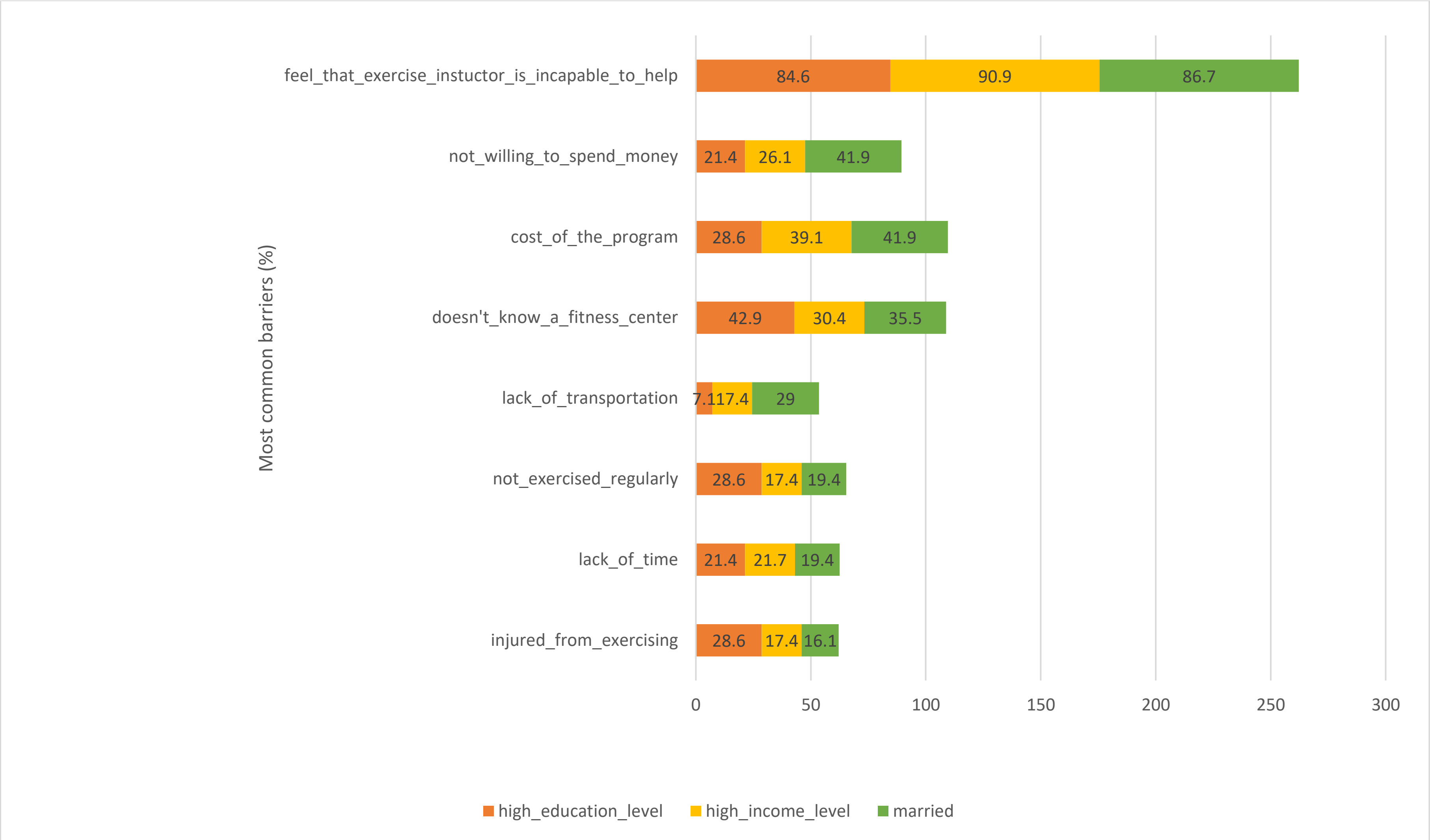

Figure 3. The most common PA barriers in the group with high education, high income and married marital status

Our results indicate that all the top five barriers for exercise were common for people from the low education (N=30) and low-income group (N=21) (figure 2). Education levels have previously been shown to be associated with both work-related and leisure-time physical activity and somewhat to total PA [28]. Healthy persons with lower educational levels show more work-related physical activity, but less leisure-time physical activity. Lower education levels can be accompanied by lower income, which is depicted by the commonality of exercise barriers found across these groups in this study (figure 2) and in line with findings of other stroke survivors [9,15]. Lower incomes could result from difficulties of stroke survivors to find work which in turn could induce low self-esteem, and low confidence which may further lower participation in exercise, as such introducing a negative vicious circle [29,30]. Similar to findings from HIC [15], LMIC [9], general population [31] as well as specific neurological populations [15,32], we found that participants in our study reported costly programs and lack of transport facilities as a barrier for participation in exercise programs. As many reported the incapability of the fitness instructor for setting up an individualized exercise program that meets their specific needs, this warrants further attention in stroke management policies. Therefore, targeting education, income and environmental factors, might eventually help in successful improvement of participation in structured PA programs. Furthermore, ethnic differences were seen in the reported frequencies of the barriers. Therefore, research should be promoted on the change in physical fitness levels after barrier removal, as exercise barriers might change over time and people might still not feel comfortable or see the need to exercise. For instance, if there is a cultural difference in acceptance of a larger body size across ethnic groups or a need to uphold sociocultural identity, a person might still not be motivated to maintain the recommended PA level [33]. Perhaps, an intervention to alter this complex behaviour, such as awareness campaigns or exercise programs, must have behaviour, or a measurable consequence of behaviour, as its end point [34]. Conclusively, exercise barriers are not similar enough across ethnic groups in this cohort to be targeted by one generalized intervention. Additionally, a HIC study [15] reported lack of energy as a common barrier to exercise and lack of time as a least reported exercise-barrier, whilst our study participants from a high-income and high education level reported lack of time, being injured during an exercise session and the fact that they haven't exercised regularly as exercise barriers. The exercise-barrier "lack of time" was least reported and might reflect the employed status of a part of this group, as this is largely reported as an exercise-barrier by healthy employed adults [35]. This in contrast to the HIC study amongst stroke survivors where "lack of time" reflected their unemployed stroke population [15]. However, lack of time was also reported by people from India as an exercise-barrier whilst they were unemployed [16]. Hence, careful individualized assessment is necessary in order to understand why people have low participation in structured PA programs. Moreover, despite a low PA level, scores on exercise self-efficacy were good. And most of our participants were interested in starting an exercise program and felt that it would improve their condition, which suggests that they are already intrinsically motivated to exercise. Literature shows that self-efficacy explains exercise adherence in chronic stroke survivors [36]. The high level of self-efficacy in our cohort might indicate that they believe to have the capability to reach and maintain a healthy level of exercise. That it still does not result in a higher PA level in our study might be due to the presence of several environmental/facility exercise barriers and the lack of specific exercise programs and specialized coaching during exercise after stroke.

Strengths and limitations

It should be kept in mind that the imbalance of the ethnic groups, the high-ambulating group of participants as well as the sample size within this study might prevent generalization of results. Nevertheless, an important strength of this study is the first in its kind for Suriname and that it provided information on patient-reported exercise barriers after stroke for a setting with scarce resources in a multi-ethnic population with a high level of confidence to perform exercise. Furthermore, we were not able to explore PA facilitators [37]. The importance of facilitators is emphasized in the study by Simpson et al. (2021). Information of facilitators might have facilitated the development of successful structured PA programs. The study by Simpson et al. (2021) [37] suggested support to exercise (external encouragement/qualified personnel) as a facilitator and at the same time lack of support to exercise was also identified through our survey as a barrier. Findings of this study might serve as a strategy for physiotherapists to tailor exercise interventions in order to improve exercise participation of the participants.

Data on PA in our study was obtained from a Garmin device of which the algorithm for calculation of energy expenditure and steps/day was not known. This algorithm is likely to be based on healthy individuals whilst stroke survivors might show an increased energy expenditure for the same activity compared to healthy age-matched controls[2]. We tried to minimize bias as much as possible by putting the Garmin device on the non-paretic side of the body for 7 consecutive days.

Furthermore, self-reported data such as the exercise barriers in this study are subject to response bias (‘socially desirable responding’) [38] which we need to take into account when designing and conducting PA programs. Moreover, there is no known evaluation of reliability and validity of the BPAD in stroke survivors, but the study by Rimmer et al. [39] suggests adequate reliability and validity for the use of the BPAD in people with chronic disabilities (N=149). Eventually, we advise that it would be best to design feasibility studies before conducting large PA programs in order to develop the best possible intervention.

Conclusions

Demographic and socio-economic variables did not explain the low PA level in our study population. These stroke survivors reported several barriers. Physiotherapists can therefore tailor stroke exercise programs according to personal barriers, include policy-making bodies to tackle environmental barriers and educate movement instructors for customized post-stroke exercise. Future research should evaluate feasibility and (cost)effectiveness of tailored exercise programs.

References

1. M.J. Field NG, T.S. Sundaram, S. Nicholson, G. Mead. Physical activity after stroke: a systematic review and meta-analysis. ISRN Stroke 2013;2013:13.
2. Sarah L. Galea M-JL, , Coralie English, Louise Ada. Sedentary versus active behavior in people after stroke. physical therapy reviews 2014;20:1-7.
3. A. V. Jarbandhan MJMH, R. Buys, F. S. Diemer, S. M. Baldew, J. Aartman, L. M. Brewster, G.A. van Montfrans, G.P. Oehlers, H.E.J. Veeger, J.Toelsie, L. Vanhees. Prevalence of self-reported stroke in association with ethnic background within a multi-ethnic population in Paramaribo, Suriname: Results from the HeliSur study. Neurology Asia 2016;21:303-10.
4. Turk-Adawi KI, Grace SL. Narrative review comparing the benefits of and participation in cardiac rehabilitation in high-, middle- and low-income countries. Heart, lung & circulation 2015;24:510-20.
5. 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; a journal of cerebral circulation 2014;45:2532-53.
6. Winstein CJ, Stein J, Arena R, et al. Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke 2016;47:e98-e169.
7. Baldew SS, Krishnadath IS, Smits CC, Toelsie JR, Vanhees L, Cornelissen V. Self-reported physical activity behavior of a multi-ethnic adult population within the urban and rural setting in Suriname. BMC Public Health 2015;15:485.
8. Baert I, Feys H, Daly D, Troosters T, Vanlandewijck Y. Are patients 1 year post-stroke active enough to improve their physical health? Disability and rehabilitation 2012;34:574-80.
9. Idowu OA, Adeniyi AF, Ogwumike OO, Fawole HO, Akinrolie O. Perceived barriers to physical activity among Nigerian stroke survivors. Pan Afr Med J 2015;21:274.
10. Nicholson S, Sniehotta FF, van Wijck F, et al. A systematic review of perceived barriers and motivators to physical activity after stroke. Int J Stroke 2013;8:357-64.
11. Mead G, Bernhardt J, Kwakkel G. Stroke: physical fitness, exercise, and fatigue. Stroke Res Treat 2012;2012:632531.
12. Tornbom K, Sunnerhagen KS, Danielsson A. Perceptions of physical activity and walking in an early stage after stroke or acquired brain injury. PLoS One 2017;12:e0173463.
13. Prakash V, Shah MA, Hariohm K. Family's presence associated with increased physical activity in patients with acute stroke: an observational study. Braz J Phys Ther 2016.
14. Adeniyi A, Idowu O, Ogwumike O, Adeniyi C. Comparative influence of self-efficacy, social support and perceived barriers on low physical activity development in patients with type 2 diabetes, hypertension or stroke. Ethiop J Health Sci 2012;22:113-9.
15. Rimmer JH, Wang E, Smith D. Barriers associated with exercise and community access for individuals with stroke. J Rehabil Res Dev 2008;45:315-22.
16. Mohammad Usman Akhtar SA, Man Mohan Mehndiratta. Barriers associated with community access by stroke patients in Indian population. Indian Journal of Physiotherapy and Occupational Therapy An International Journal 2012;7.
17. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189-98.
18. Pang MY, Eng JJ, Dawson AS, McKay HA, Harris JE. A community-based fitness and mobility exercise program for older adults with chronic stroke: a randomized, controlled trial. J Am Geriatr Soc 2005;53:1667-74.
19. Diemer FS, Baldew SM, Haan YC, et al. Aortic pulse wave velocity in individuals of Asian and African ancestry: the HELISUR study. J Hum Hypertens 2020;34:108-16.
20. Initiave OPaHD. OPHI Country Briefing 2017: Suriname. University of Oxford: Oxford Department of International Development; 2017.

21. Nooijen CF, Post MW, Spijkerman DC, Bergen MP, Stam HJ, van den Berg-Emons RJ. Exercise self-efficacy in persons with spinal cord injury: psychometric properties of the Dutch translation of the Exercise Self-Efficacy Scale. Journal of rehabilitation medicine 2013;45:347-50.
22. Kroll T, Kehn M, Ho PS, Groah S. The SCI Exercise Self-Efficacy Scale (ESES): development and psychometric properties. Int J Behav Nutr Phys Act 2007;4:34.
23. Natalie A. Fini AEH, Jenny Keating, Jacinta Simek, Julie Bernhardt. How physically active are people following stroke? Systematic review and quantitative synthesis. Physical Therapy 2017;97:707-17.
24. G A M van den Bos 1 JPJMS, G P Westert, A van Straten. Socioeconomic variations in the course of stroke: unequal health outcomes, equal care? J Epidemiol Community Health 2002;56:943-8.
25. Maike Miriam Grube H-CK, Georg Walter, Jane Thümmler, Andreas Meisel, Ian Wellwood, Peter Ulrich Heuschmann. Association between socioeconomic status and functional impairment 3 months after ischemic stroke: the Berlin Stroke Register. Stroke 2012;43:3325-30.
26. Coralie English PJM, Claire Tucak, Julie Bernhardt. Physical activity and sedentary behaviors in people with stroke living in the community: a systematic review. Phys Ther 2014;94:185-96.
27. Saunders DH, Greig CA, Mead GE. Physical activity and exercise after stroke: review of multiple meaningful benefits. Stroke; a journal of cerebral circulation 2014;45:3742-7.
28. He XZ, Baker DW. Differences in leisure-time, household, and work-related physical activity by race, ethnicity, and education. J Gen Intern Med 2005;20:259-66.
29. Wolfenden B, Grace M. Returning to work after stroke: a review. International journal of rehabilitation research Internationale Zeitschrift fur Rehabilitationsforschung Revue internationale de recherches de readaptation 2009;32:93-7.
30. Peters GO BS, Oyeyemi AY, Hamzat TK. Determinats of return to work among Nigerian stroke survivors. Disability and rehabilitation 2013;35:455-9.
31. Cowan RE, Nash MS, Anderson KD. Exercise participation barrier prevalence and association with exercise participation status in individuals with spinal cord injury. Spinal Cord 2013;51:27-32.
32. Khalil H, Nazzal M, Al-Sheyab N. Parkinson's disease in Jordan: Barriers and motivators to exercise. Physiother Theory Pract 2016;32:509-19.
33. Ard JD, Zunker C, Qu H, et al. Cultural perceptions of weight in African American and Caucasian women. Am J Health Behav 2013;37:3-13.
34. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 2011;6:42.
35. Heesch KC, Brown DR, Blanton CJ. Perceived barriers to exercise and stage of exercise adoption in older women of different racial/ethnic groups. Women Health 2000;30:61-76.
36. Caetano LCG, Pacheco BD, Samora GAR, Teixeira-Salmela LF, Scianni AA. Self-Efficacy to Engage in Physical Exercise and Walking Ability Best Predicted Exercise Adherence after Stroke. Stroke Res Treat 2020;2020:2957623.
37. Simpson LA, Eng JJ, Tawashy AE. Exercise perceptions among people with stroke: Barriers and facilitators to participation. Int J Ther Rehabil 2011;18:520-30.
38. McDonald JD. Measuring personality constructs: the advantages and disadvantages od self-reports, informant reports and behavioral assessments. Enquire 2008;1:75-94.
39. James H Rimmer BBR, W. Roosevelt. Validation of the Barriers to Physical Activity and Disability Survey for older individuals with disabilities. In: APHA, ed. The 129th Annual Meeting of APHA. Atlanta, GA: APHA; 2001.

Chapter 5
Feasibility of a home-based physiotherapy intervention to promote post-stroke mobility: a randomized controlled pilot study.

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Abstract

Objectives: Home-based physiotherapy interventions to improve post-stroke mobility are successful in high-income countries. These programs require less resources compared to center-based programs. However, feasibility of such an intervention in a low and middle-income setting remains unknown. Therefore, this study aimed to assess feasibility and preliminary effectiveness of a home-based semi-supervised physiotherapy intervention to promote post-stroke mobility in a low resource setting.

Design: Prospective randomized controlled trial.

Methods: Chronic stroke patients were recruited and randomized into either an intervention group (IG (N=20)) or a control group (CG (N=10)). The IG received a 3-days-a-week home-based physiotherapy program that was supervised in the first 4 weeks and tele-supervised during the second 4 weeks. The physiotherapy program consisted of walking as well as functional and mobilization exercises. The CG received usual care. Feasibility outcome measures included adherence, patient satisfaction and safety. Efficacy measures included functional walking capacity (six-minute walk test (6MWT), functional balance (Berg Balance Scale (BBS), upper extremity (UE) function (Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire and handgrip (HG) strength). Two-way analysis of variance was used for data analysis.

Results: Thirty participants (61.8 ± 9.2 years old, 13 men) were enrolled in the study. The intervention was completed by 14 participants (70%). Adherence was affected by rainy season associated infrastructural problems (n=2), the medical status of participants (n=3) and insufficient motivation to continue the program without direct supervision (n=1). No adverse events were noted and participants were satisfied with the program. Functional walking capacity (57.2 ± 67.3m, p=0.02) and UE function (-9.8 ± 15.2, p=0.04) improved in the IG compared to no change in the CG. HG strength was unaltered and a ceiling effect occurred for BBS.

Conclusion: Our home-based semi-supervised physiotherapy intervention seems safe, associated with moderate to high levels of engagement and patient satisfaction and results in functional improvements.

Introduction

Stroke rehabilitation reduces the risk for recurrent stroke, improves mobility and independency during Activities of Daily Life (ADL) [1-7]. Hence, various types of physiotherapeutic programs for rehabilitation have been assessed for their success rate [7-12].

During home-based physiotherapy interventions the physiotherapist (PT) usually visits a patient at home to conduct the intervention [13,14], as opposed to tele-physiotherapy where the objective is to allow medical experts to manage their patients through telecommunication technologies without requiring the patient to leave their home, or the PT to be onsite [15]. Several studies [6,7,12,14,16,17] have shown that home-based therapy, including tele-physiotherapy, improved independence compared to conventional care and is more cost-effective compared to physiotherapy in the hospital [12,18]. Today, home-based and tele-physiotherapy programs are of increasing interest and appear to have a high success rate for improving post-stroke mobility [6,7,12-14,16,17]. However, their applicability in LMIC has yet to be documented [6] since most of these home-based physiotherapy studies have been conducted in High Income Countries (HIC) [6,7,12,16,19-22]. Moreover, due to high costs and limited availability of traditional rehabilitation services, stroke rehabilitation is underutilized in LMICs. Poor mobility due to bad road conditions, traffic jams and poverty further limit the accessibility of rehabilitation services. Only few studies have looked in to this in a LMIC setting; the ATTEND home-based rehabilitation trial (India) [23] , the SMART tele-rehabilitation trial (India and Nigeria),[24] the RECOVER trial (China) [25] and feasibility study F@ce (Uganda) [26]. The latter comprised of an 8-week mobile phone supported, family-centered intervention that was found to improve ADL and self-efficacy of ADL. The ATTEND trial [23] inquired for dependency and mortality of the patient at 6 months and found no difference between the control and the intervention group when care was shifted to family at home in comparison to usual care. Through the RECOVER mobile phone app, acute stroke survivors would be followed for improvement in ADL via a 2-year randomized controlled trial. The SMART trial comprised of an eight-week DVD-based intervention for improvement of functional outcomes [24]. Results for the RECOVER and SMART trials have not yet been published. Today, no structural home-based or tele-physiotherapy program is available for chronic stroke survivors in Suriname. Currently, reimbursed therapy sessions at the rehabilitation center in the capital of Suriname are offered for a maximum of ten sessions in one year. Suriname is contextually unique: socio-economic barriers, cultural barriers, uncoordinated care, under-diagnosis, low awareness, lack of research, etc. limit the capacity to develop successful strategies against the rising burden of disease [27]. From this point of view, the SunRISe (Stroke Rehabilitation In Suriname) project was initiated, in which we developed an 8-week home-based semi-supervised physiotherapy program to improve functioning of chronic stroke survivors in the urban area of Suriname. The aim of this pilot study was to assess the feasibility and safety of this program. Additionally, the clinical efficacy of this approach was explored. We hypothesize that this program will be feasible in a low-income setting and will induce a clinically important improvement. Furthermore, this study will generate efficacy estimates to inform sample size calculation and best primary outcome measures for designing a properly powered randomized controlled trial in the future.

Methods

Participants

A convenience sample of 30 chronic stroke patients was randomly recruited from the database of the Academic Hospital Paramaribo (AZP) and the community between April 2016 and April 2017. Potential eligible patients with stroke, and some of their general physicians, were called in order to evaluate eligibility for the baseline exercise test according to the inclusion and exclusion criteria. Inclusion criteria were chronic stroke patients who had a stroke at least 6 months ago, had medical clearance to participate in a moderately intense exercise program, were living at home, were not already undertaking regular exercise or physiotherapy, had a mild to moderate stroke deficit (defined by Fugl Meyer test score of 27 to 90 for upper and lower extremities [4]), had a Functional Ambulation Classification score ≥ 3 and were able to understand measurement procedures (defined as Mini Mental State Examination score >24 [5]). Exclusion criteria were: absolute and relative contraindications to exercise testing (according to the American Heart Association guidelines) [28] as well as other neurological deficits leading to disability. Contractures, hypertony or spasticity were no reason for exclusion as long as the participants adhered to all above mentioned inclusion and exclusion criteria. The Board of Ethics and Research of Ministry of Health in Suriname approved this study (VG 023-15) and all participants gave their written informed consent. The study was prospectively registered on ClinicalTrials.gov with identifier: NCT02717715.

Study design and outcome assessment

This study was an eight-week feasibility pilot study with a randomized controlled trial design. As all aspects of the trial (recruitment, assessment, treatment allocation and intervention) were executed by one single person (A.J.), no blinding for group allocation was performed. Data were collected at the Department of Physiology of the Anton De Kom University of Suriname. A questionnaire was developed to obtain information on age, sex, ethnicity, dominant side, affected body side, type of stroke, time post-stroke, presence of diabetes, hypertension, chronic obstructive pulmonary disorders and smoking status. These variables together with measures of walking capacity, physical activity (PA) and exercise self-efficacy were collected at baseline (T0), after 4 weeks (IG only) (T4) and after 8 weeks (T8).

Feasibility

Evaluation for feasibility of the intervention was based on [29]: (1) how many participants finished the intervention (adherence); (2) preliminary effectiveness; (3) adverse events due to the intervention (safety) and (4) patient satisfaction and perception of the intervention.

Patient satisfaction and perception was evaluated using a self-developed questionnaire consisting of 7 questions evaluating how satisfied they were with the different parts of the program, to be rated on a 5-point scale: 1, very unsatisfied; 2, unsatisfied; 3, don’t know; 4, satisfied; 5, very satisfied. The questionnaire finished with an optional open question “What would you recommend us to make our program better?”.

Clinical efficacy

Primary outcome measure of efficacy was functional walking capacity assessed by the 6MWT [30]. For this test, participants were instructed to walk continuously at their fastest pace for 6 minutes on a hallway of 30m with turning points at each end. They were told to cover as much ground as possible. Standardized verbal reassurance was given during the test. Subjects were allowed to use assistive devices (e.g. cane) and to rest when needed and chairs were placed at each end of the hallway and in the middle. All participants received the same standardized instructions and encouragement. The maximal distance covered in six minutes was recorded in meters.

Functional variables further included the Disabilities of the Arm, Shoulder and Hand (DASH) score, maximal handgrip (HG) strength, and the Berg Balance Scale (BBS). The DASH questionnaire [31] is a 30-item self-report questionnaire to assess disabilities in the upper extremity. Higher scores indicate more severity of symptoms and disability. Handgrip strength was measured using a hand dynamometer with an adjusted handle (Suahan Digital SH5003, Korea). The upper arms were supported next to the body, with the elbow joint in 90° degrees. The participant performed the maximal handgrip test 3 times alternating the paretic (P) and non-paretic (NP) arm with intervals of 30 seconds of rest [32]. The highest value for each hand was recorded. Balance control was evaluated by the BBS, consisting of 14 tasks and a score range of 0-56 [33].
The SCI exercise Self-Efficacy Scale (ESES, Dutch version), consisting of 10 items to be scored on a 4-point-likert scale, was used to obtain information on exercise self-efficacy [34].

Interventions

Participants were randomized on a 2:1 ratio to either the intervention group (IG) or usual care (UC), using a computerized random number generator (www.randomization.com). The group allocation list was kept with the supervisor (R.B.) and every new inclusion was consequently added and allocated to the group as indicated in this list. Although initially a 1:1 randomization was planned, after discussing the resources for the testing following delays due to equipment issues, the number of patient tests was reduced by shifting to a 2:1 randomization. The 2:1 randomization allowed to gather as much information as possible on feasibility and safety of the intervention program while still collecting data for exploratory comparative analysis. Participants in the IG received a home-based, semi-supervised physiotherapy program. The CG received usual care. At this moment usual care for chronic stroke patients in Suriname consists of ten physiotherapy sessions (with only 54% of the costs per session are refundable) a year for people insured by the largest governmental health insurance company. So, by the time people after stroke are in the chronic phase after stroke, they do not have any therapy sessions left for that year. Moreover, if no physiotherapy is requested by the patient, none is given which is most often the case.
Overall, the intervention employed a holistic approach [35] bringing together physical fitness improving exercise, functional exercise, upper limb exercise as well as patient education according to the needs of the patients (table 1). The home-based physiotherapy program included stair climbing, sit-to-stand exercise [4] and walking [36]. Upper extremity exercises were incorporated in the start-up and ending phases of each training session and consisted of proprioceptive neuromuscular facilitation techniques and mobility exercises. All treatment sessions between T0 and T4 (supervised phase, 3 times/week, 70 minutes/session) were supervised by a physiotherapist. During these first 4 weeks, exercise intensity was monitored using a Garmin Forerunner 225 watch on the non-paretic arm for heart rate measurements [37] along with a BORG scale [38]. The number of steps were measured using a pedometer (Yamax Digiwalker SW-200, Japan) [39] placed on the non-paretic leg at the level of the knee [40] and step counts per training session were noted. In addition, blood pressure (BP) measurements were done before, during and after the sessions in sitting position in order to monitor blood pressure response to exercise and ensure safety. At the end of

the first 4 weeks, patients were reassessed for the above-mentioned efficacy outcome measures in order to track progress and adapt the exercise intensity accordingly. Between T4 and T8 (tele-coaching phase), the instructions were to continue the same individually tailored program without supervision, with help from the participants' usual caregiver if necessary, and with a progressive exercise volume defined by duration and BORG scale as well as a pedometer step goal [41]. Patients were asked to log their performance in a diary, logging exercise durations, exercise intensity (BORG scale) and step counts. The physiotherapist provided weekly telephone encouragements and instructions.

Table 1. Overview intervention program

Duration	Training phase**	Content of intervention	Progression of intervention
10-15 min	Starting up (putting on devices such as Yamax pedometer, Garmin watch; measuring resting blood pressure***).	Mobility exercise: Slow marching in one place, ankle circles; Shoulder, hip circles (slowly); Shoulder, elbow, wrist, hand and fingers movements slowly (all in the direction of PNF techniques)	Progression of upper limb exercises were based upon individual responses to the intensity.
40-45 min	Lower limb strengthening endurance exercise (As patients progressed, the number and length of rest periods were also decreased. As performance improved tasks were made more challenging (complexity of a task, number of repetitions, in various body positions).)	Stair climbing exercise: (intensity increased gradually after first 5 minutes of exercise with perceived exertion 4-5 out of 10 on BORG scale)	During stair climbing manual assistance was reduced as necessary for safe climbing without an orthosis
		Resting period (2-5min)	
		Sit-to-stand exercise: (2 sets of 5 and gradual increase to 3 sets of 10 with variable speed)	As the patients progressed resting periods during sit-to-stand exercise was decreased.
		Resting period (2-5min)	
		Walking (with or without assistive device): (amount of steps as target, with gradual increase in intensity, based on perceived exertion 4-5 out of 10 on BORG scale)	As the patient progressed, walking was done without an assistive device. Balance was challenged during walking by using ankle strategies. Walking was conducted on various surfaces including hardened ground and grass. During walking emphasis was on instructions including walking kinematics such as equal strides, cadence, weight shift, arm swing and equal limb loading.
		Resting period (2-5min)	

Duration	Training phase**	Content of intervention	Progression of intervention
10-15 min	Ending program: upper limb rehabilitation, patient and family education^ (taking off devices; measuring resting blood pressure***)	Mobility exercise (including repositioning of shoulder where needed), PNF techniques for upper and lower limb followed by slow stretching. Information about stroke etiology and progression of stroke symptoms together with information on food choices and comorbidities such as high blood pressure and diabetes.	

PNF, Proprioceptive Neuromuscular Techniques; min, minutes; **Based on the Health Navigator Model & Chronic Care Model; * Standardized blood pressure measurements; ^Based on the Transtheoretical model.*

Data analysis

Database management was performed by use of Microsoft Excel 10.0. Intention to treat analysis was performed and therefore all patients who were enrolled and who were randomly allocated, are also included in the analysis, and are analyzed in the group to which they were randomized. Imputations for missing data among primary (6MWD) and secondary (DASH score, handgrip strength and Berg Balance Scale) outcomes, were performed using mean substitution.
Given the small sample size and the increased risk for type 2 error inherent to ITT analysis, an additional per-protocol analysis was performed as well, allowing results from both analyses to be compared in order to strengthen our findings.
The Shapiro-Wilk test was used to determine normal distribution of the data. The groups were compared to evaluate differences in demographic, anthropometric and clinical parameters using unpaired t-tests or chi square test as appropriate. Exploratory evaluation of differences between and within CG and IG after 8 weeks was performed by means of 2-way mixed methods design analysis of variance with time as a repeated-measures factor. Effects sizes were calculated by means of partial eta square as obtained from ANOVA. SPSS version 21.0 was used to perform statistics. Statistical significance was set at $p<0.05$.
Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this study.

Results

Participants

The study flow is shown in Figure 1. Out of fifty-nine patients who were eligible for participation, the first thirty patients that agreed to participate, were randomized to either IG (n=20) or CG (n=10).

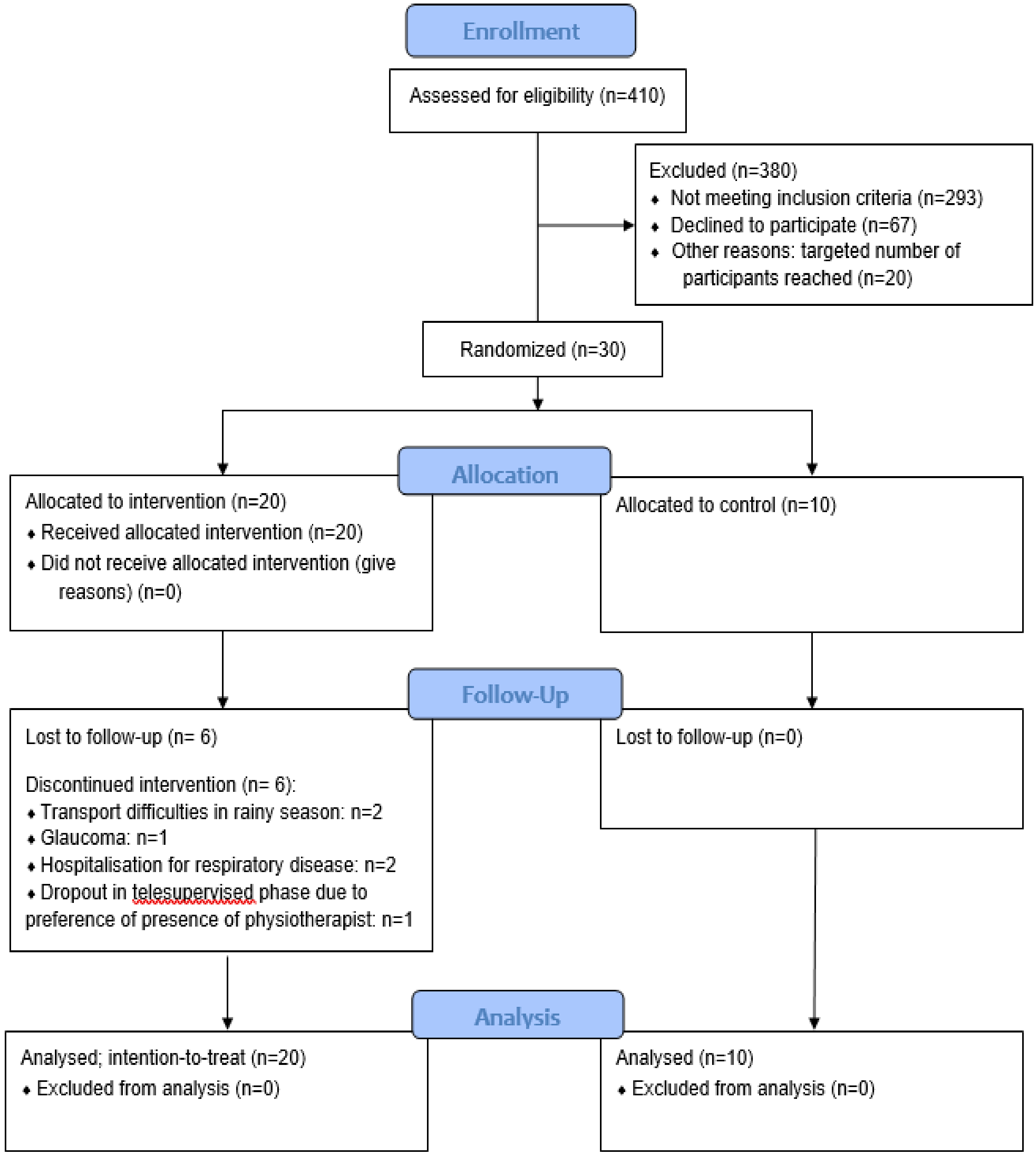

Figure 1. Flow of the SunRISe study.

Demographic and clinical characteristics of the participants are shown in Table 2. The mean age of the participants was 61.8±9.2 and 43% were men. Most participants had suffered ischemic stroke and were from Asian background. The mean time post-stroke was 3.3 years. At baseline, no significant differences were present between IG and CG, apart from the presence of diabetes, which was higher in the control group (p=0.045). None of the participants were on a regular schedule of physiotherapy, therefore control group participants did not receive any exercise therapy in the 8-week timeframe of the study.

Table 2. Demographic and clinical characteristics of the study population

	All N=30	IG N=20	CG N=10
Sex (N, male)	13	9	4
Age (mean ± SD, years)	61.8 ± 9.2	61.6 ± 9.1	62.2 ± 9.1
Time post-stroke (mean ± SD, years)	3.3 ± 3.4	3.1 ± 3.5	4.5 ± 3.1
Type of stroke (N)			
Ischemic	27	18	9
Hemorrhage	3	2	1
Ethnic background (N)			
Asian	16	10	6
African	9	7	2
Other	5	3	2
Recurrent stroke (N, yes)	8	5	3
Affected body side (N, right)	17	13	4
Dominant side (N, right)	27	18	9
Diabetes (N, yes)	17	9	8
COPD (N, yes)	3	3	0
Hypertension (N, yes)	25	16	9
Former smoking (N, yes)	13	8	5
Current smoking (N, yes)	6	3	3
Current alcohol use (N, yes)	8	5	3

**CG, Control Group; COPD, Chronic Obstructive Pulmonary Disease; IG, Intervention Group.*

Feasibility

Adherence to the program

Fourteen of the twenty (70%) IG participants completed the full intervention (Figure 1). Drop outs during the supervised phase of the intervention were because of the rainy season (N=2), sudden development of glaucoma (N=1; diabetes patient) and hospitalization for respiratory problems (N=2; history of COPD). One drop out (N=1) during the tele-supervised intervention was due to a preference for supervised physiotherapy. One participant reported to need help from a relative for attaching the pedometer for the tele-supervised sessions.

During the rehabilitation sessions, the mean number of steps gradually increased from 2026±1352 steps during the first session to 2990±1617 steps in the last week of the intervention as is also reflected by the 6MWT results half-way and at the end of the intervention (Figure 2).

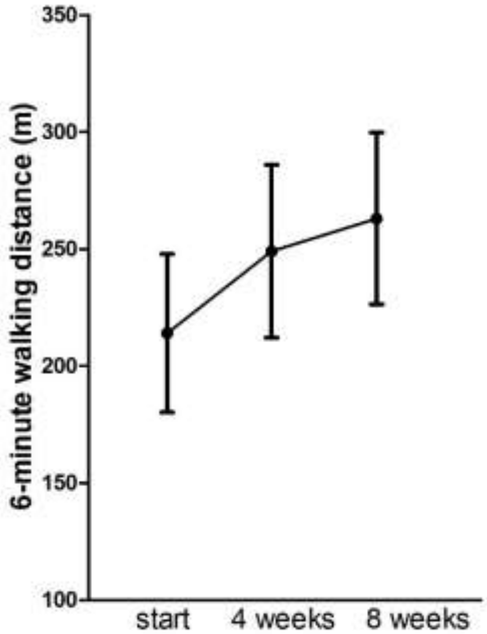

Figure 2. Changes in the primary outcome measure within the Intervention Group.

Adverse events
No adverse events related to physical activity were noted during the study.

Patient satisfaction and perception
In Table 3, the results for patient satisfaction are provided. Participants generally experienced the program positively. A longer duration of the program/sessions would have been preferred by some of the participants.

Table 3. Patient satisfaction and perception

Number	Question	Mean T8
1	How satisfied are you with the overall design of the exercise program?	4.7
2	How satisfied were you with the duration of the treatment sessions?	4.6
3	How satisfied was the composition of the treatment sessions?	4.7
4	How satisfied were you with the offered exercises?	4.7
5	How satisfied were you with the physiotherapist?	5
6	How satisfied were you with the pedometer?	4.7
7	How satisfied were you with the telephone support?	4.8
8**	What would you recommend us to make our program better?	1. *"the program is good and can be longer as these are lifelong exercises and since I've had this program my life has changed."* (#2) 2. *"the program can be longer because the exercise is very good for us" (#5)* 3. *"Wish that the session was longer in order to give more attention to the arm exercise" (#1)*

**1, very unsatisfied; 2, unsatisfied; 3, don't know; 4, satisfied; 5, very satisfied; T8, after 8 weeks of intervention.*
***Question 8 includes patient perception and the number of patients with this comment between brackets*

Clinical efficacy

Baseline and follow-up measures are provided in Table 4. With regards to 6MWD, the IG started at a non-significantly lower level (227 ± 125m) compared to the CG (302 ± 117m), and increased their walking distance with 57.2 ± 67.3m which was significantly more than the CG (0.6±29.2m) (interaction effect; $F(1, 28) = 6.36$, $p = 0.018$, $\eta_p^2 = 0.185$, power = 0.683).

An interaction effect was present for the total DASH score ($F(1, 28) = 4.54$, $p= 0.042$, $\eta_p^2= 0.140$, power = 0.539) indicating a signicant greater improvement in the IG (33 ± 26) than in the CG (0.6±2.3). There was a trend towards improvement in the BBS, paretic and non-paretic HG, but compared to the CG no significant differences were found. Mean self-efficacy score was 34.45 during baseline measurements, no difference with the CG was present. After performing per protocol analysis for the same variables, results remained similar. For 6MWD and DASH, significant group*time interaction effects were found (effect size of 0.203 and 0.133 respectively; $p<0.05$). No other interaction effects were present. Significant time effects were found for 6MWD and BBS score (effect size of 0.210 and 0.308 respectively; $p<0.05$).

Table 4. Changes in outcome measures

	Intervention group (N=14)		Control group (N=10)		Group effect	Time effect	Group*time interaction effect
	Baseline	Week 8	Baseline	Week 8			
Walking							
6MWD (m)	227±126	285±143	303±117	303±129	0.310	0.192*	0.185*
Upper extremity function							
DASH score	41.0±23.8	31.2±19.8	33.9±26.6	34.5±25.8	0.002	0.113	0.140*
Handgrip paretic hand (kg)	11.7±8.9	13.8±10.0	19.5±15.8	19.4±15.3	0.074	0.038	0.048
Handgrip non paretic hand (kg)	29.6±8.3	29.7±9.3	29.5±8.8	27.9±10.6	0.003	0.019	0.025
Balance							
BBS score	50.8±4.5	54.3±4.4	51.4±7.0	53.0±6.4	0.001	0.308*	0.056
Self-efficacy							
ESES score	34.4±5.3	36.8±3.3	35.7±2.5	35.8±3.1	0.088	0.000	0.143

**Significant result at $p < 0.05$*

6MWD, Six-Minute Walking Distance; DASH, Disabilities of the Arm, Shoulder and Hand; BBS, Berg Balance Scale; ESES, Exercise Self-Efficacy Scale

Discussion

In this study we documented the feasibility of a self-developed 8-week home-based semi-supervised physiotherapy intervention to promote functional walking capacity, UE function and functional balance in chronic stroke survivors living in a LMIC setting.

Feasibility

Fourteen of the twenty people enrolled in the program completed the full program which equals a 70% successful participation rate. Other feasibility studies [42,43] with chronic stroke patients reported similar participation numbers after testing home-based or tele-physiotherapy programs. Our IG had a high exercise self-efficacy. Studies show that self-efficacy is important to stimulate and maintain PA behavior. Haworth et al. [44] demonstrated that self-efficacy might increase apart from an intervention program, which could be seen in our CG.

As could be expected, we had a few dropouts in the IG. The dropouts in the supervised phase were all the result of infrastructural problems and health issues, and not directly related to our intervention program. An environment where the walking area could better be used in rainy conditions and where the sewerage would protect against overflow of access water [45], would further have increased the feasibility of this intervention. It seems warranted that improved infrastructure and safe walking areas should be part of an integral stroke-care plan [45] in the LMIC, since a simple exercise such as walking might be enough to improve functional walking capacity post-stroke [46]. Additionally, more regular medical follow-up after hospital discharge, would improve overall health and increase participation in secondary prevention programs, which should also be an important focus in developing countries as prevention generally is a cost saving strategy in the long run.

A drop out in the tele-supervised phase may indicate a need for further individualization of the home-based program [47] and/or a preference or a need for more supervised therapy sessions before entering the tele-supervised phase.

Adverse events

None of the participants experienced any adverse events, despite that more than half of the study population presented with diabetes and hypertension and/or used diuretics, B-blockers, and/or statins [48].

Acceptability

As exercise was one-on-one in both phases, this intervention can be categorized as labor intensive, but the simplicity of the intervention (requiring no equipment, no expensive technology nor special education) made it possible for the caregiver to help with supervision, especially during the tele-supervised phase. The physiotherapy program was easily fitted in each participants' house and neighborhood. Hence, the participants perceived the intervention as supportive. This follows the rationale that a persons' functioning is the result of dynamic interactions between several factors, such as health conditions and environmental factors [49].

Clinical efficacy

Results from both the intention-to-treat and the per protocol analysis were in line with each other, documenting significant effects in 6MWD and DASH score. The observed improvement in 6MWD in the IG (57m) was similar to findings from other home- and community-based studies (range 45-85m) [19,50]. The minimal clinical important difference for the 6MWD in patient studies with stroke is between 34-50 m [51,52] so it can be concluded that the program was effective in improving walking capacity. Our study had a power of 0.6 with an effect size of 0.18. In order to confirm our findings, a full scale RCT with a power of 0.8 would need twenty-three participants in each treatment group in order to be able to reject the null hypothesis (type I error probability 0.05).

Also consistent with the findings of Gordon et al. [46], the IG in our study increased in their distance walked, which then has implications for functional ambulation and participation in the community. We expected this improvement in the IG. However, we did not find any effect on paretic and non-paretic HG. This might be explained by UE functional recovery, which appears to be slower than that of the lower extremity [53]. Moreover, both groups show a large SD for the paretic and non-paretic HG strength, which might be a consequence of our small sample size. The latter might also explain why we did not find any statistical difference between IG and CG for this variable. Considering the effects found in the DASH score and HG strength (at baseline and after the program), the fact that HG strength represents overall physical strength [54,55], and its influence on functional walking capacity [56], we advise a full scale RCT to include both of these measurements to further investigate this.

At last, the improvement of functional balance alongside functional walking capacity in the IG, can be explained by the correlation between these two measurements in post-stroke patients [57]. But, compared to the CG we did not find a difference for functional balance between groups, as they both seemed to be at the same level after 8 weeks. And, possibly, the BBS reached its ceiling effect in this study group making it difficult to evaluate balance improvement [58] between groups. A future trial should probably look into a different strategy to assess balance as this is an important aspect of physical fitness and important in the prevention of falls.

Limitations and strengths

Ideally, a full-scale RCT should stratify for age and sex in order to exclude effects of these factors. In the context of Suriname, ethnic background might also need to be considered in the stratification as cultural differences might warrant therapeutically different approaches. In our study no baseline differences were found for these factors. In a powered efficacy trial, it is also advised to have a T4 measurement for the CG, but because of limited resources along with the main objective of evaluating feasibility of the full intervention, we decided to exclude this.

The study measurements were not performed by a blinded researcher as the full study was executed by one investigator, assisted by master students. Although all possible efforts were made to conduct the measurements in a standardized manner, potential bias from knowing the group allocation cannot be ruled out.

The 6MWT was an appropriate alternative compared to the peak oxygen uptake measured by a symptom-limited graded cardiopulmonary exercise test (CPET). Initially, peak oxygen uptake was set as primary outcome of this study, however due to technical problems and unavailability of timely technical support and resources for repair of this lab infrastructure, this evaluation could not be performed in the majority of participants. Therefore, results from the 6MWT also included in the protocol, were used to evaluate the primary outcome measure of walking capacity. The 6MWT requires minimal equipment, was conducted in our institute by paramedical personnel and without any adverse events. Furthermore, the self-efficacy questionnaire in this study was originally constructed for the spinal cord injury population. Haworth et al. [44] used a self-constructed exercise self-efficacy scale (ESS) in a group with stroke and SCI patients (grouped as patients with acquired neurological pathologies). Though, the psychometric properties were not established for the ESS, it was successfully used for both the stroke and SCI population. And compared to the ESES we did not notice any differences in the questions. A part of the encountered stroke population during the recruitment phase was not fit enough for this intervention, hence an adapted program for them might be needed and our program and study results cannot be generalized to the entire chronic stroke population. Furthermore, as time of chronicity showed large variability and a maximum time of chronicity was not included in the eligibility criteria, there may have been large variability of health conditions between participants as well. However, all participants could benefit from physiotherapy. Similarly, our study results do not allow for drawing conclusions as to whether or not differences in comorbidities in the study groups have influenced intervention efficacy.

Conclusions

Our findings suggest that our home-based semi-supervised physiotherapy intervention is safe, associated with moderate to high levels of engagement and patient satisfaction and induces walking improvement. However, conducting a full-scale RCT might imply the need to tackle infrastructural problems in this LMIC. Larger studies are warranted for confirmation of efficacy, cost-effectiveness and ethnic/cultural effects.

References

1. Kraft GH, Fitts SS, Hammond MC. Techniques to improve function of the arm and hand in chronic hemiplegia. Archives of physical medicine and rehabilitation 1992;73:220-7.
2. Bang DH, Shin WS. Effects of robot-assisted gait training on spatiotemporal gait parameters and balance in patients with chronic stroke: A randomized controlled pilot trial. NeuroRehabilitation 2016;38:343-9.
3. Ferrarello F, Baccini M, Rinaldi LA, et al. Efficacy of physiotherapy interventions late after stroke: a meta-analysis. J Neurol Neurosurg Psychiatry 2011;82:136-43.
4. Duncan P, Studenski S, Richards L, et al. Randomized clinical trial of therapeutic exercise in subacute stroke. Stroke; a journal of cerebral circulation 2003;34:2173-80.
5. Pang MY, Eng JJ, Dawson AS, McKay HA, Harris JE. A community-based fitness and mobility exercise program for older adults with chronic stroke: a randomized, controlled trial. J Am Geriatr Soc 2005;53:1667-74.
6. Group CS. Therapy-based rehabilitation services for stroke patients at home. Cochrane Database of Systematic Reviews 2003.
7. Young JB, Forster A. The Bradford community stroke trial: results at six months. BMJ 1992;304:1085-9.
8. Green J, Forster A, Bogle S, Young J. Physiotherapy for patients with mobility problems more than 1 year after stroke: a randomised controlled trial. Lancet 2002;359:199-203.
9. Langhammer B, Stanghelle JK. [Physiotherapy after stroke--a randomized controlled trial]. Tidsskr Nor Laegeforen 2001;121:2805-9.
10. Shutter L, Whyte J. Increased intensity of physiotherapy after stroke. Stroke; a journal of cerebral circulation 1999;30:2242-3.
11. Glasgow Augmented Physiotherapy Study g. Can augmented physiotherapy input enhance recovery of mobility after stroke? A randomized controlled trial. Clin Rehabil 2004;18:529-37.
12. John B Young AF. The Bradford community stroke trial: eight week results. 1991;5.
13. Piron L, Tonin P, Trivello E, Battistin L, Dam M. Motor tele-rehabilitation in post-stroke patients. Med Inform Internet Med 2004;29:119-25.
14. Sarfo FS, Ulasavets U, Opare-Sem OK, Ovbiagele B. Tele-Rehabilitation after Stroke: An Updated Systematic Review of the Literature. J Stroke Cerebrovasc Dis 2018;27:2306-18.
15. American Telemedicine Assocation Telemedicine frequently asked questions (FAQs). 2013. at http://www.americantelemed.org/learn/what-is-telemedicine/faqs.)
16. Reunanen MA, Jarvikoski A, Talvitie U, Pyoria O, Harkapaa K. Individualised home-based rehabilitation after stroke in eastern Finland--the client's perspective. Health Soc Care Community 2016;24:77-85.
17. Gladman J, Forster A, Young J. Hospital- and home-based rehabilitation after discharge from hospital for stroke patients: analysis of two trials. Age Ageing 1995;24:49-53.
18. Young J, Forster A. Day hospital and home physiotherapy for stroke patients: a comparative cost-effectiveness study. J R Coll Physicians Lond 1993;27:252-8.
19. Marsden DL, Dunn A, Callister R, McElduff P, Levi CR, Spratt NJ. A Home- and Community-Based Physical Activity Program Can Improve the Cardiorespiratory Fitness and Walking Capacity of Stroke Survivors. J Stroke Cerebrovasc Dis 2016;25:2386-98.
20. Dodakian L, McKenzie AL, Le V, et al. A Home-Based Telerehabilitation Program for Patients With Stroke. Neurorehabil Neural Repair 2017;31:923-33.
21. Siemonsma P, Dopp C, Alpay L, Tak E, Meeteren N, Chorus A. Determinants influencing the implementation of home-based stroke rehabilitation: a systematic review. Disability and rehabilitation 2014;36:2019-30.
22. Linder SM, Rosenfeldt AB, Reiss A, et al. The home stroke rehabilitation and monitoring system trial: a randomized controlled trial. Int J Stroke 2013;8:46-53.

23. Pandian JD, Felix C, Kaur P, et al. FAmily-Led RehabiliTaTion aftEr Stroke in INDia: the ATTEND pilot study. Int J Stroke 2015;10:609-14.
24. Jones KM, Bhattacharjee R, Krishnamurthi R, et al. Methodology of the Stroke Self-Management Rehabilitation Trial: an international, multisite pilot trial. J Stroke Cerebrovasc Dis 2015;24:297-303.
25. Yan LL, Chen S, Zhou B, et al. A randomized controlled trial on rehabilitation through caregiver-delivered nurse-organized service programs for disabled stroke patients in rural china (the RECOVER trial): design and rationale. Int J Stroke 2016;11:823-30.
26. Kamwesiga JT, Eriksson GM, Tham K, et al. A feasibility study of a mobile phone supported family-centred ADL intervention, F@ce, after stroke in Uganda. Global Health 2018;14:82.
27. M. van Dijk EvdS, H. van Vlaardingen, E. Vollebregt. Minor beyond borders: Ketenzorg in Suriname bij een CVA. Suriname: Revalidatiecentrum Paramaribo, Hogeschool Rotterdam, Instituut voor Gezondheidszorg; 2019 Januari 2019.
28. Gibbons RJ, Balady GJ, Bricker JT, et al. ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). J Am Coll Cardiol 2002;40:1531-40.
29. Orsmond GI, Cohn ES. The Distinctive Features of a Feasibility Study: Objectives and Guiding Questions. OTJR (Thorofare N J) 2015;35:169-77.
30. Eng JJ, Dawson AS, Chu KS. Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil 2004;85:113-8.
31. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996;29:602-8.
32. Sunderland A, Tinson D, Bradley L, Hewer RL. Arm function after stroke. An evaluation of grip strength as a measure of recovery and a prognostic indicator. J Neurol Neurosurg Psychiatry 1989;52:1267-72.
33. Makizako H, Kabe N, Takano A, Isobe K. Use of the Berg Balance Scale to predict independent gait after stroke: a study of an inpatient population in Japan. PM & R : the journal of injury, function, and rehabilitation 2015;7:392-9.
34. Nooijen CF, Post MW, Spijkerman DC, Bergen MP, Stam HJ, van den Berg-Emons RJ. Exercise self-efficacy in persons with spinal cord injury: psychometric properties of the Dutch translation of the Exercise Self-Efficacy Scale. Journal of rehabilitation medicine 2013;45:347-50.
35. Hale LA, Piggot J. Exploring the content of physiotherapeutic home-based stroke rehabilitation in New Zealand. Archives of physical medicine and rehabilitation 2005;86:1933-40.
36. Moore SA, Hallsworth K, Jakovljevic DG, et al. Effects of Community Exercise Therapy on Metabolic, Brain, Physical, and Cognitive Function Following Stroke: A Randomized Controlled Pilot Trial. Neurorehabil Neural Repair 2014.
37. Claes J, Buys R, Avila A, et al. Validity of heart rate measurements by the Garmin Forerunner 225 at different walking intensities. J Med Eng Technol 2017;41:480-5.
38. Sage M, Middleton LE, Tang A, Sibley KM, Brooks D, McIlroy W. Validity of rating of perceived exertion ranges in individuals in the subacute stage of stroke recovery. Top Stroke Rehabil 2013;20:519-27.
39. Kamal AK, Shaikh Q, Pasha O, et al. A randomized controlled behavioral intervention trial to improve medication adherence in adult stroke patients with prescription tailored Short Messaging Service (SMS)-SMS4Stroke study. BMC Neurol 2015;15:212.
40. Vanroy C, Vissers D, Cras P, et al. Physical activity monitoring in stroke: SenseWear Pro2 activity accelerometer versus Yamax Digi-Walker SW-200 pedometer. Disability and rehabilitation 2014;36:1695-703.
41. Baert I, Feys H, Daly D, Troosters T, Vanlandewijck Y. Are patients 1 year post-stroke active enough to improve their physical health? Disability and rehabilitation 2012;34:574-80.

42. Simpson B, McCluskey A, Lannin N, Cordier R. Feasibility of a home-based program to improve handwriting after stroke: a pilot study. Disabil Rehabil 2016;38:673-82.
43. Sarah Carroll CG, Susan Lewis, Marion McMurdo, Falko Sniehotta, Marie Johnston, Derek Johnston, Judy Scopes, Gillian Mead. The use of pedometers in stroke survivors: are they feasible and how well do they detect steps? Arch Phys Med Rehabil 2012:466-70.
44. Haworth J, Young C, Thornton E. The effects of an 'exercise and education' programme on exercise self-efficacy and levels of independent activity in adults with acquired neurological pathologies: an exploratory, randomized study. Clin Rehabil 2009;23:371-83.
45. Moran M, Van Cauwenberg J, Hercky-Linnewiel R, Cerin E, Deforche B, Plaut P. Understanding the relationships between the physical environment and physical activity in older adults: a systematic review of qualitative studies. Int J Behav Nutr Phys Act 2014;11:79.
46. Gordon CD, Wilks R, McCaw-Binns A. Effect of aerobic exercise (walking) training on functional status and health-related quality of life in chronic stroke survivors: a randomized controlled trial. Stroke 2013;44:1179-81.
47. Caetano LCG, Pacheco BD, Samora GAR, Teixeira-Salmela LF, Scianni AA. Self-Efficacy to Engage in Physical Exercise and Walking Ability Best Predicted Exercise Adherence after Stroke. Stroke Res Treat 2020;2020:2957623.
48. Bouchard MP. Medications and exercise. ACSM's Health & Fitness Journal 2012;16:34-6.
49. Bilbao A, Kennedy C, Chatterji S, Ustun B, Barquero JL, Barth JT. The ICF: Applications of the WHO model of functioning, disability and health to brain injury rehabilitation. NeuroRehabilitation 2003;18:239-50.
50. Moore SA, Jakovljevic DG, Ford GA, Rochester L, Trenell MI. Exercise Induces Peripheral Muscle But Not Cardiac Adaptations After Stroke: A Randomized Controlled Pilot Trial. Arch Phys Med Rehabil 2016;97:596-603.
51. Ada Tang JE, Debbie Rand. Relationship between perceived and measured changes in wlaking after stroke J Neurol Phys Ther 2013;36:115-21.
52. Perera S, Mody, S., et al. Meaningful change and responsiveness in common physical performance measures in older adlts. Journal of the American Geriartrics Society 2006;54:743-9.
53. Lee KB, Lim SH, Kim KH, et al. Six-month functional recovery of stroke patients: a multi-time-point study. International journal of rehabilitation research Internationale Zeitschrift fur Rehabilitationsforschung Revue internationale de recherches de readaptation 2015;38:173-80.
54. Garcia PA, Dias JM, Dias RC, Santos P, Zampa CC. A study on the relationship between muscle function, functional mobility and level of physical activity in community-dwelling elderly. Rev Bras Fisioter 2011;15:15-22.
55. Eng JJ, Chu KS, Dawson AS, Kim CM, Hepburn KE. Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. Stroke; a journal of cerebral circulation 2002;33:756-61.
56. Zhang Q, Lu H, Pan S, Lin Y, Zhou K, Wang L. 6MWT Performance and its Correlations with VO(2) and Handgrip Strength in Home-Dwelling Mid-Aged and Older Chinese. Int J Environ Res Public Health 2017;14.
57. Pohl PS, Duncan PW, Perera S, et al. Influence of stroke-related impairments on performance in 6-minute walk test. J Rehabil Res Dev 2002;39:439-44.
58. Chen H, Smith SS. Item Distribution in the Berg Balance Scale: A Problem for Use With Community-Living Older Adults. J Geriatr Phys Ther 2019;42:275-80.

Chapter 6

General discussion

This dissertation was divided into two parts: three cross-sectional studies and one longitudinal study. In short, the aims of these studies were:

1. A. To describe the prevalence of stroke in urban Suriname in association to ethnic background.
   B. To study the relationship between functional walking capacity and upper extremity (UE) function.
   C. To explore factors associated with a low physical activity (PA) level.
2. To test the feasibility of semi-supervised home-based PA interventions since PA is shown to be reduced in post-stroke survivors[1].

We elaborate on the aims of each of the studies followed by methodological considerations, the impact of this dissertation and, at the end, we propose recommendations for future stroke research.

Modification of post-stroke PA through interventions faces implementation problems due to fewer patient care resources like environmental and infrastructural problems as well as fragmented health care services. Moreover, in some ethnic groups the risk for stroke and other cardiovascular disorders is higher, for instance, the prevalence of stroke is higher for Hispanics in the USA compared to Caucasians[2]. Hence, due to the multi-ethnic population of Suriname it is important to include ethnic background as a stroke-related risk factor[3,4] in this dissertation.

6.1 The prevalence of stroke in association to ethnic background

In chapter 2 we found a difference in the prevalence of several risk factors for stroke among the ethnic groups: Hindustani, Creole, Maroon and Javanese. Hindustani reported more diabetes and dyslipidaemia compared to the other ethnic groups. In addition, Creoles reported a higher prevalence of smoking. For high blood pressure, which is an independent risk factor for stroke[5], no difference was found between ethnic groups. Our findings are in line with other studies that show Hindustani's to have a higher risk for diabetes mellitus compared to other ethnicities [6,7]. Likewise, another study showed higher smoking habits in Creoles[3]. This national study [3] reported higher prevalence of dyslipidaemia in the Creoles followed by the Javanese, which is opposed to our findings. In this national study a higher prevalence of mean diastolic and systolic hypertension was found in Hindustani and Creoles, respectively [3]. These differences might be explained by the fact that in our study we reported on overall blood pressure, not discriminating between diastolic and systolic blood pressure. Moreover, the national study[3] included a larger and mixed rural/urban sample of relatively healthy Surinamese citizens, whereas we merely included citizens from urban Suriname.

Furthermore, in contrast to our findings, studies in the USA reported ethnic differences in the prevalence of stroke[8,9]. This contrast may be explained by the fact that genetic, other environmental and lifestyle factors can influence the relationship between ethnic background and the prevalence of stroke. For example, a study[10] in Singapore did not identify ethnicity as a causation of stroke but underscored a predisposition in South Asians for vascular disease. Additionally, other risk factors such as a lack of adequate PA levels or dietary habits, which were not assessed in our study, are known to differ in ethnic groups within the general population of Suriname[4,11]. For example, compared to Hindustani, the Javanese reported the lowest percentage adequate PA levels[4]. Additionally, a dietary study claimed that Hindustani reportedly consumed more soft drinks compared to other ethnic groups[11]. Moreover, some lay belief systems may also co-exist, for instance, African and African Caribbean women reportedly believed that the cause of their stroke was due to witchcraft or someone wishing them wrong, suggesting an apparent lack of control over stroke[12]. Finally, it was evident that the population with stroke in the HELISUR study had at least one comorbid condition, which supports the need for more research in this multi-ethnic population. Moreover, lack of an adequate physical activity level is another stroke-related impairment and risk factor for recurrent stroke.

6.2 Factors associated to reduced physical activity levels after stroke

In chapter 4 we expected the low level of PA because this was already stated in literature amongst other stroke populations [13], the population with chronic disabilities [14] as well as in the local population [4]. In the latter differences were found along ethnic lines, which was not the case in our study. This might be explained by ethnic disbalance in our study group, but could also have resulted from other variables such as stroke-related impairments. Especially when these findings for PA level were not related to demographic and socio-economic variables. However, the low level of PA is to be expected in post-stroke survivors, especially in combination with high perceived exercise-barriers [15]. Our study participants reported a high average number of barriers, which is in line with other stroke studies [15,16]. Between ethnic groups these environmental/facility PA-barriers were identical, however individual exercise barriers were distinct. These environmental/facility exercise-barriers were also demonstrated in studies from HIC [15], LMIC [16], the general population [17] as well as the specific neurological populations [15,18]. In contrast, individual exercise-barriers were distinct across other stroke studies e.g., while stroke survivors from Nigeria [13] reported barriers such as being embarrassed to exercise, American stroke participants reported lack of interest [15]. It was notable that while patients from Asian descent mostly reported not knowing how to exercise as an exercise-barrier, patients from Non-Asian descent mostly reported being injured from exercising as an exercise-barrier. For all these different findings in ethnic groups, our study as well as other national studies [3,19,20] underscore the design and development of ethno-specific programs.

Furthermore, the most relevant factors that future PA interventions should consider, are related to personal factors such as *fatigue, lack of interest, not knowing how to exercise, lack of family support, PA will worsen my condition and structured PA will not change my condition* and "*feeling that an exercise instructor would not be able to develop a PA program according to the needs of someone with a stroke*". These reported barriers may constitute major challenges for the uptake and facilitation of regular physical activity Sometimes people think that exercise is boring ("lack of interest"). This attitude might also be part of the pre-stroke status, since low levels of PA and PF are both risk factors for stroke [21]. It may be more difficult for someone with a sedentary lifestyle to pick up physical activity because fatigue will come during PA [21].

Fatigue, defined as a feeling of physical tiredness and lack of energy [22], might be the consequence or result of an overall low physical fitness level of a stroke survivor[21]. Moreover, the overall imbalanced dietary intake of an average Surinamese [11] in combination with chronic comorbidities such as hypertension and diabetes (as discussed in **chapter 2)** in a stroke survivor might induce fatigue symptoms during PA. In such cases, perhaps extrinsic motivation (by introducing incentives) during a personalised physiotherapy exercise program in combination with patient education might help the patient to start up small activities further improving the intensity gradually in order to increase overall endurance over time [23].

Moreover, despite low PA levels, scores on exercise self-efficacy were good. Most of our participants were interested in starting an exercise program and felt that it would improve their condition. The most common personal PA-barrier was: "*feeling that an exercise instructor would* *not be able to develop a PA program according to the needs of someone with a stroke*", which may explain why we see these barriers in combination with a high self-efficacy. Literature shows that self-efficacy explains PA adherence in chronic stroke survivors[24]. The high level of self-efficacy in our cohort might indicate that they believe to have the capability to reach and maintain a healthy level PA. That it still does not result in a higher PA level in our study might be due to the presence of several environmental/facility barriers and the lack of specific exercise programs for stroke [24] or the presence of other stroke-related impairments (see **chapter 2 and 3**). Moreover, that most of our study population were interested in starting an exercise program suggests that they are already intrinsically motivated to perform exercise and need tailored structured programs by trained exercise instructors in order to prevent overjustification [23].

Following the results in chapter 4, demographic and socio-economic variables did not explain low PA levels. Education and income are commonly studied, but conflicting results have been reported. This suggests more research in other potential factors limiting post-stroke PA. Lower education levels may be related with a lower income, which is depicted by the commonality of exercise barriers found across these groups in our study and in line with findings of other stroke survivors[15,16]. Lower incomes could result from difficulties of stroke survivors to find work which in turn could induce low self-esteem, and low confidence which may further lower participation in exercise, as such introducing a negative vicious circle [25,26]. All of these findings underscored a complex interaction of issues in the capacity, motivation and opportunity category from the COM-B model from Michie et al. (2011) [27]. Hence, there is an important need for the development of a PA program that considers interventions [27] such as education, persuasion, incentivization, training and stratification according to ethnic background. Michi et al. (2011) [27] proposes a framework that involves three essential conditions: capability, opportunity and motivation, termed as COM-B system. It proposes nine intervention functions and seven policy categories aimed at addressing these conditions. However, before starting the development of a PA program, it was important to improve our insight in the six-minute walk test (6MWT), a frequently used test in most stroke studies [28,29] since it was well tolerated by patients and better reflects ADL than other walking tests [28,30,31]. Hereby, it was notable that handgrip strength and functional walking capacity, two important indicators of functional recovery after stroke [32,33], are also related to ethnic background [34-36]. For example, a study in New York [37] stated that there are differences in hand grip strength, walking speed and body mass index within several Asian groups. These variables are known to be associated to 6MWD [32,38,39]. Teramoto et al. [40], however, suggested no difference in 6MWD at any age between Caucasians and non-Caucasians (Asians). But a Surinamese study already suggests that cut-off values for BMI differs between ethnic groups [41]. This suggests that there is more need for research regarding differences along ethnic lines for functional walking capacity and grip strength.

6.3 The association between UE function and functional walking capacity

Following the results from chapter 3 we found an association between a decreased paretic handgrip strength and a lower 6MWT performance. A possible explanation might be that both of these parameters are indicators of overall muscle strength as they appear to be associated to other muscle groups of the body [32,42,43]. The findings of this study are complementary to a previous study among elderly where the 6MWT performance and handgrip strength (HGS) were correlated to each other [44]. In this population of elderly muscle loss due to aging, vascular disease and malnutrition was evident [45]. Moreover, literature indicates that the estimated prevalence of stroke-related sarcopenia is 42% [46]. Our results might, therefore, be a consequence of overall aging, frailty [47], Sarcopenia or functional recovery after stroke. However, this does not explain the influence of the BBS and SLR on the relationship between non-paretic HGS and the 6MWT.

Explaining the association between non-paretic handgrip strength (HGNP) and the 6MWT by balance control and gait asymmetry is less evident. Non-paretic HGS, associated to the ipsilateral muscle strength in post-stroke survivors [48], is important for compensation of the affected arm. Moreover, it is also important for forward movement of the body in post-stroke survivors [49].While previous studies underscore the presence of compensation strategies [50,51] during hemiparetic gait, the 6MWT appeals to exertion of maximum effort requiring more muscle work and coordination between segments. In these situations, it is to be expected that compensation strategies, including excessive arm work [52], will increase due to (neuro)muscular fatigue mechanisms [53-55] that, ultimately might limit overall 6MWT performance, most likely also due to the already increased cost of hemiparetic gait [56]. This might explain why the relationship between non-paretic HGS and the 6MWT is influenced by the BBS and SLR (or gait asymmetry). Moreover, the altered coordination in stroke survivors between affected arm and unaffected leg, compared to the unaffected arm and affected leg [49], is more likely to be manifested due to a relatively increased gait speed during this test.

Furthermore, we demonstrated no association between functional walking capacity and paretic UE function quantified by the DASH and the SIS (hand function domain). We did not expect this, but a possible explanation might be that compared to handgrip tests, these surveys take more items such as fine UE motor skills (for example, tying a shoe lace), symptomatic (for example, do you have pain in your arm?), environmental (for example, are you able to sleep due to pain in your arm? Are you able to use the same technique during your work?) and social items (for example, problems during sexual activities) into account [57,58]. In contrast to our study, the study by Muren et al. (2008) [59] in stroke survivors showed a positive correlation between the SIS (hand function domain) and the 6MWT. Compared to our study, the variation in sample size, BMI score and level of functional walking capacity in the study by Muren et al. (2008) are factors that might be responsible for these discrepancies. Moreover, there could be other factors overseen in the association between UE function and the 6MWT, as the UE exists of different segments connecting the hand via the shoulder and the trunk to the lower limbs. For instance, it has been demonstrated that trunk control (sitting for 30 seconds) predicted independent walking ability and motor functional outcome [60]. Additionally, literature indicated that, for example, active finger extension was able to predict recovery of function of the paretic arm. Thus, alternatives for UE movement and function scales could have been active finger extension [61], shoulder abduction, the Nine Hole Peg Test in combination with Motricity Index and the Frenchay Arm Test [62]. However, the DASH and SIS surveys were preferred because they were useful as self-administrated tools in this low resource setting.

In the future we might need to adapt the term “arm recovery” instead of “UE function” to include measures of body functions or structure (such as muscle strength) and activities and participation (such as the ability to perform work with the same technique with the paretic arm).

Our study highlights that the association between paretic HGS and the 6MWT is stronger that the associations of non-paretic handgrip strength, sex, age, balance control, gait asymmetry and the 6MWT. The study findings encourage the need for more research on influential factors of the 6MWT performance such as active finger extension or trunk control in order to be able to improve our insight in the performance of functional walking capacity. From this study we gathered valuable information to help the development of the feasibility study.

6.4 Feasibility study

According to the behaviour change wheel by Michie et al. (2011) [27], there are nine intervention strategies of which a few apply according to the exercise barriers reported by our study group, namely education, persuasion, incentivization, training, environmental restructuring and enablement. From these nine intervention strategies, we adapted a few straightaway in our physiotherapy intervention to minimize implementation problems of the program. Additionally, according to the division of the ICF model, we provide facilitation in the area of “functionality” and “disability” of the post-stroke survivor [63] which is in line with the American Heart Association (AHA) Stroke Recommendations [64]. We assume that with this intervention, our study indirectly influences positive outcomes for participation, which is part of the ICF model as is recommended by the AHA Stroke Guidelines [63].

Feasibility

Out of twenty participants, fourteen completed the 8-week physiotherapy program—elaborated in **chapter 5**—, which is comparable to the 70% success rate also seen in other feasibility studies [65,66] amongst stroke survivors. Our IG had a high exercise self-efficacy. Studies show that self-efficacy is important to stimulate and maintain PA behavior. Haworth et al. [67] demonstrated that self-efficacy might increase apart from an intervention program, which could be seen in our CG.

As could be expected, we had a few dropouts in the IG. The dropouts in the supervised phase were all the result of infrastructural problems and health issues, and not directly related to our intervention program. An environment where the walking area could better be used in rainy conditions and where the sewerage would protect against overflow of access water [68], would further have increased the feasibility of this intervention. It seems warranted that improved infrastructure and safe walking areas should be part of an integral stroke-care plan [68] in the LMIC, since a simple exercise such as walking might be enough to improve functional walking capacity post-stroke [69]. Additionally, more regular medical follow-up after hospital discharge, would improve overall health and increase participation in secondary prevention programs, which should also be an important focus in developing countries as prevention generally is a cost saving strategy in the long run.

A drop out in the tele-supervised phase may indicate a need for further individualization of the home-based program [24] and/or a preference or a need for more supervised therapy sessions before entering the tele-supervised phase.

None of the participants experienced any adverse events, despite that more than half of the study population presented with diabetes and hypertension and/or used diuretics, B-blockers, and/or statins [70]. In fact, we do not expect any further impact due to this, as there was also no change in the type of medication and dosage of the medication during the intervention program [71]

As exercise was one-on-one in both phases, this intervention can be categorized as labor intensive, but the simplicity of the intervention (requiring no equipment, no expensive technology nor special education) made it possible for the caregiver to help with supervision, especially during the tele-supervised phase. The physiotherapy program was easily fitted in each participants' house and neighborhood. Hence, the participants perceived the intervention as supportive. This follows the rationale that a persons' functioning is the result of dynamic interactions between several factors, such as health conditions and environmental factors [63]. Moreover, our program not only facilitated communication between the caregiver and the patient but also between the therapist and the caregiver. Unfortunately, we did not include interviews with the caregiver in this study. It is advisable to include the caregiver's point of view regarding the feasibility of the home-based semi-supervised program [72], since involvement of the caregiver motivates higher post-stroke PA [73].

Socio-economic adaptations

Apart from environmental barriers, financial issues were reported as barriers in **chapter 4**. In **chapter 5** we therefore calculated the number of the supervised sessions in the intervention based on the maximal number of treatments covered annually by insurance companies in Suriname and based on a combination of earlier studies [74,75]. The largest insurance company in Suriname only reimburses 10 physiotherapy treatments per year for 55% of the amount of each session. In 12 treatments of supervised sessions at home, we demonstrated improvement in mobility, in terms of functional walking capacity and functionality. Due to truncated insurance coverage, we decided to administer the next 12 treatments via tele-supervision. However, if the current intervention form is to be applied in Suriname the patient must pay 45% of each of these ten treatments, whilst two supervised sessions and 12 semi-supervised sessions have to be paid for 100% by the patient.

Clinical efficacy

Results from both the intention-to-treat and the per protocol analysis were in line with each other, documenting significant effects in 6MWD and DASH score. The observed improvement in 6MWD in the IG (57m) was similar to findings from other home- and community-based studies (range 45-85m) [76,77]. The minimal clinical important difference for the 6MWD in patients with stroke is 44 m[78] so it can be concluded that the program was effective in improving walking capacity. However, our study had a power of 0.6 with an effect size of 0.18, which means that a larger sample size is needed in order to prove effectivity of this program. In order to confirm our findings, a full scale RCT with a power of 0.8 would need twenty-three participants in each treatment group in order to be able to reject the null hypothesis (type I error probability 0.05).

Also consistent with the findings of Gordon et al. [69], the IG in our study increased in their distance walked, which then has implications for functional ambulation and participation in the community. We expected this improvement in the IG. However, we did not find any effect on paretic and non-paretic HG. This might be explained by the chronicity of stroke in this study population, ageing[44] and the proportional recovery after stroke. Moreover, both groups show a large SD for the paretic and non-paretic HG strength, which might be a consequence of the heterogeneity in arm strength in our study population. The latter might also explain why we did not find any statistical difference between IG and CG for this variable. Considering the effects found in the DASH score and HG strength (at baseline and after the program), the fact that HG strength represents overall physical strength [79,80], and its influence on functional walking capacity [44], we advise a full scale RCT to include both of these measurements to further investigate this.

At last, the improvement of functional balance alongside functional walking capacity in the IG, can be explained by the correlation between these two measurements in post-stroke patients [55]. But, compared to the CG we did not find a difference for functional balance between groups, as they both seemed to be at the same level after 8 weeks. And the BBS reached its ceiling effect in this study group making it difficult to evaluate balance improvement [81] between groups. A future trial should probably look into a different strategy to assess balance as this is an important aspect of physical fitness and important in the prevention of falls.

Our findings from our pilot study suggest that our home-based semi-supervised physiotherapy intervention is safe, associated with moderate to high levels of engagement and patient satisfaction and shows a small effect on walking improvement. However, conducting a full-scale RCT might imply the need to tackle infrastructural problems in this LMIC. Larger studies are warranted for confirmation of efficacy, cost-effectiveness and ethnic/cultural effects. Our study specifically targets lower middle-income countries where less technically advanced assessments such as the 6MWT are a better alternative compared to cardiopulmonary exercise testing. This study provides efficacy estimates to inform sample size calculation and best primary outcome measures for designing a properly powered randomized controlled trial in the future.

6.4 Methodological considerations

The evaluation tools used in the feasibility study, the Yamax Digiwalker SW-200, Garmin Forerunner 225 and the DASH questionnaire, were all validated in small local and unpublished studies [82,83] before being used to measure changes in physical activity and paretic UE function in chronic stroke survivors before, during and after the physiotherapy program. The DASH was validated due to a lack of studies [84,85] for assessment of UE function in post-stroke patients compared to other questionnaires[86], however areas for improvement were identified. Therefore, a sub-analysis was conducted to minimize bias from the DASH. We demonstrated a correlation between the DASH and the SIS hand function and handgrip strength (**chapter 3**). After conducting a systematic review (**addendum I**, unpublished), we found no clear level of evidence for the reliability, validity and accuracy of the physical activity monitors for chronic stroke survivors regarding walking distance, step count, walking speed and energy expenditure. The algorithm of the Garmin device was not disclosed and likely based on healthy individuals, therefore, possibly underestimating energy expenditure in stroke survivors[56]. Similarly, the pedometer might also underestimate the number of steps. This finding was in line with a recent review [87] about the level of PA across all stages of stroke. Keeping abovementioned factors in mind, it was considered feasible to use the Garmin Forerunner 225 for measurement of the heart rate during exercise[88] and the Yamax Digiwalker SW-200 as a motivational tool during the PA intervention [89] and the DASH questionnaire for assessment of UE function (**chapter 3 and 5**).

Moreover, these devices were worn only on the non-paretic side of the body, without use of assistive devices and during low ambulation [90].

In future clinical trials it is advisable to include at what stage of Behaviour Change, the participants engage in regular physical activity [91]. For example, the transtheoretical model describes five stages associated with behaviour change. The physiotherapist can identify a patient's readiness to change and tailor their intervention accordingly. Apart from physical and cognitive limitations and the level of exercise self-efficacy, people after stroke might suffer from misconceptions of their competency to carry out tasks [92]. Moreover, it is important to include the area of the brain that was affected. For example, complex gait patterns might be seen after cerebellar stroke resulting in ataxic gait. This might influence conclusions based on an effect of an intervention when improvement and/or assessment of gait is implemented. In addition, complex motor activities are more related to the left hemisphere[93]. Voos et al. (2008) reported greater impairment of voluntary movement in right-handed left hemispheric injured people due to stroke. Consequently, greater performance loss might be seen in right-handed people with left hemispheric injuries[93] and future studies should try to stratify for these differences. Finally, it is advised that future studies apply a minimum and maximum time for chronicity to the inclusion criteria as it might influence the performance during assessment of, for instance, gait performance [94].

In addition, cultural factors might influence PA performance negatively[95]. It should also be acknowledged that a limitation of our association studies (**chapter 3-4**) is the lack of dietary, cultural, genetic and other behavioural differences of the separate ethnic groups. Due to the small sample size Javanese and Hindustani were categorized as Asian and Creole and Maroons as African descent people. Due to random recruitment of stroke patients and the small sample size, our study resulted in an imbalanced ethnic study group.

Due to the financial crisis in Suriname, we mostly used self-reported data (**chapter 2-5)** and an easily obtainable test for functional walking capacity (the 6MWT) which demands less resources (**chapter 4 & 5**) [96]. Additionally, the Garmin watches were borrowed for free from KU LEUVEN and the pedometers were bought from VLIR-UOS funds. Furthermore, it is important to point out that questionnaires have a lower validity compared to objective measures as they depend on the participants' memory and interpretation. In addition, we also needed to take into account that people respond with socially desirable answers [97]. Nonetheless, self-reports have been shown to be valid and cost-effective [98]. A trend of underreporting rather than over reporting of stroke events, is mentioned in studies with self-reported data [99,100]. The former, emphasizes the need for effective PA interventions in treating the consequences of stroke.

At last, future research should incorporate cost-effectiveness of the program, because for this physiotherapy program the participants did not have to pay for the measurements or therapy sessions (**chapter 5**). Hence, this might have stimulated a large group participation (n > 50) [9], since one of the PA-barriers was "costly PA programs" (**chapter 4**). In addition, future research should gather information on costs—transportation-, telephone- and equipment costs—to assess cost-effectiveness of the physiotherapy intervention. Results of our feasibility study cannot be blindly extrapolated to international post stroke rehabilitation programs. In general, stroke survivors from other countries or from other regions locally may have other barriers for physical activity than our cohort of stroke survivors. Moreover, our results cannot be generalized to non-ambulatory stroke patients, patients with severe cognitive problems, severe psychological problems, vision problems and other motor disability profiles e.g., hemi-neglect). Future trails might also need to investigate patients from the sub-acute stage of recovery [101]. Thus, we are only presenting a tip of the iceberg.

6.5 General conclusion

To summarize, the hypothesis for a high prevalence in an urban area such as Paramaribo was confirmed, but a relationship between stroke and the four largest ethnic groups was not. Additionally, our hypothesis regarding an association between UE function, quantified as handgrip strength, and functional walking capacity was confirmed. We also confirmed our hypothesis regarding low participation in structured PA programs and ethnic background backed up by several high-perceived exercise barriers per ethnic group. Finally, just as expected the home-based semi-supervised physiotherapy intervention was feasible.

From our findings in this dissertation, we may conclude that stroke risk factors and self-reported exercise-barriers are high and that tailored interventions are needed in Suriname to face the low levels of PA and exercise in chronic stroke survivors. Defragmentation in public health sectors may not improve overall stroke care. Current physiotherapy programs can be developed and adjusted to test the effectivity of our exercise program in another cohort of stroke survivors. In addition, results from the feasibility program may be used to start a national program for changes in stroke policy considering Furthermore, the health profiles of stroke survivors are heterogeneous [102], which emphasizes the need for customized care. Stroke survivors in our study indicate high perceived PA-barriers and this underscores the importance of tailored PA programs, in which the prescription of simple exercise and motivational PA monitors might not be enough.

Ethnic differences in PA behaviour should be studied in collaboration with social scientists like medical anthropologists. Interdisciplinary research might better help to understand the complexities of combined ethnic predisposition, deep cultural roots, lay belief systems, eating behaviour and the devastating economic situation of the country and how it hinders post stroke recovery. Our results indicate the importance of further exploration of change in PA behaviour in chronic stroke survivors, especially after removal of the self-reported PA barriers (as they can change over time) and after application of tailored PA interventions.

Impact of the dissertation and future recommendations

This dissertation indicates that there is a stroke burden in the capital of Suriname. In fact, it provides important knowledge regarding stroke in LMICs, where stroke studies are scarce. Moreover, the results demonstrate that a prevalence study is feasible with limited resources. In addition, this dissertation informs on the feasibility of a physiotherapy home-based semi-supervised intervention in a middle-income country with less financial resources in a multi-ethnic population from different cultural backgrounds. Furthermore, our study underscores that ethnic background influences the level of PA after stroke and, therefore, the necessity for tailored PA interventions.

Furthermore, in Suriname, the fragmented health care services from the inpatient and outpatient setting as well as organizations need to synergize. This is needed in order to establish 1) stroke units for delivering improved primary stroke care [64], 2) integrated rehabilitation teams that are certified for treating patients during the (sub)acute and chronic phase of stroke [64], 3) an integrated regional ambulance service (including helicopter service) for efficient transport to the nearest stroke care unit, 4) less expensive services for healthcare transport, 5) an increase of neighbourhood walkability [103] vis-a-vis better local infrastructure to prevent water floods in the urban area and 6) specialized stroke healthcare packages in which a choice is made for coverage of long-term physiotherapy instead of fragmentation of long-term multidisciplinary services.

During the feasibility study we documented that health problems were an important reason for dropouts as well as unsupervised rehabilitation. Therefore, it seems necessary for stroke survivors to have an intensified/regular medical follow-up, especially given the high prevalence of co-morbidities such as chronic diabetes and chronic hypertension, which is line with what is reported in the literature [75,104]. Preventive measures need to be implemented for non-communicable diseases in every region of the country e.g., environmental/social planning: educational programs, awareness programs in the community, increase neighbourhood walkability, and improvement of sewer drainage to prevent flooding of streets (table 1). Future randomized controlled trials (RCT's) following this feasibility study should cover environmental PA barriers and cost-effectiveness to ensure that the future rehabilitation program will fit into the current and future Surinamese healthcare landscape. Moreover, an improvement in keeping of medical records as well as follow-up on discharged patients can increase medical registration data and facilitate future research in stroke. Regarding this issue, it is advisable to recruit patients from more than one hospital when planning to conduct a full-scale RCT.

Strategies for intervention should seek to influence behaviour of the stroke survivor according to the COM-B model by Michie et al. In addition, these actions should not be limited to the development of guidelines, but more importantly to the implementation through results from local RCT's. Service tasks should be improved by planning workshops for fitness instructors, college drop-outs, rehabilitation specialists and physiotherapists for specialized stroke care to patients at home. Marketing strategies to increase the awareness of stroke and its risk factors should be implemented on daily basis. These strategies can be in the form of awareness campaigns in the community through interactive radio programs, short films, Facebook pages and ads on local television channels. The biggest challenge to these activities is sustainable funding. Nonetheless, the Surinamese Union for Stroke Survivors is an important stakeholder that can contribute to policy content and represent the interests of their members and request the attention of relevant local ministries e.g., registration in the social guide through Ministry of Social Services, restitution of medication through Ministry of Health. In Brazil, for instance, positive results were noted when the National Stroke Policy Act was accepted in 2012 [105]. The act ensured the reimbursement of stroke acute care by the medical hospital, decreased costs of primary care of stroke, and the investment in hospital stroke units. Some of the key elements of the 2012 National Stroke Policy Act of Brazil included: definition of the requirements and levels of stroke centres; promotion of stroke telemedicine; definition of the Line of Stroke Care to integrate available resources and other health programs; and initiatives to increase awareness about stroke within the population. These are in line with the domains of stroke system of care as defined by the AHA recommendations [64]. Similarly, with the introduction of a national stroke policy act in Suriname, the battle against stroke can become a national priority.

Home-based semi-supervised physiotherapeutic programs need individualization according to personal and environmental barriers, whilst facilitating satisfactory therapy sessions in its current form and framework. It appears to be a promising way to increase mobility after stroke, however, large randomized controlled trials are warranted together with the examination of the cost-effectiveness of such a program. Cost-effectiveness may be important for clinical application of the home-based semi-supervised physiotherapy program apart from its positive results on improvement of mobility. The current financial crisis in Suriname emphasizes the need for a policy change in order to implement this program without problems. For example, it should be suggested that a part of the government take in fuel goes to patients that need total re-imbursement of all the sessions as part of a social package for CVA survivors, in order to increase chances to participate in this program. This policy document can be presented to the Ministry of Social Services, as the National Organization for Stroke in Suriname is now formally registered by their Board in the local register for organizations with disabled people in order to claim a part of the yearly government budget for local projects. Guidelines for home-based tele-supervised stroke rehabilitation should be formulated for Suriname and other middle-income countries [64]. Moreover, policies and programs should be written in order to contribute to the successful execution of cost-effectiveness studies.

Table 1. Overview future recommendations

Intervention/ Components [27]	Recommendations	Domains Stroke System of Care [64]	Intervention/ Actions
1. Enablement through results from research with introduction research line at the medical faculty: mobility after stroke Enablement (: Increasing means/reducing barriers to increase capability or opportunity) 2. Environmental restructuring: health system/ legislation (: Making or changing laws) 3. Modelling (: Providing an example for people to aspire to or imitate)	1. A) Assess enablers and barriers for long-term maintenance of PA B) Develop local guidelines for physiotherapy management: mobility after stroke C) study cost-effectiveness of home-based physiotherapy programs 2. A)Regular medical follow-up with an online integrated rehabilitation team to reduce costs (neurologist, general practitioner, physiotherapist, speech therapist, occupational therapist and caregiver). B) tailor health insurance packages to personalized packages according to needs of patient 3. Improve patient and caregiver participation in the local organization for stroke or people with a disability; recruit volunteers; connect with other local/international organizations to learn from experience and to collaborate for example Singapore National Stroke Organization/ World Stroke Organization/local organizations for speech therapy/occupational therapy/psychology/epilepsy/neurology	1. Secondary prevention 2. Continuous quality improvement 3. Community education	1. by initiating this as physiotherapy master thesis research topics and promote this research through the national organization for stroke and SVF; integrate results through legislation by connecting with government bodies/preparing petitions/policy documents to the government. 2. A) contact these specialists personally; construct a writing group to write this project; execute after changes in the law B) suggest generic way in the standard health insurance package in order to improve necessary care. 3. through local ads, radio programs, short films share success stories of stroke survivors performing PA/exercise
4. Education (: Increasing knowledge or understanding) / Service provision (Delivering a service)	4. Conduct large RCTs in order to study effects of individualized PA interventions imbedded in a behavior framework [27]	4. Stroke rehabilitation; Continuous quality improvement	4. Write research document in the form of a faculty project to be executed in phases. 5. Develop Dutch and Sranan Tongo campaign material;

5. Communication/marketing (:Using print, electronic, telephonic or broadcast media) 6. Training (: Imparting skills) / Education (Service provision)	5. Mass media campaigns for target groups (e.g., patients, caregivers, people at high-risk, children in primary schools); Awareness campaigns for colleagues (e.g., physiotherapists, medical practitioners, specialists, nurses, home care providers, speech therapists, occupational therapists etc.) 6. A) Educational courses to train for specialized stroke care target group: movement instructors (from IOL), college drop-outs with affinity for movement & health and caregivers. B) organize workshops for capacity building; target group: colleagues. C) organize and attend public lectures to educate the general public	5. Community education; Primary prevention 6. Stroke rehabilitation; Continuous quality improvement	search for funding with a core group of volunteers with a warm heart for this project and target group; develop a website for stroke information; acquire a building (and ground plot) with social facilities and a gym for engagement of stroke survivors; develop a free stroke phone line for free stroke information driven by Surinamese volunteers; active engagement with the ministry of Land and Forest Management and Ministry of Natural Resources; connect with Singapore National Stroke Association and Heart & Stroke Foundation in Barbados to learn from their experience. 6. Construct a team for project writing: physical therapist, psychologist, education expert, neurologist; develop a course based on modules with options for distance learning; connect with working class organizations for attendance of public lectures.
7. Legislation 8. Guidelines (: Creating documents that recommend or mandate practice. This includes all changes to service provision) /	7. Introduce National Stroke Policy Act 8. Participate in policy committees 9. Improvement of drainage system in the urban setting (environmental strategies: infrastructure)	7. Primary and secondary prevention 8. Continuous quality improvement 9. Community education	7. By first constructing a writing team for this project; develop an extensive policy document; suggest that part of the government take on fuel goes to improving PA and participation in stroke exercise; suggest a higher

Regulation (: Establishing rules or principles of behaviour or practice) / Restriction (:Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)) 9. Environmental/ social planning (environmental restructuring) 10. Environmental/ social planning (environmental restructuring) 11. Guidelines; Service provision 12. Education; Service provision 13. Guidelines; Service provision	10. More parks and malls nearby to stimulate PA among people at risk and CVA survivors; Try to invoke auto-free Sundays in the city of Suriname 11. Adjusted packages from health insurance companies for stroke survivors in order to promote full reimbursement of stroke care on primary and secondary level 12. Set up WHO STEPS Stroke Surveillance System (urban and rural Suriname) 13. Unite fragmented health care systems over the country	10. Primary and secondary prevention 11. Emergency Medical Services 12. Secondary prevention; continuous quality improvement 13. Stroke rehabilitation; Continuous quality improvement	monthly benefit for disabled people due to stroke and discounts on the use of sneakers for PA; offer this to the ministry of Sport and Recreation in Suriname and Ministry of Health 8. Write a policy document (national organization for stroke) in order to improve the health system for stroke care; partner with various stakeholders to explore formation of national coalition to advocate for policies aimed at improving PA (after stroke) e.g., auto-free Sundays in the city of Suriname; connect with other countries to learn from experience such as Jamaica; offer a final policy document to the Ministry of Health. 9. Work together with the Faculty of Environmental Sciences to improve this public health issue by writing a policy document and searching for funds. 10. through government policies; Make this part of the intervention in the project to promote mobility after stroke 11. Write the project; connect with Brazil (learn from their experience) and other

			countries such as Jamaica. 12. Connect with the Public Health Department at the Medical Faculty to learn from their experience and write a new project together in order to make Stroke STEPS study a national study. 13. Identify a core stroke team with a member from every district; Connect with other hospitals (connect with the neurologists and directors), health insurance companies and district managers in order to take advice for prevention of implementation problems; evaluate current or develop guidelines with a core stroke team.

- Not included yet: Coercion: Creating expectation of punishment or cost [27].

References

1. Aguiar LT, Nadeau S, Martins JC, Teixeira-Salmela LF, Britto RR, Faria C. Efficacy of interventions aimed at improving physical activity in individuals with stroke: a systematic review. Disabil Rehabil 2020;42:902-17.
2. White H, Boden-Albala B, Wang C, et al. Ischemic stroke subtype incidence among whites, blacks, and Hispanics: the Northern Manhattan Study. Circulation 2005;111:1327-31.
3. Krishnadath IS, Toelsie JR, Hofman A, Jaddoe VW. Ethnic disparities in the prevalence of metabolic syndrome and its risk factors in the Suriname Health Study: a cross-sectional population study. BMJ Open 2016;6:e013183.
4. Baldew SS, Krishnadath IS, Smits CC, Toelsie JR, Vanhees L, Cornelissen V. Self-reported physical activity behavior of a multi-ethnic adult population within the urban and rural setting in Suriname. BMC Public Health 2015;15:485.
5. Kario K, Ishikawa J, Pickering TG, et al. Morning hypertension: the strongest independent risk factor for stroke in elderly hypertensive patients. Hypertens Res 2006;29:581-7.
6. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet 1991;337:382-6.
7. Enas EA, Yusuf S, Mehta JL. Prevalence of coronary artery disease in Asian Indians. The American journal of cardiology 1992;70:945-9.
8. Aldayel AY, Alharbi MM, Shadid AM, Zevallos JC. The association between race/ethnicity and the prevalence of stroke among United States adults in 2015: a secondary analysis study using Behavioural Risk Factor Surveillance System (BRFSS). Electron Physician 2017;9:5871-6.
9. Nadruz W, Jr., Claggett B, Henglin M, et al. Racial Disparities in Risks of Stroke. N Engl J Med 2017;376:2089-90.
10. De Silva DA, Woon FP, Chen CL, Chang HM, Wong MC. Ethnic South Asian ischaemic stroke patients have a higher prevalence of a family history of vascular disease compared to age, gender and diabetes-matched ethnic Chinese subjects. J Neurol Sci 2009;285:118-20.
11. Nahar-van Venrooij LMW, Marhe E, Antonius-Smits C, Krishnadath IS. Adequate and excessive food consumption in Suriname: a multiethnic middle-income country. Int J Public Health 2018;63:1059-69.
12. Calvin Moorley RN SC, Nova Corcoran Stroke among African-Caribbean women: lay beliefs of risks and causes. Journal of Clinical Nursing 2016;25:403-11.
13. Baert I, Feys H, Daly D, Troosters T, Vanlandewijck Y. Are patients 1 year post-stroke active enough to improve their physical health? Disabil Rehabil 2012;34:574-80.
14. Tudor-Locke C, Craig CL, Aoyagi Y, et al. How many steps/day are enough? For older adults and special populations. Int J Behav Nutr Phys Act 2011;8:80.
15. Rimmer JH, Wang E, Smith D. Barriers associated with exercise and community access for individuals with stroke. J Rehabil Res Dev 2008;45:315-22.
16. Idowu OA, Adeniyi AF, Ogwumike OO, Fawole HO, Akinrolie O. Perceived barriers to physical activity among Nigerian stroke survivors. Pan Afr Med J 2015;21:274.
17. Cowan RE, Nash MS, Anderson KD. Exercise participation barrier prevalence and association with exercise participation status in individuals with spinal cord injury. Spinal Cord 2013;51:27-32.
18. Khalil H, Nazzal M, Al-Sheyab N. Parkinson's disease in Jordan: Barriers and motivators to exercise. Physiother Theory Pract 2016;32:509-19.

19. Krishnadath IS, Nahar-van Venrooij LM, Jaddoe VW, Toelsie JR. Ethnic differences in prediabetes and diabetes in the Suriname Health Study. BMJ Open Diabetes Res Care 2016;4:e000186.
20. Krishnadath IS, Jaddoe VW, Nahar-van Venrooij LM, Toelsie JR. Ethnic differences in prevalence and risk factors for hypertension in the Suriname Health Study: a cross sectional population study. Popul Health Metr 2016;14:33.
21. Saunders DH, Sanderson M, Hayes S, et al. Physical fitness training for stroke patients. Cochrane Database Syst Rev 2020;3:CD003316.
22. Janet L. Ingles GAE, Stephen J. Phillips. Fatigue After Stroke Arch Phys Med Rehabil 1999;80:173-8.
23. Roy Oman EM. Intrinsic motivation and exercise behavior. Journal of Health Education 2013;24:232-8.
24. Caetano LCG, Pacheco BD, Samora GAR, Teixeira-Salmela LF, Scianni AA. Self-Efficacy to Engage in Physical Exercise and Walking Ability Best Predicted Exercise Adherence after Stroke. Stroke Res Treat 2020;2020:2957623.
25. Wolfenden B, Grace M. Returning to work after stroke: a review. International journal of rehabilitation research Internationale Zeitschrift fur Rehabilitationsforschung Revue internationale de recherches de readaptation 2009;32:93-7.
26. Peters GO BS, Oyeyemi AY, Hamzat TK. Determinats of return to work among Nigerian stroke survivors. Disabil Rehabil 2013;35:455-9.
27. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 2011;6:42.
28. van Bloemendaal M, van de Water AT, van de Port IG. Walking tests for stroke survivors: a systematic review of their measurement properties. Disabil Rehabil 2012;34:2207-21.
29. Kim DK, Oh DW. Repeated Use of 6-min Walk Test with Immediate Knowledge of Results for Walking Capacity in Chronic Stroke: Clinical Trial of Fast versus Slow Walkers. J Stroke Cerebrovasc Dis 2019;28:104337.
30. Dunn A, Marsden DL, Nugent E, et al. Protocol variations and six-minute walk test performance in stroke survivors: a systematic review with meta-analysis. Stroke Res Treat 2015;2015:484813.
31. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest 2001;119:256-70.
32. Park JG, Lee KW, Kim SB, Lee JH, Kim YH. Effect of Decreased Skeletal Muscle Index and Hand Grip Strength on Functional Recovery in Subacute Ambulatory Stroke Patients. Ann Rehabil Med 2019;43:535-43.
33. Yi Y, Shim JS, Oh BM, Seo HG. Grip Strength on the Unaffected Side as an Independent Predictor of Functional Improvement After Stroke. Am J Phys Med Rehabil 2017;96:616-20.
34. Pratama IK SS. Correlation between hand grip strength and functional mobility in elderly patients. In: Publishing I, ed. The 2nd Physics and Technologies in Medicne and Dentistry Symposium: IOP Publishing 2018.
35. Dourado VZ. Reference equations for the 6-minute walk test in healthy individuals. Arq Bras Cardiol 2011;96:128-38.
36. Alain G Bertoni MB, Lenore Crago, Haiying Chen, R G Barr, Benjamin Smith, Sanjiv J Shah. Abstract P151: Race/ethnic Differences in Six Minute Walk Distance Among Older

Adults: The Multi-ethnic Study of Atherosclerosis. In: Association AH, ed. AHA Epidemiology and Prevention–Lifestyle and Cardiometabolic Health 2020 Scientific Sessions2020.
37. J.Woo HA, T.P.Ng, A.A.Sayer, M.Wong, H.Syddall, M.Yamada, P.Zeng, S.Wu, T.M.Zhang. Ethnic and geographic variations in muscle mass, muscle strength and physical performance measures. European Geriartric Medicine 2014;5:155-64.
38. Janice J Eng KSC, Andrew S. Dawson, C.Maria Kim, Katherine E. Hepburn. Functional walk tests in individuals with stroke. AHA Journals 2002.
39. Beriault K CA, Gagnon C, Ménard J, Baillargeon JP, Ardilouze JL, Langlois MF. Reproducibility of the 6-minute walk test in obese adults. Int J Sports Med 2009;30:725-7.
40. S. Teramoto EO, T. Ishii, Y. Yamaguchi, H. Yamamoto, T. Mastsuse. Reference value of six-minute walking distance in healthy middle-aged and older subjects. . Eur Respir J 2000:1132-3.
41. Ingrid S.K.Krishnadath JRT, LennyNahar-van Venrooij, AlbertHofman, Vincent W.V.Jaddoe. Ethnic and sex-specific cut-off values for adult obesity in the Suriname Health Study. Obes Res Clin Pract 2016;12:336-45.
42. Rausch-Osthoff AK, Kohler M, Sievi NA, Clarenbach CF, van Gestel AJ. Association between peripheral muscle strength, exercise performance, and physical activity in daily life in patients with Chronic Obstructive Pulmonary Disease. Multidiscip Respir Med 2014;9:37.
43. Shin HI, Kim DK, Seo KM, Kang SH, Lee SY, Son S. Relation Between Respiratory Muscle Strength and Skeletal Muscle Mass and Hand Grip Strength in the Healthy Elderly. Ann Rehabil Med 2017;41:686-92.
44. Zhang Q, Lu H, Pan S, Lin Y, Zhou K, Wang L. 6MWT Performance and its Correlations with VO(2) and Handgrip Strength in Home-Dwelling Mid-Aged and Older Chinese. Int J Environ Res Public Health 2017;14.
45. Martín-Ponce E, Hernández-Betancor, I., González-Reimers, E. Prognostic value of physical function tests: hand grip strength and six-minute walking test in elderly hospitalized patients. Sci Rep 2014;4.
46. Ya Su MY, Mika O. Prevalence of stroke-related sarcopenia: A systematic review and meta-analysis. Journal of Stroke and Cerebrovascular Diseases 2020;29.
47. Syddall H CC, Martin F, Briggs R, Aihie Sayer A. Is grip strength a useful single marker of frailty? Age Ageing. 2003 Nov;32(6):650-6. doi: 10.1093/ageing/afg111. PMID: 14600007. Is grip strength a useful single marker of frailty? Age Ageing 2003;32:650-6.
48. Takahashi J, Nishiyama T, Matsushima Y. Does grip strength on the unaffected side of patients with hemiparetic stroke reflect the strength of other ipsilateral muscles? J Phys Ther Sci 2017;29:64-6.
49. Bovonsunthonchai S, Hiengkaew V, Vachalathiti R, Vongsirinavarat M, Tretriluxana J. Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke. Kaohsiung J Med Sci 2012;28:667-72.
50. Chen G, Patten C, Kothari DH, Zajac FE. Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture 2005;22:51-6.
51. Souissi H, Zory R, Boudarham J, Pradon D, Roche N, Gerus P. Muscle force strategies for poststroke hemiparetic patients during gait. Top Stroke Rehabil 2019;26:58-65.
52. Azarbayjani RYMHSHSFFMA. Effect of excessive Arm Swing on Speed and Cadence of walking. Journal of Men s Health 2020;4:1-5.

53. Sibley KM, Tang A, Patterson KK, Brooks D, McIlroy WE. Changes in spatiotemporal gait variables over time during a test of functional capacity after stroke. J Neuroeng Rehabil 2009;6:27.
54. Patterson KK, Gage, W.H., Brooks, D., Black. S.E., Mcllroy, W.E. Changes in gait symmetry and velocity after stroke: a cross sectional study from weeks to years after stroke. Neurorehabil Neural Repair 2010;24:783-90.
55. Pohl PS, Duncan PW, Perera S, et al. Influence of stroke-related impairments on performance in 6-minute walk test. J Rehabil Res Dev 2002;39:439-44.
56. Gersten JW, Orr W. External work of walking in hemiparetic patients. Scand J Rehabil Med 1971;3:85-8.
57. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996;29:602-8.
58. Margit Alt Murphy CR, Peter Feys, Ilse Lamers. An overview of systematic reviews on upper extremity outcome measuers after stroke. BMC Neurology 2015;15.
59. Muren MA, Hutler M, Hooper J. Functional capacity and health-related quality of life in individuals post stroke. Top Stroke Rehabil 2008;15:51-8.
60. Duarte E ME, Muniesa JM, Belmonte R, Aguilar JJ, Escalada F. . Early detection of non-ambulatory survivors six months after stroke. . NeuroRehabilitation 2010;26:317-23.
61. Nicola Smania Stefano P, Tinazzi Anna, BorgheroPaolo ,ManganottiAntonio, FiaschiGiuseppe, MorettoPaolo ,Boviand Mattia, Gambarin. A Simple Movement Predicting Recovery of Arm Function in Patients With Acute Stroke. Stroke 2007;38:1088–90.
62. Alan Sunderland DT, Lesley Bradley, Richard Langton Hewer. Arm function after stroke. An evaluation of grip strength as a measure of recovery and a prognostic indicator Journal ofNeurology, Neurosurgery, and Psychiatry 1989;52:1267-72.
63. Bilbao A, Kennedy C, Chatterji S, Ustun B, Barquero JL, Barth JT. The ICF: Applications of the WHO model of functioning, disability and health to brain injury rehabilitation. NeuroRehabilitation 2003;18:239-50.
64. Adeoye O, Nystrom KV, Yavagal DR, et al. Recommendations for the Establishment of Stroke Systems of Care: A 2019 Update. Stroke 2019;50:e187-e210.
65. Simpson B, McCluskey A, Lannin N, Cordier R. Feasibility of a home-based program to improve handwriting after stroke: a pilot study. Disabil Rehabil 2016;38:673-82.
66. Sarah Carroll CG, Susan Lewis, Marion McMurdo, Falko Sniehotta, Marie Johnston, Derek Johnston, Judy Scopes, Gillian Mead. The use of pedometers in stroke survivors: are they feasible and how well do they detect steps? Arch Phys Med Rehabil 2012:466-70.
67. Haworth J, Young C, Thornton E. The effects of an 'exercise and education' programme on exercise self-efficacy and levels of independent activity in adults with acquired neurological pathologies: an exploratory, randomized study. Clin Rehabil 2009;23:371-83.
68. Moran M, Van Cauwenberg J, Hercky-Linnewiel R, Cerin E, Deforche B, Plaut P. Understanding the relationships between the physical environment and physical activity in older adults: a systematic review of qualitative studies. Int J Behav Nutr Phys Act 2014;11:79.
69. Gordon CD, Wilks R, McCaw-Binns A. Effect of aerobic exercise (walking) training on functional status and health-related quality of life in chronic stroke survivors: a randomized controlled trial. Stroke 2013;44:1179-81.
70. Bouchard MP. Medications and exercise. ACSM's Health & Fitness Journal 2012;16:34-6.

71. Vanhees L, Defoor JG, Schepers D, et al. Effect of bisoprolol and atenolol on endurance exercise capacity in healthy men. J Hypertens 2000;18:35-43.
72. Johansson T, Wild C. Telerehabilitation in stroke care--a systematic review. Journal of telemedicine and telecare 2011;17:1-6.
73. Orla C. Sheehan MGW, Alka Ahuja, Victor C Urrutia, Elisabeth B Marsh, David L Roth, and Jennifer A Schrack. The effect of caregivers on motivation to improve daily physical activity after stroke. International Stroke Conference Poster Abstracts Session Title: Clinical Rehabilitation and Recovery Posters II: Stroke; 2017.
74. Moore SA, Hallsworth K, Jakovljevic DG, et al. Effects of Community Exercise Therapy on Metabolic, Brain, Physical, and Cognitive Function Following Stroke: A Randomized Controlled Pilot Trial. Neurorehabil Neural Repair 2015;29:623-35.
75. Marsden DL, Dunn A, Callister R, Levi CR, Spratt NJ. Characteristics of exercise training interventions to improve cardiorespiratory fitness after stroke: a systematic review with meta-analysis. Neurorehabil Neural Repair 2013;27:775-88.
76. Moore SA, Jakovljevic DG, Ford GA, Rochester L, Trenell MI. Exercise Induces Peripheral Muscle But Not Cardiac Adaptations After Stroke: A Randomized Controlled Pilot Trial. Arch Phys Med Rehabil 2016;97:596-603.
77. Marsden DL, Dunn A, Callister R, McElduff P, Levi CR, Spratt NJ. A Home- and Community-Based Physical Activity Program Can Improve the Cardiorespiratory Fitness and Walking Capacity of Stroke Survivors. J Stroke Cerebrovasc Dis 2016;25:2386-98.
78. Fulk G. YH. Minimal clinically important difference of the 6-minute walk test in people with stroke. J Neurol Phys Ther 2018;42:235-40.
79. Garcia PA, Dias JM, Dias RC, Santos P, Zampa CC. A study on the relationship between muscle function, functional mobility and level of physical activity in community-dwelling elderly. Rev Bras Fisioter 2011;15:15-22.
80. Eng JJ, Chu KS, Dawson AS, Kim CM, Hepburn KE. Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. Stroke 2002;33:756-61.
81. Chen H, Smith SS. Item Distribution in the Berg Balance Scale: A Problem for Use With Community-Living Older Adults. J Geriatr Phys Ther 2019;42:275-80.
82. A. Jarbandhan DB, V. Cornelissen, M. van Lierop, L. Vanhees, H.E.J. Veeger, R. Buys. Shoulder pain and shoulder function after stroke : content validity and reliability of the disabilities of the arm, shoulder and hand questionnaire (DASH): a pilot study. Central Library, Anton de Kom University of Suriname: Faculty of Medical Sciences, Anton de Kom University of Suriname; 2015.
83. R. Buys AJ. Step count validity of Garmin Forerunner 225 and Yamax Digiwalker SW-200 in relation to gait characteristics in chronic stroke patients. Unpublished: Faculty of Medical Sciences, Anton de Kom University of Suriname; 2017.
84. Dalton E, Lannin NA, Laver K, et al. Validity, reliability and ease of use of the disabilities of arm, shoulder and hand questionnaire in adults following stroke. Disabil Rehabil 2017;39:2504-11.
85. Baker K, Barrett L, Playford ED, Aspden T, Riazi A, Hobart J. Measuring arm function early after stroke: is the DASH good enough? J Neurol Neurosurg Psychiatry 2016;87:604-10.
86. Lang CE, Bland MD, Bailey RR, Schaefer SY, Birkenmeier RL. Assessment of upper extremity impairment, function, and activity after stroke: foundations for clinical decision making. J Hand Ther 2013;26:104-14;quiz 15.

87. 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;97:707-17.
88. Claes J, Buys R, Avila A, et al. Validity of heart rate measurements by the Garmin Forerunner 225 at different walking intensities. J Med Eng Technol 2017;41:480-5.
89. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. JAMA 2007;298:2296-304.
90. Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke 1995;26:982-9.
91. Lawrence M, Fraser H, Woods C, McCall J. Secondary prevention of stroke and transient ischaemic attack. Nurs Stand 2011;26:41-6.
92. Toglia J, Kirk U. Understanding awareness deficits following brain injury. NeuroRehabilitation 2000;15:57-70.
93. Voos M.C. RdVLE. Comparitive study on the relationship between stroke hemisphere and functional evolution in right-handed individuals. Brazilian Journal of Physical Therapy 2008;12.
94. Kwakkel G, Kollen B, Lindeman E. Understanding the pattern of functional recovery after stroke: facts and theories. Restor Neurol Neurosci 2004;22:281-99.
95. Prigatano GP, Leathern JM. Awareness of behavioral limitations after traumatic brain injury: A cross-cultural study of New Zealand maoris and non-maoris. Clin Neuropsychol 1993;7:123-35.
96. Vanhees L, Lefevre J, Philippaerts R, et al. How to assess physical activity? How to assess physical fitness? Eur J Cardiovasc Prev Rehabil 2005;12:102-14.
97. McDonald JD. Measuring personality constructs: the advantages and disadvantages od self-reports, informant reports and behavioral assessments. Enquire 2008;1:75-94.
98. Engstad T, Bonaa KH, Viitanen M. Validity of self-reported stroke : The Tromso Study. Stroke 2000;31:1602-7.
99. O'Mahony PG, Thomson RG, Dobson R, Rodgers H, James OF. The prevalence of stroke and associated disability. J Public Health Med 1999;21:166-71.
100. Reitz C, Schupf N, Luchsinger JA, et al. Validity of self-reported stroke in elderly African Americans, Caribbean Hispanics, and Whites. Archives of neurology 2009;66:834-40.
101. Sarah Meyer GV, Nadine Brinkmann, Eddy Dejaeger, Willy De Weerdt, Hilde Feys, Andreas R. Gantenbein, Walter Jenni, Annouschka Laenen, Nadina Lincoln, Koen Putman, Birgit Schuback, Wilfried Schupp, Vincent Thijs, Liesbet De Wit. Functional and Motor Outcome 5 Years After Stroke Is Equivalent to Outcome at 2 Months Follow-Up of the Collaborative Evaluation of Rehabilitation in Stroke Across Europe. Stroke 2015;46:1613-9.
102. Winstein CJ, Stein J, Arena R, et al. Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke 2016;47:e98-e169.
103. Lovasi GS, Grady S, Rundle A. Steps Forward: Review and Recommendations for Research on Walkability, Physical Activity and Cardiovascular Health. Public Health Rev 2012;33:484-506.
104. Edwards JD, Kapral MK, Fang J, Swartz RH. Long-term morbidity and mortality in patients without early complications after stroke or transient ischemic attack. CMAJ 2017;189:E954-E61.

105. Martins SC1 P-NO, Alves CV, de Freitas GR, Filho JO, Tosta ED, Cabral NL; Brazilian Stroke Network. Past, present, and future of stroke in middle-income countries: the Brazilian experience. Int J Stroke 2013;8:106-11.

Abstract of the thesis

Stroke is a concerning cause of mortality in Suriname and the lifestyle of Surinamese people, known for their multi-ethnic background, likely endorses non-communicable diseases such as stroke and heart disease. Because of the specific setting of Suriname, namely the low resource setting and the multi-ethnic background, studies on the prevalence and physiotherapy treatment of stroke in Suriname is warranted.

This thesis aims to examine: 1) the prevalence of stroke; 2) the relationship with ethnicity controlled for traditional risk factors; 3) the factors associated to low post-stroke physical activity and functional walking capacity; 4) exercise barriers and, lastly, the feasibility of a home-based semi-supervised physiotherapy program in urban Suriname.

We report a high overall prevalence of stroke in the capital of Suriname (3.2%) which, contrary to expectations, was not related to ethnic background when controlled for age, sex, hypertension, diabetes, smoking and dyslipidemia. Due to the study design, we were not able to control for physical activity, socio-economic status and diet in the relationship between ethnicity and stroke. In another study, we found that low PA was not related to socio-economic variables such as income level, education level, marital status and ethnicity. Additionally, personal exercise barriers were not similar enough across ethnic groups to be treated equally by a generalized PA intervention. Our study population showed a high self-efficacy level for PA, however their PA level remained low compared to apparently healthy elderly. This finding might be a result from the reported high perceived barriers of which the most common reported barriers were “cost of the program”, “lack of transport” and “feeling that a fitness instructor is incapable to develop a PA program according to their needs”. The least reported barriers were “lack of energy”, “lack of interest” and “not knowing how to exercise”.

In another study, we focused on the six-minute walk test (a valid, reliable and feasible test for functional waking capacity). We demonstrated that functional walking capacity is a complex combination of, not only aerobic capacity, gait- and balance function, but also of muscle fitness, quantified as grip strength. Taking most of these findings into account, we tested the feasibility of a home-based semi-supervised physiotherapy program of 8 weeks using motivational PA tools (a pedometer and smartwatch) and less technically advanced assessments such as the 6MWT to improve mobility. Our pilot program appeared to be safe, was associated with moderate to high levels of engagement and patient satisfaction and resulted in functional improvements. We also provided efficacy estimates to inform sample size calculation and best primary outcome measures for designing properly powered randomized controlled trials in the future.

In conclusion, the prevalence of stroke is high in urban Suriname and post-stroke survivors show low physical activity levels and low functional walking capacity. They demonstrate high-perceived environmental barriers for physical activity comparable to other studies, but distinct personal barriers according to their ethnic background. Therefore, research on the effect of tailored PA interventions stratified for ethnic background are warranted in which the use of less technically advanced measurements is advised with a cost-effective semi-supervised home-based setting to guarantee its feasibility.

Samenvatting van het proefschrift

De levensstijl van Surinamers onderschrijft een hoge mortaliteitscijfer als gevolg van een CerebroVasculair Accident (CVA), een niet-overdraagbare aandoening. Vanwege de specifieke setting van Suriname, namelijk het lage inkomen en de multi-etnische achtergrond, is onderzoek naar de prevalentie, onderliggende verbanden in relatie tot verlaagde fysieke activiteit en functionele loopcapaciteit en fysiotherapie van CVA-patienten in Suriname gerechtvaardigd.

Het doel van dit proefschrift was om in het stedelijk gebied van Suriname het volgende te onderzoeken: 1) de prevalentie van CVA; 2) de relatie tussen een CVA en etniciteit gecontroleerd voor traditionele risicofactoren; 3) de factoren die geassocieerd zijn met een lage fysieke activiteit en functionele loopcapaciteit; 4) de barrières voor lichaamsbeweging en 5) de haalbaarheid van een semi-gesuperviseerde fysiotherapie interventie aan huis.

We rapporteerden een hoge algemene CVA prevalentie in de hoofdstad van Suriname (3,2%) die, in tegenstelling tot de verwachtingen, niet gerelateerd was aan etnische achtergrond bij controle op leeftijd, geslacht, hypertensie, diabetes, roken en dyslipidemie. Vanwege de onderzoeksopzet waren we niet in staat om te controleren op fysieke activiteit, sociaal-economische status en voeding. In een volgende studie vonden we ook geen verband tussen een laag fysieke activiteitsniveau, ethniciteit en sociaal-economische status. We vonden wel opmerkelijke barrières voor het volgen van een gestructureerde programma’s met oefeningen, namelijk: dat de instructeur niet voldoende in staat is om te voorzien aan de behoeftes van een CVA-patient tijdens het oefenen; dat de kosten van een programma hoog zijn en men een tekort heeft aan transport faciliteiten. Bovendien waren persoonlijke barrières niet hetzelfde tussen etnische groepen. De minst gerapporteerde belemmeringen waren "gebrek aan energie", "gebrek aan interesse" en "niet weten hoe te oefenen".

Het is dus goed mogelijk dat gepersonaliseerde oefenprogramma’s, die niet te duur zijn en aan huis gegeven kunnen worden door een gespecialiseerde trainer succes kunnen hebben om CVA-patienten op been te helpen. In een volgende studie, concluderen wij dat de 6-minuten wandeltest (6MWT) een complexe combinatie is van niet alleen aerobische capaciteit, gang- en balansfunctie, maar ook van spierkracht.. Rekening houdende met bovengenoemde bevindingen, hebben we de haalbaarheid getest van een semi-gesuperviseerde fysiotherapie programma aan huis gedurende 8 weken o.a. met behulp van motiverende toestellen (een pedometer en een smarthorloge) op vooruitgang van o.a. de functionele wandelcapaciteit. Ons pilot programma bleek veilig te zijn, ging gepaard met matige tot hoge niveaus van betrokkenheid en patiënttevredenheid en resulteerde in functionele verbeteringen. Met de gegevens uit dit pilot programma kunnen wij de steekproefomvang berekenen voor een grotere randomised controlled trial.

We mogen concluderen dat de CVA-prevalentie in het stedelijk gedeelte van Suriname hoog is. Bovendien hebben mensen met een CVA een lage fysieke activiteitsniveau en een lage wandelcapaciteit, mogelijk vanwege andere factoren dan socio-economische status en ethnische achtergrond. Een groot deel van de mensen met een chronsiche CVA geeft aan dat oefenprogramma’s te duur zijn en dat zij te kampen hebben met transport faciliteiten en dat instructeurs niet capabel genoeg zijn om te voorzien in hun behoefte tijdens het oefenen. Er zijn ook verschillen tussen ethnische groepen te zien qua barriers voor het oefenen. Nader onderzoek moet uitwijzen of semi-gesuperviseerde fysiotherapie programma's aan huis gestratificeerd voor etnische achtergrond een verandering kunnen brengen in de functionele wandelcapaciteit en de barrières voor oefenprogramma's.

Bijstellingen

“ Zowel institutionele als thuisgebaseerde revalidatie programma’s lijken niet betaalbaar voor mensen met een chronische beroerte in Suriname”

“Ondanks de verhoogde bewustwording is er nog steeds gebrek aan therapietrouw voor hypertensie patienten”

“De financiele situatie in Suriname is geen weerspiegeling van het eetgedrag van Surinamers”

Appositions

“Both institutional and home-based rehabilitation programs do not seem to be affordable for people with chronic stroke in Suriname”

“Despite increased awareness, there is still a lack of compliance with hypertension patients”

“The financial situation in Suriname is not a reflection of the eating behavior among Surinamese”

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Personal contribution:

I contributed to the conception and design of the different studies. I acquired the data and/or supervised on data acquisition by master students during their master thesis work. I performed statistical analyses and interpreted the data. I wrote and revised the article drafts and took care of the submission of the final version of the manuscripts.

Conflict of Interest:

None

Professional career of Ameerani Jarbandhan

Education, diplomas and membership:

2005-2010	: BSc in Physiotherapy (Anton de Kom University of Suriname, (AdeKUS), Faculty of Medical Sciences (FMeW)
2010-2011	: MSc in Human Movement Sciences at the Free University Amsterdam (VU Amsterdam), Faculty of Human Movement Sciences.
2012-now	: Lecturer at the Department of Anatomy, FMeW, AdeKUS.
2013-2016	: Part time lecturer at the E.F.S. college, the Foundation Central Training for Nurses and Practitioners of Related Professions (C.O.V.A.B.)
2011-2019	: Member MDO-team for Clinical Gait Analysis in the Human Movement laboratory at the FMeW.
2012-2014	: Member of the Blood Bank Board for representation of the FMeW.
2012-2017	: Member Selection Committee at the FMeW.
2012-2018	: Member Election Committee at the FMeW.
2013-2021	: Member of Education Board FMeW for Physical Therapy (member of three different committee's)
2017-now	: PAHO trainer for EPPE course, Georgetown, Guyana
2017 (May)	: PAHO EPPE participant of train-the-trainer course, Kingston, Jamaica
2015 (Oct)	: PAHO participant of Effective Project Planning and Evaluation (EPPE) course, Paramaribo, Suriname
2018	: MOOC participant on Implementation Research (completion in December 2018) organized by WHO
2016-now	: Member of the Surinamese Union for People after Stroke ('Vereniging Verder na een Beroerte")
2018-now	: 2nd Secretary and 1st Treasurer of the Board of the Surinamese Union for People after Stroke.
2019-2020	: Finished two-year Course successfully on Professionalization of Lecturers at the Anton de Kom University of Suriname ("Docent ProfessionaliseringsOpleiding")
2021-now	: Exam-Coordinator Physical Therapy Course, FMeW, ADeKUS

List of Publications

IJmker T., Houdijk H., Lamoth C.J., Jarbandhan A.V., Rijntjes D., Beek P.J., van der Woude L.H. (2013): Effect of balance support on the energy cost of walking after stroke. *Archives of Physical Medicine and Sciences*, 94(11), 2255-2261.

IJmker T., Houdijk H., Lamoth C.J., Jarbandhan A.V., Rijntjes D., Beek P.J., van der Woude L.H. (2013). The influence of balance support on the metabolic cost of walking in stroke patients during overground and treadmill walking. *Gait & Posture*, 38(1), S86.

Diemer F., Aartman J., Karamat F., Baldew S., Jarbandhan A., van Montfrans G., Oehlers G., Brewster L. (2014). Exploring cardiovascular health: The Healthy Life in Suriname (HELISUR) study. A protocol of a cross-sectional study. *British Medical Journal Open*, 4, e006380.

Jarbandhan A., Hoozemans M., Buys R., Diemer F., Baldew S., Aartman J., Brewster L., van Montfrans G., Oehlers G., Veeger H.E.J., Toelsie J., Vanhees L. (2016). Prevalence of self-reported stroke in association with ethnic background within a multi-ethnic population in Paramaribo, Suriname: results from the HeliSur study. *Neurology Asia*, 21(4), 303-310.

Aartman J., Diemer F., Karamat F., Bohte E., Baldew S., Jarbandhan A., van Montfrans G., Oehlers G., Brewster L. (2017). Assessing the feasibility of the Healthy Life in Suriname Study: using advanced hemodynamics to evaluate cardiovascular risk. *Revista Panamericana de Salud Pública*, 41, e46

Gajapersad A., Jarbandhan A., Bipat R. (2020). The physiotherapeutic management of post stroke shoulder pain: a systematic review. *Examines in Physical Medicine & Rehabilitation*

Jarbandhan A., Toelsie J., Bipat R., Freedrik J., Vanhees L., Buys R., Veeger H.E.J. (2021) A cross-sectional study to assess an association between upper extremity function and functional walking capacity in chronic stroke survivors**.** *Cardiorespiratory Physiotherapy, Critical care and Rehabilitation*

Jarbandhan A., Toelsie J., Veeger H.E.J., Bipat R., Vanhees L., Buys R. (2021) Feasibility of a home-based physiotherapy intervention to promote post-stroke mobility: a randomized controlled pilot study. *PLOS ONE*

Clinical experience:

2011-now	: Clinical Gait Analysis at the Human Movement laboratory at the FMeW.
2011-2012	: Physiotherapist at the Ashim Medical Centre, Suriname.
2016-now	: Home-based Physiotherapist and co-owner of SUMITRA fysio & yoga Centre.
2015 (May-Aug)	: Training under Mr. Dwarka Panday for management, preservation of Human Cadavers.

List of Poster presentations:

2016 (March)	: 2nd place winner for Poster presentation AdeKUS Research Days 2016: *Validity and reliability of the disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire for post-acute stroke patients, Paramaribo, Suriname*
2014-2015	: Research in Human Movement laboratory FMeW: *Validity and reliability of the disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire for post-acute stroke patients, Paramaribo, Suriname*
2015 (Dec)	: Participation symposium Scientific research organized by SRCS (Scientific Research Center Suriname), Paramaribo, Suriname
2015 (May)	: Poster presentation at the EuroPrevent 2015 organized by the European Association for Cardiovascular Prevention and Rehabilitation (EACPR), Lisbon, Portugal *"Ethnic differences in self-reported risk profile of stroke survivors in urban Suriname"*.
2015 (March)	: Oral presentation regarding doctoral thesis during Studium General of Mechanical Engineering Faculty.
2014 (July)	: Participant Cardiac Rehabilitation symposium, organized by SPAOGS in Paramaribo, Suriname
2014 (May)	: Poster presentation at the EuroPrevent 2014 organized by the European Association for Cardiovascular Prevention and Rehabilitation (EACPR), Amsterdam, Nederland *"Preliminary findings of the Healthy Life in Suriname (HELISUR) study: the self-reported risk profile of stroke patients"*
2014	: Speaker at Health Conference: "*Self-reported risk profile of stroke patients in Paramaribo: preliminary findings, the HELISUR study*"
2013	: Research Human Movement laboratory FMeW: The prevalence of Duchene Muscle Dystrophy in Suriname, Suriname
2013	: Research Human Movement laboratory FMeW: The immediate effect of cane use on gait quality in Surinamese stroke survivors.
2012	: Research days AdeKUS: The effect of additional load on gait pattern in children with cerebral palsy and typically developed children, Suriname
2012	: Research days AdeKUS: Learn to walk: setting up a human motion laboratory in Suriname, Suriname
2012	: Research days AdeKUS: Gait analysis in a adreno-myeloneuropathy patient. A case study, Suriname.

Addendum I

A systematic review of the validity, reliability and accuracy of physical activity monitors in chronic stroke patients

In preparation for re-submission: Jarbandhan A., Bipat R., Makhaisingh R., Buys R., Vanhees L., Veeger H.E.J. A systematic review of the validity, reliability and accuracy of physical activity monitors in chronic stroke patients.

Abstract

Purpose: Physical activity monitoring devices are frequently used in stroke populations, but there is little evidence in the literature regarding their validity, reliability and accuracy. The aim of this study is to review the status of validity, reliability and accuracy of physical activity monitors in chronic stroke patients systematically.

Material and methods: Two independent researchers systematically searched five databases and relevant studies from reference lists. The STROBE guidelines established the methodological quality. Inclusion criteria were: (1) studies that used accelerometer-based physical activity monitors or pedometers in chronic stroke survivors; (2) clinical trials examining the validity, reliability and accuracy of accelerometers and/or pedometers in people who suffered a stroke more than 6 months ago; (3) studies including people with any age, sex or type of stroke; (4) studies published in English between 2009 and 2019.

Results: Out of the 662 studies that were identified, seven met the inclusion criteria. These seven studies represented 193 participants with chronic stroke and had a STROBE quality between 19 and 22. We found a poor to high validity, reliability and accuracy for accelerometers measuring absolute and relative measures of PA. Good accuracy and fair reliability were found for pedometer and GPS use regarding absolute measures of PA. And no validity for a smartphone application was reported for relative measures of PA. Unfortunately, all studies had a significant risk of bias due to small sample sizes, insufficient use of statistics and heterogeneity of study methods.

Conclusions: There is no doubt that PA monitors can be used as motivational tools to increase PA levels, but accelerometers and pedometers should only be used after testing their psychometric properties and feasibility in the stroke population. That some studies find a significant difference whilst others do not, does not mean that the PA devices are not appropriate for measurement of PA. Some studies either lack an adequate sample size, whilst others use inappropriate statistical methods. Findings from this review confirm that the level of reliability, validity and accuracy for the PA monitors remains unclear.

Keywords:
STROBE; validity, reliability, accuracy; chronic stroke; psychometric properties physical activity monitors

Introduction

Physical activity (PA) is one of the main rehabilitation strategies used in stroke[1]. PA monitoring devices are, therefore, frequently used in stroke populations whereas the literature provides poor evidence regarding their validity, reliability and accuracy[2]. In the chronic phase after a stroke, patients generally do not reach the level of physical activity (PA) intensity and volume that is necessary for health benefits [3]. Depending on the level of impairment, chronic stroke survivors resume their activities of daily life when they return to their usual environment at home, but in general show a significant decrease in PA [4]. This increases the need for PA intervention and, therefore, accurate measurement of PA in this group of stroke survivors.

Physical activity can be assessed by means of criterion, subjective and objective methods [5]. Criterion methods such as direct calorimetry (Energy expenditure measured by heat loss or heat production) and indirect calorimetry (measurement of heat production or Energy Expenditure (EE) by measuring oxygen consumption and/or carbon dioxide production) are highly reliable when compared to other PA assessment tools [5]. These methods—facilities, tools, and expertise—are however expensive, and readily available in every research setting. Subjective methods such as questionnaires on the other hand are easy to use, especially with larger sample sizes and are a low-cost method for PA assessment [5]. The results of PA questionnaires can however be influenced by age or the complexity of a questionnaire [5]. Moreover, this method depends on interpretation and perception of the questions by the patient [5]. On the contrary, objective methods like accelerometers and pedometers are available on the market and offer a simple method for recording PA in real life [2]. These relatively inexpensive and discreet objective tools have many advantages: they monitor voluntary PA, are easy to wear, and can provide valid data in healthy adults [5]. In addition, these tools may motivate people to adapt a more active lifestyle [6].

Activity monitoring devices have already been evaluated in previous reviews. A review on the validity and reliability of accelerometry in chronic stroke survivors by Gebruers et al. (2010), stated that the large variety of psychometric properties reported, is for want of more research [7]. According to a review by Block et al. (2016) about the remote use of PA monitors on several neurological diseases including stroke [8], report no information on the validity and reliability of these devices. A finding from this review was that the use of remote PA monitors in the stroke population was associated with functional recovery following rehabilitation and goal-oriented intervention which was concluded from one study with 15 subjects wearing a Stepwatch Activity Monitor. A third systematic review [2] with studies up to March 2017 reported that accuracy tends to be better when accelerometers are placed at the ankle in the stroke population, however small sample sizes were a limitation of the included studies. Moreover, this review solely used two databases in their search (PubMed and CINAHL) [2]. Based on the abovementioned studies, , we might conclude that findings regarding the validity, reliability and accuracy of PA monitors remain inconclusive [2,7,8].

In light of the existing literature, acritical appraisal of sample size and the appropriate use of statistical sampling methods was deemed relevant. In this study we systematically reviewed the literature published between 2009 and 2019 in five different databases on the concurrent validity, test-retest reliability and accuracy of PA monitors for chronic stroke survivors measuring absolute measures of PA (e.g. step count, time spent walking) and relative measures of PA (e.g. energy expenditure).

Methods

This systematic review has been conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [9]. For this study the following definitions were used: (1) accuracy: the proximity of the measurement result to the true value; (2) reliability: when a device produces the same result on the same person on different occasions; (3) validity: when a device accurately measures the variable it is intended to measure or how truthful the research results are [10]. This study includes the criterion validity and the test-retest reliability. Criterion validity is determined by comparing test scores with the performance of another measure [10]. The test-retest reliability is preferable when the test being measured is stable [10], estimating the true effect of inconsistency on the accuracy of a measure. This review is registered on PROSPERO, CRD42019135203.

Study selection

The following inclusion criteria were applied: (1) studies that used accelerometer-based physical activity monitors and/or pedometers in chronic stroke survivors; (2) clinical trials examining the validity, reliability and accuracy of accelerometers and/or pedometers in people who suffered a stroke more than 6 months ago; (3) studies including people with any age, sex or type of stroke; (4) studies published in English between 2009 and 2019.

The exclusion criteria were: (1) studies with acute or subacute stroke survivors; (2) studies with a subjective measure for physical activity as a criterion or measure of PA; (3) upper extremity studies and case reports; (4) new engineering techniques implying other PA assessment tools than pedometers and/or accelerometer-based technology.

Data sources and search strategies

The search of PubMed (MEDLINE), EMBASE, CINAHL, PEDro, Web of Science included the following string: *(acceleromet* OR pedometer OR step* OR physical activity monitor OR physical activity device) AND (stroke OR CVA) AND (chronic) AND (valid* OR reliability OR accuracy).*

Data extraction

Two independent researchers systematically reviewed the selected studies. They screened the records of the databases on title and abstracts according to the eligibility criteria. Subsequently, they screened the full text publications. Finally, they screened the reference lists of these publications for studies that met the inclusion criteria. With the aid of the 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) guidelines eligible studies were assessed for their methodological quality [11]. These guidelines comprise a checklist of 22 items that correlate to title, abstract, introduction, methods, results and discussion sections of articles. The maximum score is 22, with a higher number representing a better methodological quality [11]. Studies were not excluded based on quality. A third researcher resolved discrepancies. The results from the included studies were descriptively summarized. Reliability was accepted to be high when $r \geq 0.80$, adequate when $0.40 \leq r \leq 0.70$ and poor when $r \leq 0.40$ [12]: Validity was high when r was between 0.62 – 0.93 (using oxygen consumption as criterion measure). From the selected studies we also used the reported level of agreement of the Bland-Altman plots for accuracy. Since there is no uniform criterion for an acceptable accuracy, we used the reported findings of these studies and categorized PA devices based on these criteria.

Results

(Figure 1 near here) *Selection of the studies included in the systematic review*

Study selection
Initial screening found 648 studies (80: PubMed (MEDLINE), 13: EMBASE, 232: CINAHL, 0: Pedro, 323: Web of Science). After adjusting for duplicates, 525 studies remained. Based on title and abstract, another 512 studies were excluded for the following reasons: (1) No validity, reliability or accuracy study; (2) not concerning people with stroke; (3) not evaluating accelerometry, pedometer or physical activity. Out of the remaining 13 studies, seven studies met the inclusion criteria after examining the full text (figure 1).

(Table 1 near here) *Methodological quality of the included studies*

Study characteristics
Table 1 summarizes the methodological quality of the studies according to the STROBE guidelines. The quality score ranged between 19 and 22. Only one study (2018) calculated its sample size with a power of at least 0.9 [13]. Sample sizes ranged from 12 to a maximum of 43. Solely one study (2016) [14] presented the correlation coefficients (and its p-values) together with the use of the traditional Bland Altman plot. Table 2 summarizes the aim of the studies, type of participants, devices used and the criterion used as gold standard together with the results of the studies.
In total 193 participants were studied. Information about the type of stroke was only available in three studies [13,15,16] which included patients with both ischemic and hemorrhagic stroke.

(Table 2 near here) *Overview of the included studies*

Reliability, validity and accuracy of the investigated devices
Four studies reported on reliability [14,15,17,18], four studies on validity [13,14,17,19] and two studies on accuracy [16,18] (Table 2). Physical activity parameters that were investigated included energy expenditure [13-15,19], step count [14-19], gait parameters [17] and time spent walking [14]. Six studies [13-17,19] used accelerometry-based physical activity monitoring, one study investigated pedometers [18], one study investigated GPS-based watch [14] and one study studied a smartphone application [13].
The FEedback to STimulate Activity (FESTA) [17], the Actical [15], SenseWear Armband (SWA) [14,19], the Fitbit One [16], the ActivPAL [14], GT3X ActiGraph, Yamax Digiwalker Pedometer [18], a Garmin forerunner [14] and the Google Fit smartphone application [13] were investigated in the included studies (Table 2).

Validity, reliability and accuracy of accelerometers
The FEedback to STimulate Activity (FESTA) device is a tri-axial accelerometer designed to determine number of steps, number of walking bouts, covered distance and ambulatory activity profiles. It can be worn around the back site of the waist. Moreover, video recording was the criterion method used to determine validity of the FESTA and high ICC's for step count during three different walking speeds ranging from 0.841 to 0.971 were reported [17]. Test-retest reliability of the FESTA for measuring step count was reportedly high (ICC 0.938-0.972) [17].

The Actical is a tri-axial accelerometer, worn on the hip, that measures free living physical activity (total activity counts per day and the total energy expenditure per day (kcal/d)). The test-retest reliability of the Actical was excellent for activity counts and energy expenditure [15], with ICC's between 0.94 and 0.98. Excellent ICCs between the paretic and non-paretic hips for activity counts and energy expenditure were found (ICC 0.94 to 0.99).

The SenseWear Pro Armband (SWA) is a physical activity monitor that uses multiple sensors including heat flux, galvanic skin response, skin temperature, along with a two-axis accelerometer. It is worn on the back of the upper arm and provides estimates of energy expenditure.

The SWA measures between both arms were evaluated against the SAM (for steps) and Oxycon Mobile Metabolic Cart (for EE) as a criterion [19]. A moderate level of agreement with ICC of 0.682 for steps and 0.620 for energy expenditure was found. Validity of SWA measures taken on the paretic arm was poor (ICC=0.586) for energy expenditure and poor (ICC=0.220) for steps. There was a good level of agreement between SWA measured energy expenditure and the golden standard for the unaffected arm (ICC=0.702). The validity of SWA when placed on the unaffected arm remained poor for evaluating step count (ICC<0.352), with step counts being underestimated by the SWA. Mahendran et al. (2016) [14] reported that validity and reliability could not be calculated for the SWA due to lack of data.

The ActivPAL is a uni-axial accelerometer worn on the middle of the thigh. ActivPAL data are interpreted by their software to provide measures of steps, time spent walking and energy expenditure. Intra Class Correlations between 0.718 and 0.994 were reported for validity of step count at different walking speeds [14]. Validity of the ActivPAL for evaluating time spent walking was excellent (ICC 0.997). With regard to test-retest reliability, ICC's between 0.654 and 0.977 were reported for step count, between 0.659 and 0.999 for time spent walking and between 0.821 and 0.991 for energy expenditure. The Fitbit One is a commercially available physical activity monitoring device based on tri-axial accelerometry that provides information on step count and is worn at the level of the waist belt. A higher accuracy was measured at higher walking speed compared to slower walking [16]. For lower walking speeds, the Fitbit error was lower when the device was attached at the level of the non-paretic ankle.

The GT3X Actigraph is a tri-axial accelerometer giving outputs as counts per period of time (epochs). It estimates energy expenditure by converting its counts/min into kcal by using an algorithm. A fair association was found between the Actigraph and the EE measures acquired from the Cortex Metamax 3B (r=0.37) [13].

Validity and reliability of a GPS-based device and a smartphone application
The Garmin Forerunner is a GPS enabled sports watch that can be accompanied by the Garmin footpod accessory to add accelerometry data to the readings of the Garmin Forerunner device. The registered data such as step counts and time spent walking can be obtained from the Garmin connect website. An ICC of 0.986 for the validity of step count (golden standard: direct observation, manual step counter) and an ICC of 0.999 for time spent walking during an outdoor circuit (golden standard: direct observation, calibrated stopwatch) was found for the Garmin Forerunner 405CX [14]. With regard to test retest reliability, ICC for step count equaled 0.805, and for time spent walking, ICC equaled 0.970. One study (2018) [13] evaluated a smartphone application

and reported no associations for EE measurements obtained from this application compared to the gold standard (data from the Cortex Metamax 3B).

Validity, test-retest reliability and accuracy of pedometers
One single study (2008) [18] tested the accuracy and reliability of a pedometer, namely the Yamax Digiwalker. This device is a classic pedometer that measures step count and is worn on the waist belt. Variable validity (bias of 31 steps, 29% variability, p=0.026, ICC= 0.64) and acceptable reliability (ICC=0.58) was reported for this pedometer [18].

Discussion

This systematic review examined the literature published between 2009 and 2019 regarding the validity, reliability and accuracy of PA devices in chronic stroke survivors. We found that the validity, test-retest reliability and accuracy of accelerometers, footpods in combination with a GPS and pedometers varied between poor to high for absolute measures of PA[13-17,19] according to the studies examined. The reliability of relative measurements of PA such as energy expenditure by accelerometers are fair to high in chronic stroke survivors[14,15,19], but not valid when measured by a smartphone application [13] according to the studies we included. Unfortunately, all studies had a significant risk of bias due to small sample sizes, insufficient use of statistics and heterogeneity in study methods.

Accelerometry
According to Klassen et al. (2016) [16] accelerometers should be positioned on the non-paretic side of the body at the level of the ankle for better results in step count whilst others prefer the hips for better reliability[15]. Positioning the device around the ankle does not prevent counts of steps whilst tapping the foot in a sitting position. Compared to Giggins et al. (2017)[2] our review, however, also included two other accelerometry studies stating that positioning on the back[17] or at the non-paretic thigh[14] is highly reliable for step count. Unfortunately, all of these studies [14-17] had a significant risk of bias, due to a small sample size or insufficient statistical analysis. The latter was also stated by Gebreurs et al (2010)[7] about papers that they included for the review. Gebreurs et al (2010)[7] included studies until October 2008 on accelerometry. Overall, accelerometry is reportedly valid and reliable in patients with stroke in the chronic phase for absolute measurements of PA[14,15]. However, this finding is limited when walking speed is slow (0.3-0.5 m/s) and when it is positioned on the paretic side. On the other hand, good validity during speeds < 0.4 m/s[14] are shown and high reliability between measurements from the paretic hip compared to the non-paretic hip[15] are reported. Unambiguous findings from different studies[14,15] might be a consequence of the fact that none of these studies had an adequate sample size in order to have valid results from inferential statistics.
Hemiparetic gait is characterized by more variable and smaller vertical movements compared to gait in able-bodied individuals[20]. Accelerometers that are manufactured to be more sensitive to vertical movements (such as the Actical[15]) may have more difficulty in accurately counting steps during hemiparetic gait.
In the studies by Rand et al. (2009)[15] and Mahendran et al. (2016)[14] there was adequate to high reliability seen of the uni-axial accelerometers, but these studies largely included high ambulating post-stroke participants, and an inadequate sample size. A previous review reported that slower gait speed seems to be associated with higher inaccuracy[7], but this was challenged by findings from Klassen et al. (2016)[16]. They reported that accuracy was adequate when the tri-axial

accelerometer was placed at the level of the non-paretic ankle during a walking speed between 0.3-0.5 m/s[16]. Tri-axial accelerometers are suggested to be more appropriate for evaluations during continuous walking patterns instead of interrupted walking patterns as seen during hemiparetic walking (especially with spasticity) possibly because of less thigh acceleration. Hence, placing a tri-axial accelerometer on the paretic limb increases its chance for larger underrepresentation of actual steps taken.

Moreover, authors claim that validity of relative measurements of PA (i.e. energy expenditure) by accelerometers was fair to excellent in chronic stroke survivors [14,15,19], though one study suggested measurements not to be valid [13] due to the thresholds of caloric expenditure that are generally based on healthy adults instead of stroke patients. For example, a study by Serra et al. (2017)[21] suggested that revised cut points should be applied to better reflect activity related calories for the population of stroke survivors, because of 2-fold increase in energy expenditure during hemiparetic gait [22]. In addition, the algorithms were disclosed, the sample size was inadequate, and accelerometers were rarely compared to the golden standard[14,15,19]. This negatively affected the accelerometer studies that measured the validity of energy expenditure. A study[13] based on a calculated sample size with a power of 0.98 concluded that energy expenditure measures obtained from a tri-axial accelerometer were not valid when compared to the criterion measure (gold standard: data from Cortex Metamax 3B), however authors did not use the traditional Bland Altman plot along with the correlation coefficients. Thus, it is still difficult to draw conclusions. This study[13] was not included before in previous reviews[2,7].

Methodological considerations

Only one single study [13] calculated its sample size, whilst the rest of the studies did not. In addition, just one study [14] presented the correlation coefficients together with the use of the traditional Bland Altman plot. It is advisable to calculate sample sizes in order to have valid results from inferential statistics. A small sample size with wide variations might still result in high correlations introducing more interpretation bias [23]. It is recommended to use the Bland Altman plot when comparing the measurements from an old technique with a new one or when testing the level of repeatability of a device. Studies often use the correlation coefficients, but they measure the strength of a relation between two variables, not the agreement between them [23]. Moreover, several definitions were used for PA, with inconsistent measurement of PA across papers and algorithms of measurement for energy expenditure were disclosed. Therefore, we could not conclude what the level of reliability, validity and accuracy of PA devices was for chronic stroke patients.

Moreover, only three studies [13,15,16] reported the type of stroke but none reported the area of the brain that was affected. This is of importance, because complex gait patterns after e.g. cerebellar stroke resulting in ataxic gait can differ, due to displacement of the center of gravity (e.g. hip hiking, circumduction or lower walking speed) during walking [24] negatively changing the accuracy of the mechanism of the accelerometer or pedometer for that matter.

Pedometers

The Yamax Digiwalker SW-200 digitally counts steps while making use of a spring-coiled lever arm that closes a circuit during change in positions. Another neurological patient group with gait deficits showed inaccurate measures of step counts during slow gait speed (0.6-0.9 m/s) in comparison to a high gait speed (1.11-1.5 m/s)[30]. In contrast to this, it was suggested that step counts acquired from the Yamax Digiwalker pedometer are valid during low intensity walking of longer duration only if they are worn on the non-paretic limb and at the level of the knee in post-acute stroke survivors [25]. An explanation could be the higher acceleration in the knee joint during hemiparetic walking[24] making pedometers more sensitive to recording movements in the vertical axis. But this study (2014)[25] was also underpowered. Because of limited data regarding the use of pedometers in real life and in the rehabilitation setting for stroke patients we could not draw a consistent conclusion. Considering the potential benefits of using pedometers for increasing physical activity[26], further research is needed to assess the reliability and validity of pedometers in stroke survivors in the chronic phase.

Other physical activity monitors

The SenseWear Pro ArmBand (SWA) is designed to measure energy expenditure (EE) during PA using multiple sensors. It is sensitive to heat production during exercise and uses a two-axis accelerometer and algorithms in order to calculate EE during different activities [27]. The findings of the studies [14,19] suggest that the SWA is only applicable for stroke survivors who are moderately impaired with a higher average gait speed, but adjustments to the used algorithms seem also necessary for this specific population [21]. It is suggested to use the SWA on the non-paretic arm to avoid error from low arm swing during hemiparetic gait or change in paretic arm vascularization[27] which is also recommended for the use of the Garmin Forerunner 405CX. However, another study (2009)[28] among post-acute stroke patients opposes the use of multisensor activity monitors for the measurement of EE based on decreased vascularization on the paretic side, as well as unknown EE algorithms or algorithms based on healthy individuals used in the monitors, and position of the sensors. However, this study[28] was, conversely, limited by a small sample size.

This review not only re-confirms findings from previous studies, but also adds relevant information any new studies[13] regarding the validity, reliability and accuracy of physical activity monitors in chronic stroke survivors. Nevertheless, the significance of this review is limited by studies mostly with inadequate sample sizes and inappropriate use of statistical methods. In addition, most of the participants in this study had a mean walking velocity of 0.7 m/s, which can be classified as a high ambulating population after stroke [29]. Therefore, the findings cannot be generalized to the general population of chronic stroke survivors. Further investigation is therefore warranted.

Conclusions

Based on the available literature retrieved from 5 databases and published between 2009 and 2019, the evidence for the validity, reliability and accuracy regarding physical activity monitors remains unclear. Our findings challenge the conclusions of Gebreurs et al. (2010) [7] and Giggins et al. (2017) [2] regarding the use of accelerometry for absolute measures of PA in the stroke population. Correct placement of the accelerometer and adaptation to slower gait speeds do not render any difference in validity and reliability for absolute measures of PA. Hemiparetic gait is complicated, therefore, caution is needed for variables such as walking velocity, and the type of accelerometry or severity of stroke-related impairments. Additionally, accelerometers are not reliable for relative measures of PA such as energy expenditure due to stroke-related changes and unknown algorithms. Nevertheless, more research is necessary with adequate study designs (with for instance a calculated sample size, appropriate use of statistics) in order to have a better assessment of psychometric properties.

References

1. Winstein CJ, Stein J, Arena R, et al. Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke 2016;47:e98-e169.
2. Oonagh Giggins LC, Lorcan Walsh. Physical activity monitoring in Patients with Neurological disorders: a review of novel body-worn devices. Digit Biomark 2017;1:14-42.
3. Baert I, Feys H, Daly D, Troosters T, Vanlandewijck Y. Are patients 1 year post-stroke active enough to improve their physical health? Disabil Rehabil 2012;34:574-80.
4. Butler EN, Evenson KR. Prevalence of physical activity and sedentary behavior among stroke survivors in the United States. Top Stroke Rehabil 2014;21:246-55.
5. Vanhees L, Lefevre J, Philippaerts R, et al. How to assess physical activity? How to assess physical fitness? Eur J Cardiovasc Prev Rehabil 2005;12:102-14.
6. Sullivan JE, Espe LE, Kelly AM, Veilbig LE, Kwasny MJ. Feasibility and outcomes of a community-based, pedometer-monitored walking program in chronic stroke: a pilot study. Top Stroke Rehabil 2014;21:101-10.
7. Gebruers N, Vanroy C, Truijen S, Engelborghs S, De Deyn PP. Monitoring of physical activity after stroke: a systematic review of accelerometry-based measures. Arch Phys Med Rehabil 2010;91:288-97.
8. Block VA, Pitsch E, Tahir P, Cree BA, Allen DD, Gelfand JM. Remote Physical Activity Monitoring in Neurological Disease: A Systematic Review. PLoS One 2016;11:e0154335.
9. Foster RL. Reporting guidelines: CONSORT, PRISMA, and SQUIRE. J Spec Pediatr Nurs 2012;17:1-2.
10. Groth-Marnat G. Handbook of psychological assessment2009.
11. Meerpohl JJ, Blumle A, Antes G, Elm E. [Reporting guidelines are also useful for readers of medical research publications: CONSORT, STARD, STROBE and others]. Dtsch Med Wochenschr 2009;134:2078-83.
12. Cicchetti DV. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. Psychological Assessment 1994;6:284-90.
13. Faria GS, Polese JC, Ribeiro-Samora GA, Scianni AA, Faria C, Teixeira-Salmela LF. Validity of the accelerometer and smartphone application in estimating energy expenditure in individuals with chronic stroke. Braz J Phys Ther 2018.
14. Niruthikha Mahendran SSK, Emma Downie, Phoebe Ng, Sandra G. Brauer. Are Accelerometers and GPS Devices Valid, Reliable and Feasible Tools for Measurement of Community Ambulation After Stroke? BRAIN IMPAIRMENT 2016;17:151-61.
15. Rand D, Eng JJ, Tang PF, Jeng JS, Hung C. How active are people with stroke?: use of accelerometers to assess physical activity. Stroke 2009;40:163-8.
16. Klassen TD, Simpson LA, Lim SB, et al. "Stepping Up" Activity Poststroke: Ankle-Positioned Accelerometer Can Accurately Record Steps During Slow Walking. Phys Ther 2016;96:355-60.
17. Punt M, van Alphen B, van de Port IG, et al. Clinimetric properties of a novel feedback device for assessing gait parameters in stroke survivors. J Neuroeng Rehabil 2014;11:30.
18. Charlotte Elsworth HD, Charlotte Winward, Ken Howells, Johnny Collett, Andrea Dennis, Catherine Sackley, Derick Wade. Pedometer step counts in individuals with neurological conditions. Clinical Rehabilitation 2008;23:171-5.
19. Manns PJ, Haennel RG. SenseWear Armband and Stroke: Validity of Energy Expenditure and Step Count Measurement during Walking. Stroke Res Treat 2012;2012:247165.

20. Olney SJ, Griffin MP, McBride ID. Temporal, kinematic, and kinetic variables related to gait speed in subjects with hemiplegia: a regression approach. Phys Ther 1994;74:872-85.
21. Serra MC, Balraj E, DiSanzo BL, et al. Validating accelerometry as a measure of physical activity and energy expenditure in chronic stroke. Top Stroke Rehabil 2017;24:18-23.
22. Gersten JW, Orr W. External work of walking in hemiparetic patients. Scand J Rehabil Med 1971;3:85-8.
23. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
24. Farris DJ, Hampton A, Lewek MD, Sawicki GS. Revisiting the mechanics and energetics of walking in individuals with chronic hemiparesis following stroke: from individual limbs to lower limb joints. J Neuroeng Rehabil 2015;12:24.
25. Vanroy C, Vissers D, Cras P, et al. Physical activity monitoring in stroke: SenseWear Pro2 activity accelerometer versus Yamax Digi-Walker SW-200 pedometer. Disabil Rehabil 2014;36:1695-703.
26. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. JAMA 2007;298:2296-304.
27. Koehler K, Drenowatz C. Monitoring Energy Expenditure Using a Multi-Sensor Device-Applications and Limitations of the SenseWear Armband in Athletic Populations. Front Physiol 2017;8:983.
28. Mandigout S, Lacroix J, Ferry B, Vuillerme N, Compagnat M, Daviet JC. Can energy expenditure be accurately assessed using accelerometry-based wearable motion detectors for physical activity monitoring in post-stroke patients in the subacute phase? Eur J Prev Cardiol 2017;24:2009-16.
29. Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke 1995;26:982-9.

Tables and figure

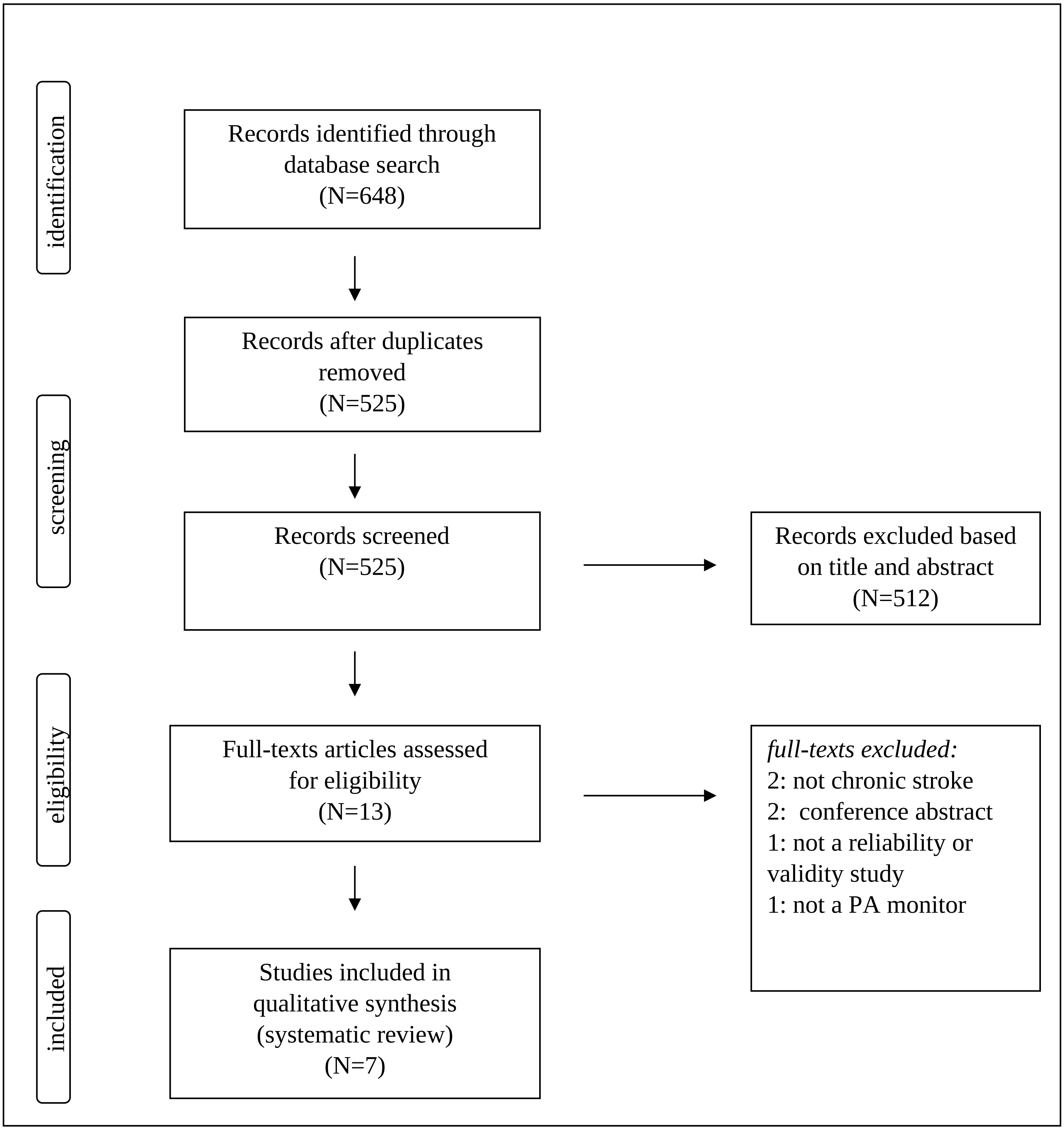

Figure 1 Selection of the studies included in the systematic review**.**

Table 1. Methodological quality of the included studies.

		STROBE items																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	**Total Score**
Author, year	**Elseworth C. et al. 2009**	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	**19**
	Rand D. et al. 2009	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	**20**
	Punt M. et al. 2014	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	**19**
	Manns P.J. et al. 2012	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	**19**
	Klassen T.D. et al. 2016	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	**21**
	Mahendran N. et al. 2016	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	**21**
	Faria G. et al. 2018	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**22**

**STROBE: Strengthening of the Reporting of Observational studies in Epidemiology*

Table 2. Overview of included studies

Author , Year	Aim of the study	Population	Measures of PA	PA monitor	Criterion	Results
Punt M. et al., 2014[17]	The criterion validity and test –retest reliability of the FESTA for walking activity	*N=33 for validity, N=27 out of these 33 for Reliability; Mean age: 61.8 ± 8.8 years	Walking distance; gait parameters; number of steps	FESTA (tri-axial accelerometer; placed on the back)	Video analysis	High validity and test –retest reliability
Rand D. et al., 2009[15]	The day-to-day reliability of accelerometry	N=40; mean age 66.5 ± 9.6 years	total activity & EE (Free-living PA for 3 days)	Actical (tri-axial accelerometer placed on each hip)	6 MWT	High reliability for each the activity counts and the EE across 3 days and between paretic & non-paretic hip. Adequate reliability between PA recorded at home and 6MWT at laboratory.

Author , Year	Aim of the study	Population	Measures of PA	PA monitor	Criterion	Results
Elsworth C. et al. 2009[18]	The accuracy of a pedometer in relation to a manual step count tally	N=20; mean age 56 ± 16 years	Step count	Yamax digiwalker SW-200 (pedometer placed on the hip)	Manual step count tally	Good accuracy and fair test-retest reliability
Manns P. et al., 2012[19]	Validity of SWA	N=12; mean age 64.2 ± 10.4 years	EE and step count	SWA (bi-axial accelerometer; on each arm)	- Oxycon mobile metabolic cart (EE) - SAM (step count)	Fair validity for EE and poor validity for step count

Author , Year	Aim of the study	Population	Measures of PA	PA monitor	Criterion	Results
Klassen T. et al. 2016[16]	Accuracy of one accelerometer	N=43; Mean age 65 ± 10.6 years	Walking steps (during 7 different walking speeds)	Fitbit One (on non-paretic waist and ankle; tri-axial accelerometer)	Video recordings	Accuracy was good when placed at the ankle compared to the waist (gait speed between 0.4 – 0.9 m/s) No steps recorded when gait speed was 0.3 – 0.5 m/s at the level of the waist, whilst steps were recorded in a large number of cases at the level of the ankle compared to the waist.

Author , Year	Aim of the study	Population	Measures of PA	PA monitor	Criterion	Results
Mahendran. et al. 2016[14]	Reliability, validity and feasibility of accelerometers and a portable GPS for community ambulation	N=15; Mean age: 63.4 ± 8.3 years	Step count; time spent walking; distance walked; EE (during 3 walking tasks: treadmill - and 6 minute walk test, 200m outdoor circuit)	ActivPAL (uni-axial accelerometer on non-paretic thigh); SWA (bi-axial accelerometer on paretic arm: triceps muscle); Garmin forerunner 405CX (portable GPS, position not reported)	Direct observation of investigators (calibrated stop watch; manual step counter; trundle wheel; field notes for exact location)	- **ActivPAL**: high reliability and validity for step count, time spent walking. For EE high reliability found. - **Garmin:** high reliability and validity for step count and time spent walking; poor reliability and validity for distance walked - **SWA:** not enough values for calculation of validity and reliability

Author , Year	Aim of the study	Population	Measures of PA	PA monitor	Criterion	Results
Faria et al. 2018[13]	Concurrent validity of ActiGraph accelerometer and Google Fit smartphone application	N=30*; Mean age: 62 ± 12 years	EE	GT3X ActiGraph accelerometer (tri-axial accelerometer on paretic ankle); Google Fit Smartphone Application (front pocket of paretic lower limb)	Cortex Metamax 3B	Do not provide valid measures of EE

**(only study with calculated sample size)*

***EE: Energy Expenditure; FESTA: FEedback to Stimulate Activity; GPS: Global Positioning System; PA: Physical Activity; SAM: Stepwatch Activity Monitor; SWA: SenseWear Armband.*