The influence of an 8-week water intervention on executive functioning and mobility in healthy older individuals

By

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DECLARATION

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

Background: Inevitable cognitive decline of Executive Function (EF) and Mobility, though quintessential for successful ageing, is already evident in apparently healthy older adults, aged 50 – 64 years. A water training environment might be ideal to simultaneously capitalise on neuroplasticity and Mobility, yet limited research applies. The elderly (≥ 65 years), specific EFs and aspects of Mobility are the focus of research.

Aim: Primarily, the influence of a high-intensity, 8-week water-based exercise intervention (WBEI) on EF and Mobility of healthy older adults were investigated. Secondly, it's influence on Health-related Quality of Life (HRQoL) and Physical Functioning to execute activities of daily living (ADL) pertained. It was hypothesised the WBEI would lead to greater EF and Mobility improvements, compared to non-exercising older adults.

Methods: A single-blinded randomised control trial divided forty-one, healthy older adults (50 - 64 years) into a high-intensity WBEI group (Experimental: EXP; $\bar{x}$ 55.23 ± 4.37; n = 22) and non-exercising Control (CON) group, attending time-matched-attention (TMA) relaxation and educational activities ($\bar{x}$ 59.05 ± 4.09; n = 19) with thrice, weekly sessions (45 minutes duration). Pre-and post-tests were completed. The two primary outcome variables were EF and Mobility with outcome measures and tests for EF were: Attention and Working (WM) - Digit Span Forward (DSFW) and -Backward (DSBW); Cognitive flexibility (CF) - Trail Making Test A and B (TMT A and TMT B); Inhibitory control (IC) - Walking Stroop Carpet (WSC). Outcome measures and tests for Mobility: Gait variables (single-task and cognitive dual-task) - the 7-metre instrumented Timed-up and Go (iTUG); Functional Capacity and Gait speed – the Six-minute walk test (6MWT). Secondary variables were as follow: Global Cognition - Montreal Cognitive Assessment (MoCA); Depressive Mood - Patient Health Questionnaire (PHQ-9); Health-related Quality of Life (HRQoL) - Short-Form Health Survey (SF-36) and Physical Function (PF-10).

Results: Treatment effects were found for: IC (P = 0.03), Gait speed (P = 0.003), Functional Capacity (P = 0.01), HRQoL (P = 0.04) and Physical Functioning (P = 0.008). Post-hoc analysis indicated improvement (P < 0.05) for both groups on IC for WSC Total duration (TD) on certain congruent, incongruent and average scores of incongruent Conditions. Only the EXP-group improved IC for TD on incongruent Condition 3 (P < 0.0001) and WSC derived scores (P < 0.05). Improved TD on single-task (ST) iTUG (P < 0.05) was found for both groups, yet only for CON group's TD on dual-task (DT) iTUG (P = 0.03). Gait speed (GS) for iTUG cognitive DT walking improved for the EXP group. Postural transition of Turn-to-sit (TTS) deteriorated (P = 0.01) for the CON group. Post-hoc results for secondary outcome were: Global Cognition (P = 0.0001), visual spatial ability (P = 0.049), memory (P = 0.04), Depressive Mood (P = 0.01), HRQoL (P = 0.0018) and PF-10 (P = 0.006) for the EXP group. With TMT B and ratio scores, CF improved (P < 0.05) for the CON group only but Physical Functioning decreased (P = 0.002).

Conclusion: The hypothesis is partially supported with the high-intensity WBEI for older adults, effectivly increasing IC and Mobility, whilst enhancing Cognition and decreasing Depressive Mood, to execute ADL and

enhance HRQoL. Training in water might be an ideal environment to address EF- and Mobility decline in older adults.

OPSOMMING

Agtergrond: Normale veroudering lei tot ‘n afname in noodsaaklike Uitvoerende Funksie(EF) en Mobiliteit, reeds sigbaar in oënskynlik gesonde, ouer volwassene (50 – 64 jaar). ‘n Water-gebaseerde oefenprogram (WBEI) kan ‘n ideale omgewing bied vir gelyktydige bevordering van neuroplastisiteit en Mobiliteit. Navorsing oor waterintervensies is beperk en gerig op bejaardes (≥ 65 jaar).

Doel: Die primêre doel was ondersoek oor die invloed van ‘n 8-weke, hoë-intensiteit WBEI vir ouer volwassenes op EF en Mobiliteit, terwyl die sekondêre doel ‘n ondersoek was oor invloed op gesondheidsverwante lewenskwaliteit (HRQoL) en Fisiese Funksionaliteit (PF-10) vir uitvoering van daaglikse aktiwiteite (ADL). Dis gehipotetiseer dat die WBEI EF en Mobiliteit sal verbeter inteenstelling met die groep sonder oefeninge.

Metodes: Een-en-veertig gesonde ouer volwassenes (ouderdom: 50 – 64 jaar) is ewekansig toegewys aan twee groepe, met beide hoof-navorser en deelnemers blind gelaat. Die Eksperimentele groep (‘EXP group’; $\bar{x}$ 55.23 ± 4.37; n = 22) het aan ‘n 8-weke, hoë-intensiteit WBEI deelgeneem, teenoor die Kontrole groep (‘CON group’; $\bar{x}$ 59.05 ± 4.09; n = 19) se ontspannings- en opvoedkundige aktiwiteite. Alle sessies was drie keer per week vir 45minute. Voor- en na-toetsing is vir beide groepe uitgevoer. Twee primêre uitkomste EF en Mobiliteit, geld. Uitvoerende funksie is as volg gemeet: Aandag en Werksgeheue (WM) met die ‘Digit Span Forward (DSFW)’ en -‘Backward (DSBW)’; Kognitiewe buigsaamheid (CF) met die ‘Trail Making Test A and B (TMT A and B)’; Inhibitiewe beheer (IC) deur die ‘Walking Stroop Carpet (WSC)’. Mobiliteit is op grond van verkose loopgang-veranderlikes tydens beide enkel-taak (‘single-task’) en kognitiewe dubbel-taakuitvoering (‘cognitive dual-task’) gemeet deur die 7-meter ‘instrumented Timed-up and Go (iTUG)’- toets. Funksionele Kapasiteit, sowel as spoed tydens loopgang, is bepaal met die ‘Six-minute walk test (6MWT)’. Die sekondêre veranderlikes en meetmiddels was as volg: Globale Kognisie - ‘Montreal Cognitive Assessment (MoCA)’, Depressiewe gemoed - Pasiënt-gesondheidsvraelys (‘PHQ-9’), gesondheidsverwante lewenskwaliteit (HRQoL) - Verkorte Gesondheidsvraelys (SF-36), asook Fisieke Funksionering in uitvoering van ADL - Fisieke Funksioneringsvraelys (PF-10).

Resultate: Behandelingseffekte is as volg verkry: IC (P = 0.03), versnelde loopgang (GS) (P = 0.003), Funksionele Kapasiteit (P = 0.01), HRQoL (P = 0.04), sowel as PF-10 (P = 0.006). Post-hoc analise toon beide groepe verbeter IC vir WSC Totale tydsduur (TD) op onderskeie kongruente, inkongruente, en gemiddelde tellings van inkongruente Kondisies (P < 0.05). Verbetering in IC vir TD tydens die inkongruente Kondisie 3 (P < 0.0001), asook afgeleide WSC-tellings (P < 0.05) is gevind vir die EXP-groep. Beide groepe toon korter tydsduur vir TD tydens die enkel-taak (ST) loopgang iTUG – toets (P < 0.05). Slegs die CON groep verbeter beduidend (P = 0.03) in TD met die kognitiewe dubbel-taak (DT) tydens die iTUG, waarteenoor slegs die EXP groep hul GS tydens die kognitiewe DT in hierdie toets verbeter (P < 0.05). Draai-tot-sit (‘Turn-to-sit: TTS’) verswak vir die CON groep, by voltooing van die ST loopgang (P = 0.01). Post-hoc analise vir sekondêre uiteenkomste is as volg gekry vir die EXP groep: Globale Kognisie (P = 0.0001), visuele ruimtelike vermoë (P = 0.049), geheue (P = 0.04), gemoedsverbetering (P = 0.01), HRQoL (P = 0.0018), asook PF-10 (P = 0.006). Kognitiewe buigsaamheid soos gemeet deur die TMT B, asook verhoudingstellings, het slegs vir die CON-groep (P < 0.05) verbeter maar die CON groep het beduidend (P = 0.002) verswak in PF-10 tellings.

Gevolgtrekking: Gedeeltelike ondersteuning van die hipotese, bevestig dat die hoë-intensiteit WBEI gemik op ouer volwassenes, effektief is in die verbetering van IC en Mobiliteit, asook Globale Kognisie en Depressiewe gemoed. Verbeterde uitvoering van ADL en verhoogde HRQoL is tot gevolg. Water bied 'n ideale oefeningsomgewing, waardeur die afname in EF en Mobiliteit van die ouer volwassene aangespreek kan word.

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NRF National Research Foundation

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LIST OF ABBREVIATIONS AND ACRONYMS

ACSM	American College of Sport Medicine
AD	Alzheimer's disease
ADL	Activities of daily living
ANOVA	Analysis of variance
AU	Arbitrary units
BMI	Body mass index
BP	Bodily pain
C2	Congruent walking condition
C3C	Condition 3: incongruent colour
C4W	Condition 4: incongruent word
Cad	Cadence
CANTAB	Cambridge Neuropsychological Test Automated Battery
CF	Cognitive flexibility
cm	Centimetre
CNS	Central nervous system
CTUG	Cognitive Timed-up-and-Go
CON	Control group
DS	Double support
DSBW	Digit Span Backwards
DSFW	Digit Span Forwards
DT	Dual-task
DTave	Dual-task average
DTC	Dual-task-Cost
DTC%Ave	Dual-task-Cost average
DTnumber	Dual-task number
DTword	Dual-task word
EF	Executive Function
EXP	Experimental group

fMRI	Functional magnetic resonance imaging
GE	Group effect
GHP	General health perceptions
GMH	General mental health
GS	Gait speed
HRQoL	Health-related Quality of Life
IC	Inhibitory control
ID	Interference difference
IR	Interference ratio
iTUG	Instrumented Timed-up and Go
Kg	Kilogram
MCI	Mild cognitive impairment
min	Minute
MoCA	Montreal Cognitive Assessment
6MWT	Six-Minute walk test
n	Number in total
NCD	Non-communicable disease
OA	Osteoarthritis
P	P-value
PAR-Q	Physical Activity Readiness Questionnaire
PHQ-9	Patient Health Questionnaire
PF-10	Physical Functioning Subscale
QoL	Quality of Life
RAPA	Rapid Assessment of Physical Activity
RHR	Resting heart rate
RLEP	Role limitations because of emotional problems
RLH	Role limitations because of physical health problems
ROM	Range of motion (Joint related)
RPE	Rate of perceived exertion
s	Seconds

SA	South Africa
SEM	Standard error of measure
SF	Social functioning
SF-36	Short Form Health Survey
SL	Stride length
SS	Serial subtraction
ST	Single-task
STAC	Scaffolding Theory of Ageing and Cognition
STS	Sit-to-stand
SV	Stride velocity
TD	Total duration
TE	Treatment effect
TMA	Time-matched-attention
TMT	Trail Making Test
TMT A	Trail Making Test A
TMT B	Trail Making Test B
TMT_D	Trail Making Test difference score
TMT_R	Trail Making Test ratio score
TTS	Turn-to-sit
UN	United Nations
VEF	Vitality (energy / fatigue)
WBEI	Water-based exercise intervention
WBEP	Water-based exercise pilot
WEI	Water-exercise intervention
WHO	World Health Organisation
WM	Working memory
WSC	Walking Stroop Carpet

>	Greater than
<	Smaller than
≥	Greater than or equal to
≤	Smaller than or equal to
%	Percentage
$\bar{x}$	Average

DEFINITIONS OF KEY TERMINOLOGY

Apparently healthy: The concept of "apparently healthy" is quite complex, and frequently used. However, a comprehensive, clear definition is still needed, especially when assessing the older populations. For the purpose of this study we accepted that the participants fall in the apparently healthy category, if they were cleared as "healthy" by their respective physicians (Sairam et al., 2014), do not have severe mental, psychological or physical diseases, including physical limitations preventing successful engagement in physical activity (American Heart Association, 1972).

Activities of daily living (ADL): This term encompasses all basic activities, normally executed during everyday tasks, albeit meal preparation, walking, dressing or bathing (Diamond, 2015).

Gait speed: Refers to the forward distance (2 step lengths) travelled during the gait cycle and divided by the gait cycle duration" (APDM Mobility Lab™©).

Elderly: The World Health Organisation (WHO) defines the term "elderly" as the time when an individual (≥ 65 years) can begin to receive pension benefits and occupational retirement (World Health Organisation, 2008).

Executive Functioning (EF): Essential mental skills that support activities of daily living i.e. the ability to plan tasks, paying attention and multi-tasking. Three main components of EF has been identified as Inhibitory control (IC), Cognitive flexibility (CF) (or set-shifting), and Working memory (WM) (Diamond, 2013):

- **Inhibitory control (IC):** Diamond (2013) states that IC is an essential ability to choose between different choices, focussing attention on a particular stimulus, or creating various possibilities and choices. More specifically, IC of attention enables an individual to pay selective attention, suppressing unnecessary attention to other stimuli. This allows an individual to inhibit him/herself from acting according to one's habits by controlling attention, behaviour thoughts and emotions.

- **Working memory (WM):** This core EF is responsible for the general storage of information in the frontal cortex. Working memory is critical to incorporate new ideas, change actions, or considering alternatives when memories of previous experiences are recalled. Reasoning would be impossible without WM (Diamond, 2013).

- **Cognitive flexibility (CF):** The role of this core EF enables an individual to explore various option and/ideas, therefore enabling different views from different perspectives. It allows quick change or adaptation to changing environments or circumstances (Diamond, 2013).

Frailty: Having ≥ 3 chronic or life-threatening diseases (such as ischemic heart disease) and/or using ≥ 5 prescribed drugs daily during the past year (Van Mourik et al., 2014).

Mobility: Demnitz et al. (2016) described Mobility as Functional Capacity in all dynamic situations, whilst maintaining posture.

Neuroplasticity: The structural and functional neuronal changes of the brain in response to changing environments (i.e. internal or external) (Glisky, 2007; May et al., 2007).

Older adults: Individuals finding themselves within the preceding fifteen years time - line (50 – 64 years), leading up to elderly status.

Osteopenia: Refers to the loss in protein (Chodzko-Zajko et al., 2009) and mineral content of bone tissue (Compston et al., 1995).

Progressive overload: Progression principles from the initial level of intensity will be applied to ensure sufficient overload to the musculoskeletal and cardiorespiratory systems (Conradsson et al., 2012).

Processing speed: The amount of time it takes the brain from receiving and perceiving one or several stimuli to responding to the chosen stimulus (Leonard et al., 2007).

Quality of Life: Rejeski et al. (2001) stated that mainstream psychology defines Quality of Life (QoL) as a conscious cognitive judgment of satisfaction with one's life. According to the Gerontological Society of America (GSA) it involves assessing physical and mental functional status.

Sarcopenia: The progressive and generalized loss of both skeletal muscle mass and strength. It correlates with physical disability, poor Quality of Life and death (Santilli et al., 2014).

Scaffolding: Refers to the compensatory neural pathways to bypass damaged areas or circuits through the life span. These pathways might either be newly developed or can be recruited from preserved circuits of younger years (Park & Reuter-Lorenz, 2009).

Stride length (SL): The distance travelled by a foot during two consecutive strides (Salarian et al., 2010).

Stride velocity (SV): Refers to the distance covered in centimetre per second (cm/s) and measured a % the individuals stature" (Salarian et al., 2010).

Cadence (Cad): Total number of steps taken per minute, where steps are counted only when both feet touch the walking surface (step-rate) (Salarian et al., 2010).

Double support (DS): Both feet are simultaneously making contact with the walking surface (Salarian et al. 2010).

Sit-to-stand-duration (STS): The time taken from a seated position to standing completely upright (seconds; sec) (Salarian et al., 2010).

Turn-to-sit-duration (TTS): The time taken after walking, turning 180 degrees and the return to the original seated position (seconds; sec) (Salarian et al., 2010).

PREFACE

This Master in Science thesis provides in the first chapter an introduction, followed by the background pertaining to the research topic. In chapter two, the reader is introduced to the population of interest - the apparently healthy older adult, aged 50 to 64 years. Key concepts regarding Global Cognition and the related domains of Executive Functions (EF) are discussed, followed by Mobility and its various parameters. The interwoven and complex relationships between these three concepts are examined, inclusive of their age-related structural and functional alterations. Simultaneously, Health-related Quality of Life, Depressive Mood as well as autonomy in executing activities of daily living are linked with EF and Mobility decline. Neuroprotective mechanisms of the ageing brain are elucidated, with the beneficial contribution underscored of exercise training effects on EF and Mobility. The unique characteristics associated with a water-based exercise environment and its conducive effects on Global cognition, EF and Mobility is detailed. The focal point of chapter three covers the motivation and rationale for the intervention, with special reference to the research objectives and variables. A description of the methodology follows in chapter four. The intervention design relating to participants, intervention protocol, as well as tests and questionnaires used, are explained. Chapter five provides detailed results, with graphs and tables included. Finally, chapter six expands on the results to provide insight into the influence of a water-based exercise intervention on EF and Mobility in healthy older adults. Limitations and recommendations for future studies are underlined and followed by a brief conclusion. The thesis follows the Harvard referencing format. Appendices at the end of the thesis serve as clarification and expansion of aspects of the intervention. These include the following: acknowledgement of financial assistance by the National Research Foundation, Ethics approval letter, lay-out of the water-based exercise intervention, tests and questionnaires, and other information relevant to the intervention.

CHAPTER 1
INTRODUCTION

1. BACKGROUND

Global communities experience significant challenges due to the increase in population growth as life expectancy and consequently, the number of elderly (≥ 65 years) increase (Andreasen & Sørensen, 2015). Concern is expressed for instance by Ball (2012) about the rapid and global increase in retired aged populations. This population group is expected to increase from 40.2 million in 2010 to 72.1 million in the year 2030, which is nearly a two-fold (44%) increase. Meanwhile, Gerland et al. (2014) predicted countries world-wide will have to accommodate nearly 12.3 billion elderly in the next 85 years since 2014. An additional, related concern accompanying this world-wide trend in rising life expectancy (longevity) is the possible impact on an individual's Quality of Life (QoL).

Enhanced longevity does not necessarily translate to satisfactory QoL (Lo et al., 2014). There is a notable difference between QoL and Health-related Quality of Life (HRQoL). The term QoL entails multiple concepts (Rejeski et al., 2001). It refers to a conscious, yet subjective cognitive judgement, of perceived satisfaction with one's life, regarding both physical and mental functional status (Rejeski et al., 2001; Diener, 1984; Pavot & Diener, 1993). Health-related Quality of Life (HRQoL) is also a self-perceived assessment of physical and mental health (Webster & Fellar, 2016; Resjeski et al., 2001), yet it includes the term of degree to which an individual is limited in executing activities of daily living (ADLs), either due to physical or mental shortcomings.

Inevitable age-related, natural decline in cognitive function and Mobility is associated with advanced ageing (Gothe et al., 2014; Zhao et al., 2014). Furthermore, as brain volume declines annually with 0.35% from the age of 50 years, Processing speed is one of the first cognitive processes to be affected, followed by attention, planning and reasoning (Bherer et al., 2013; Alvarez et al., 2008). These neuropsychological functions collectively support and enable efficient Executive Functioning (EF) (Diamond & Ling, 2016; Park & Reuter-Lorenz, 2009). Together these are considered essential mental skills that support activities of daily living (ADL), for example: the ability to plan tasks and execute them successfully, paying attention to relevant detail, as well as multi-tasking (Diamond, 2013). Hence, EFs are responsible for autonomy via independent and safe execution of ADL, albeit meal preparation, basic grocery shopping, dressing, bathing, decision making and financial management (Diamond, 2015; Albinet et al., 2012).

Since the pre-frontal lobes of the brain, which host EFs, are observed to be one of the first regions affected by age-related decline (Alvarez et al., 2008; Hillman et al., 2008), a diminishing EF system could have detrimental effects on overall Health-related Quality of Life (HRQoL) for the older adult (Forte et al., 2015). Three interrelated components of EF have been identified by Diamond (2013) as Inhibitory control (IC), Cognitive flexibility (CF), also referred to as task-switching or set-shifting and Working memory (WM). The interwoven and co-operative nature of these components, inclusive of the vital role of Processing speed and attention in cognitive and physical functioning, is clarified in chapter two.

Researchers also found EF and Mobility are interlinked (Gothe et al., 2014). The loss of Mobility or associated neuromuscular functions could complicate executions of ADL. This may lead to decreased function, affecting an individual's independence at an older age (Martinez et al., 2015). Furthermore, it is emphasised that the current rapid increase in population growth, accompanied by age-related decline in individuals' EF and Mobility, could result in a growing number of mentally and physically impaired frail older people by 2030 (Mahishale, 2015). These individuals might require extensive financial and medical care, placing a burden on economic sustainability and health care (Hartholt et al., 2011; Bayer et al., 2007; Stevens et al., 2006).

The ability to walk is a multi-task activity relying on EF (Mirelman et al., 2012; Hausdorff et al., 2004), since researchers found EF plays a pivotal role in the support and regulation of gait and balance (Vos et al., 2013; Mirelman et al., 2012). Gothe et al. (2014) also concluded that EFs of IC and CF were predictive of Functional Mobility and independence for older adults. Even fall risk in older adults (63 – 90 years) can be predicted by an individual's EF (Chen et al., 2012). A minor fall for an older individual can lead to detrimental consequences. For instance, approximately a third of community-dwelling elderly fall annually, with 10% of those falls resulting in serious fractures and head injuries (Gillespie et al., 2015).

Insufficient activity levels, being overweight or obese during one's mid-life (the years preceding elderly status) could possibly contribute to frailty and dependency (Cooper et al., 2014; Savela et al., 2013; Strandberg et al., 2012; Chastin et al., 2011). Hence, an individual's QoL could be compromised during their elderly years (Cooper, 1997). Frailty has also been associated with poor cognition and a recent study by Gross et al. (2016) concluded EF decline and impairment predicts the onset of physical frailty. Consequently, the detrimental effect of a sedentary lifestyle, hampering cognitive functioning and Mobility during mid to late adulthood (>38 years) may have severe cascading consequences in later elderly years (McMahon et al., 2014; Wennberg et al., 2014; Jeffreys et al., 2003). Nevertheless, these cognitive and physical decrements may be significantly ameliorated with the adaptation of a physically active lifestyle through mid- to later life stages (Bherer et al., 2013; Hamer et al., 2013; Hillsdon et al., 2005).

Global pharmaceutical companies and researchers have set out to identify ways of slowing the ageing process and improving health and longevity, but it seems that physical exercise still remains at the fore as an effective strategy to prevent or postpone fragility (Viña et al., 2016). Being physically active and to exercise seems to have a notable difference. Physical activity may not necessary include all the components of a combined, full-body exercise programme (i.e. cardiovascular, resistance or flexibility). For example, swaying an arm while seated in a chair, or doing a stretching programme, could suggest an individual is executing a physical activity. However, exercising could also encompass movements that cause cardiovascular and muscular fatigue (i.e. brisk walking, jogging, playing tennis, doing weight training etc.). Bherer et al. (2013) reviewed various studies on the effect of physical activity and exercise on cognitive functioning in adults (26 – 82 years) which will be elaborated on in chapter two. The author reported that further research is required to establish which type of physical activity would mostly benefit age-related cognitive decline (i.e. tasks forming part of one's ADL or structured exercise programmes to increase fitness and muscular strength). Nevertheless, after examining the results of the studies, Bherer et al. (2013) found that emphasis needs to be placed on inclusion of both aerobic and resistance components in future training programmes in order to conserve Global Cognition (Bherer et al., 2013), whereas studies addressing motor-learning and co-ordinated movements (Voelcker-Rehage & Niemann, 2013) could also be beneficial to improve cognitive functions (Bherer et al., 2013). Recently, Albinet et al. (2016) as well as Verstynen et al. (2015) emphasised inclusion of all the above training components as crucial for enhancement of and optimal EF performance.

Concern was raised regarding the limited number of health care programmes addressing cognitive and musculoskeletal disease prevention for the older adult between 53 to 65 years (Cooper et al., 2014; Waller et al., 2016). There is an urgent need for interventions specifically aiming to slow down or prevent age-related cognitive decline (Mahishale, 2015; Park & Reuter-Lorenz, 2009) and disease prevention (Jin et al., 2015). Physical activity, especially exercise interventions could be a viable option to address both of these issues as well as lowering the risk of disease (i.e. hypertension, diabetes, cardiovascular disease) and cognitive decline.

Mid-life to older adults (53 – 65 years) may already experience age-related physical barriers caused by either falls, injuries or other medical conditions (Feigin et al., 2016; Cooper et al., 2014) resulting in physical inactivity and sedentary lifestyles. Therefore, training in a water medium is a viable option and could not only be accommodating to these barriers, but could also allow cardiovascular, physiological and muscular adaptations to take place (Albinet et al., 2016). The buoyancy of water could virtually eliminate the effects of gravity, support the individual's body weight, reducing impact on weight-bearing joints, and act as a cushion for muscles, tendons and ligaments. Furthermore, due to viscosity, drag forces and frontal resistance, water provides resistance proportionally to the effort exerted against it and can be manipulated by speed of movement to facilitate muscular strength (Sherlock et al., 2013). All the latter properties, in combination with hydrostatic pressure (i.e. water pushes equally on all body surfaces) and circulating blood flow back to the heart (venous return), training in this medium could be forgiving, effective as well as enjoyable (Fedor et al., 2015; Sato et al., 2015; Sherlock, 2014; Sherlock et al., 2013; Hale et al., 2012). It seems exercising in this environment could be an inexpensive, non-pharmaceutical way to successfully address the cognitive and Mobility degeneration phenomenon in older individuals.

In conclusion, health care organisations and governments should take the view of Mahishale (2015, p.138) to heart: "...The ageing of populations is poised to become the next global public health challenge..." Limited research is available on the effect of water-based interventions on EF and Mobility in the ageing population. Therefore, this intervention set out to determine if an 8-week water-based exercise intervention (WBEI) of high-intensity would influence EF and Mobility (inclusive of improvement in ADL), as well as self-perceived HRQoL in apparently healthy older individuals living in the Western Cape.

CHAPTER 2
LITERATURE REVIEW

2.1 BACKGROUND

Ageing is a biological, inevitable reality. Decreased cognition and Mobility performance is associated with ageing, disability (La Plante, 2014), frailty (Bherer et al., 2013), chronic diseases (Feigin et al., 2016; Cooper et al., 2014), psychological disorders like depression (Lamar et al., 2013), neurocognitive disease like Alzheimer's Disease (AD), mild cognitive impairments (MCI) or stroke (Cabeza et al., 2016; Prince et al., 2015) and a reduction in health-related Quality of Life (HRQoL) (Steptoe et al., 2015).

Aside from the unprecedented and sudden increase in global population growth (Andreasen & Sørensen et al., 2015; Mahishale, 2015; Gerland et al., 2014) in past decades, an additional concern for governments and health care systems is the accommodation of high volumes of cognitive-and-mobility-impaired (CAMI) older and elderly adults (Mahishale et al., 2015). This phenomenon would be associated with high medical costs (Hartholt et al., 2011; Stevens et al., 2006) and increased health service delivery (Bayer et al., 2007). In the year 2012 the number of people turning 60 years of age was already equivalent to approximately two persons per second (United Nations, 2012). A vast number of young adults (15 – 39 years) and older adults (53 – 64 years) are already carrying the burden of chronic, age-related diseases (Feigin et al., 2016; Cooper et al., 2014), of which neurodegenerative diseases are the largest contributors to disability in older adults and represent over 20% of years lived with disability (Jin et al., 2015). The question arises whether these disabilities could have been reduced if preventative measures were taken between the ages of 40 – 52 years. However, by the time of writing, it seems research investigating cognitive and Mobility decline for this latter age group is quite scarce. None were found that addressed the latter two components in the age group 40 – 52 years, with only a few addressing the group from 50 years to 65 years of age.

Nevertheless, Mobility is associated with independence and safe execution of activities of daily living (ADL), and considered a critical contribution to the older adult's QoL, and status of wellbeing (Davis et al., 2015). Furthermore, diminishing Mobility (i.e. incapability or difficulty to perform specific tasks) has been identified as a biomarker of cognitive decline and falls (Hsu et al., 2016), including dementia. Executive Function (EF) impairments specifically were found to coincide with Mobility impairments in everyday physical activities (McGough et al., 2017; Thibeau et al., 2017; Burgess et al., 1998) as well as gait deterioration (Beauchet et al., 2014), indicating an increased risk for progressive development of dementia, MCI and AD (McGough et al., 2017; Montero-Odasso et al., 2017; Thibeau et al., 2017; Davis et al., 2015; Beauchet et al., 2014; Jessen et al., 2014).

These results could suggest that the ability to perform any physical activity relies on the integrity and neuronal health of the pre-frontal cortex, hosting all these EFs. The pre-frontal cortex controls various motor responses including higher order mental responses, such as the ability to plan, reason, making appropriate decisions and maintaining attention while performing a task. For example, resisting temptation or avoiding inappropriate reaction to an impulse, is associated with the EF process of Inhibitory control (IC) to enable self-regulation (Snyder et al., 2015). Cognitive flexibility (CF) facilitates the ability to adapt quickly to change, whereas Working memory (WM) retrieves and keeps past or present information for usage as necessary (Diamond, 2015, 2013).

All these processes seem complex and might require healthy interactive neural pathways for optimal motor and mental responses. Therefore, these EFs as labelled by Diamond (2013), may predict an individual's level of Functional Mobility (Gothe et al., 2014; Wakefield et al., 2010). Another aspect emphasised by other authors relates to the degree of Mobility, which may be predicative of the level of efficiency pertaining to cognitive functioning (Erickson et al., 2016; Alosco et al., 2015; Best et al., 2014; Weuve et al., 2004). These two viewpoints suggest the symbiotic relationship between EF and Mobility.

Various studies show Global Cognitive functions, (including EF) and Mobility are enhanced through active lifestyles, whilst age-related cognitive decrements may even be diminished (Diamond, 2015; Mahishale et al. 2015; Zhao et al., 2014; Eggermont et al., 2009). Recent studies report that exercise in combination with cognitive training and dual-task (DT) stimulation, increased cognitive performance more positively in comparison to engagement in any type of single-task (ST) training alone (Diamond & Ling, 2016; Lauenroth et al., 2016; Law et al., 2014; Wollesen et al., 2014; Schaefer et al., 2010). Furthermore, based on the EF framework of Diamond (2013), it has been suggested that participation in aerobic activities (Diamond, 2015; Guiney & Machado, 2013; Hillman et al., 2008; Colcombe et al., 2006) of moderate- to high-intensity (Hsu et al., 2016; Fedor et al., 2015) and longer duration (Davis et al., 2015; Chodzko-Zajko et al., 2009), combined with resistance training (Chang et al., 2012; Liu-Ambrose et al., 2010; Cassilhas et al., 2007), bi-manual co-ordination and sequential learning (Diamond & Ling, 2016; Erickson et al., 2015, 2014; Niemann et al., 2014; Verstynen et al., 2012) with added intensity and resistance, seem to be recommended for promotion of neural benefits and improved EF (Diamond & Ling, 2016; Sherlock et al., 2013; Voelcker-Rehage et al., 2013).

Considering the possible physical limitations of adults finding themselves in the preceding decade prior to elderly status (50 – 64 years) (Simas et al., 2017; Feigin et al., 2016; Cooper et al., 2014), being physically active according to the aforementioned criteria could be seen as a daunting task, with the real possibility added for injury. Therefore, a water-based exercise intervention (WBEI) that complies with the suggested exercise criteria could accommodate older adults more securely. The effect of buoyancy and less resistance on joints could decrease concern for added injuries, or fall risk, as well as reduce pain from current physical limitations. Positive results regarding certain gait parameters (i.e. Gait speed, posture and balance) have been reported in a number of water-based exercise interventions (WBEI's) (Refer to Table 2.4) which will be discussed in section 2.7. At the time of writing, only a limited number of water-based studies were found addressing EF as an entity, as only certain components of EF have been explored or the main focus was on Global Cognition (Fedor et al., 2015; Schafer et al., 2015; Sato et al., 2015, 2013, 2012; Sherlock 2014; Sherlock et al., 2013). The interventions are summarised as in Table 2.3, with section 2.7 highlighting the main findings as well.

Unfortunately, it seems water-based, land-based or informative research investigating both cognition or Mobility, mostly focussed on the elderly adult above 65 years (Forte, 2015; Arca et al., 2014; Watanabe et al., 2000), young adults (Diamond, 2015; Sato et al., 2015; Schaefer et al., 2015; Chang et al., 2013) or children (Gooch et al., 2016; Diamond, 2014; Wright & Diamond, 2014; Richland et al., 2013). This means adults finding themselves in the years preceding elderly status (50 - 64 years) are neglected. Therefore, comparison of results obtained across a variety of water-based studies addressing adults of 50 – 64 years was not possible for this study.

Cognitive and physical functioning alarmingly seems to diminish from the age of 53 years (Cooper et al., 2014), especially in adults that have been inactive or sedentary during young adulthood (Cohen et al., 2017; Hoang et al., 2016; Hwang and Castelli, 2015). Cooper et al. (2014) emphasised the relevance of neural sustainability for these adults, as cardiovascular and strength training result in ameliorated physical and mental abilities (Jak, 2012), including depression (Zhai et al., 2015). Physical activity remains the best alternative as a non-pharmaceutical solution to cognitive health and physical functioning (Mahishale et al., 2015). Therefore, more research is warranted to investigate cognitive-motor, evidence-based practices for older adult, particularly for those in mid-adulthood (50 – 64 years).

2.1.1 The older adult versus the elderly placed in context

A clear distinction should be made when differentiating between the older and elderly person. It is quite challenging to establish a clear, universal definition for elderly populations, since the definition for elderly age has to take multiple factors into account. These are for example chronology, change of physical and mental capabilities, improved life expectancy and QoL (Agrawal, 2016; Sabharwal et al., 2015; United Nations, 2012).

Younger adults have been defined as individuals between 18 and 50 years (Blanchard et al., 2016; Derksen et al., 2015), but terminology used for ‘elderly’ and ‘older’ adult is often used interchangeably and over the same lifespan - between 50 to 80 years. According to the United Nations (UN), (2012) the term older population usually refers to individuals aged 60 years and older. Yet, due to increased life expectancy (with numerous individuals reaching 80 – 100 years), it is necessary to distinguish the use of the terms elderly and older populations more clearly. Societal and cultural concepts may also differ in relating to the term ‘old’ or ‘older’ (UN, 2012).

The World Health Organisation (WHO, 2012) defined elderly as the time when an individual could begin to receive pension benefits and occupational retirement, occurring between the ages of 60 and 65 years. In contradiction, Sabharwal et al. (2015) conducted a review study and pointed out definitions of elderly in health and age-specific studies could range from 50 years and above. However, the majority (95%) defined elderly age by chronology alone, referring to elderly status as ≥ 65 years.

This study required a clear distinction between the older and elderly population residing in the Western Cape, South Africa (SA). The term elderly in SA does not necessarily relate to pensioner status. According to the UN, older individuals of SA associate old age with life experience gained or an increase in dependency on family, friends or health support systems, due to physical and mental capacity changes (UN, 2012). An additional distinction is made according to gender when pension pay-outs are considered. The age bracket for pension eligibility in SA is between 60 to 64 years, with women considered for pension at an earlier age than men (60 vs. 63 years, respectively) (Lloyd-Sherlock et al., 2014; UN, 2012). Elderly status is reached at age 65 years, yet a clear definition is still warranted (Agrawal, 2016; Sabharwal et al., 2015). Therefore, this study proposed that the older adult in SA would be between 50 – 64 years and participants were in this age bracket preceding and leading up to elderly status (≥ 65 years), irrespective of pension status.

2.2 GLOBAL COGNITION AND AGEING

Global Cognition is an umbrella term encompassing all neurocognitive domains (Figure 2.1.), enabling individuals to function in their daily lives.

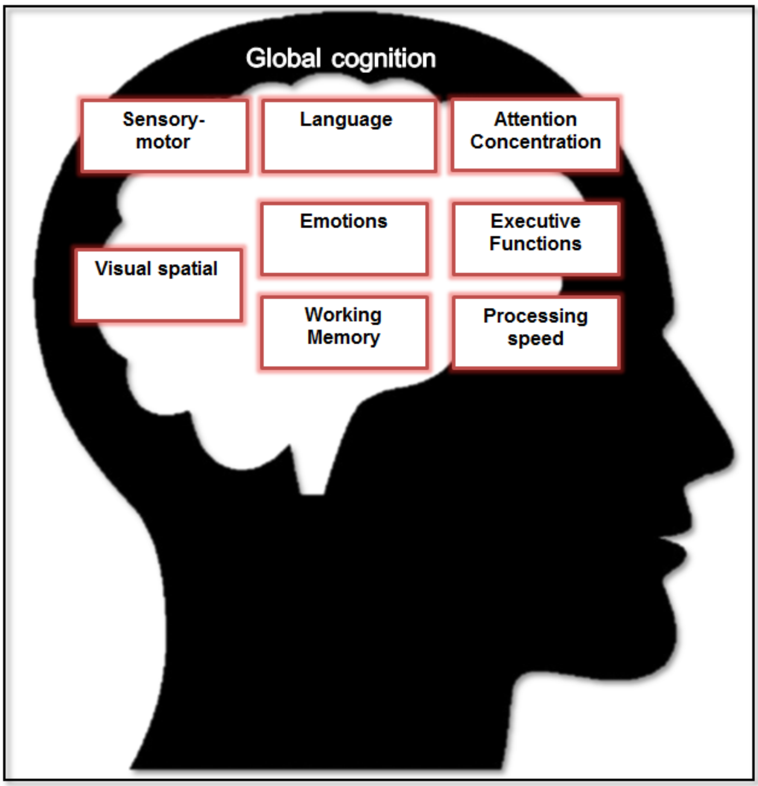


Figure 2.1 Cognitive domains.

Diminishing brain health might possibly be the most debilitating condition of old age, considering its association with several detrimental, life-altering changes. These include for example Mobility and/or Functional Capacity (La Plante, 2014) which affect the safe execution of ADL (Diamond, 2015; 2013), frailty (Gross et al., 2016; Mahishale, 2015; Bherer et al., 2013), QoL (Steptoe et al., 2015; Cooper, 1997) psychological mood behaviours (like depression) (Lamar et al., 2013), and expose the individual to neurocognitive diseases (Cabeza et al., 2016; Prince et al., 2015).

The Oxford Concise Medical Dictionary classifies the process of cognition as "…mental processes by which knowledge is acquired. These include perception, reasoning, acts of creativity, problem solving, and possibly intuition" (Martin, 2015, p.158). All these cognitive processes rely on integrated neuronal and cerebrovascular health throughout the entire brain (Xiao-Qi Ding et al., 2016; Boyle et al., 2013) and are also exclusive to specific cognitive domains, including EF. There are five fundamental cognitive domains relating to EF: WM, Episodic memory, Processing speed, attention and emotion (Cabeza et al., 2016). An overview of the interdependent and co-operative functions and skills associated with various cognitive domains are given in Table 2.1.

Table 2.1 Skills associated cognitive domains

Domain	Skills and/or cognitive functions
Memory (de Jager, 2010)	Three phases are involved in the memory process (encoding, storage and retrieval of information). Storing of memories involve 2 stages: short term memory and long-term memory. Four memory systems have been defined as: Episodic memory: Recalling specific events or situations and involves time and place. Procedural memory: Recalling the skills to perform tasks and includes well established skills for example, dressing or cycling or brushing teeth. Working memory: Recalling of words, numbers, and sounds. Storage last between 30-60 minutes. However, it should be noted that visual-spatial skills, attention span and other EFs seems to co-ordinate various aspects of Working memory. Working memory and updating of stored information have been expressed as creativity (Diamond, 2013; Lee et al., 2013). Semantic memory: Associated with language and recalling of abstract information (i.e. concepts, names of places or people or objects). Limitations in this domain could also cause the inability to find words during conversations, having difficulty in naming objects, even spelling and/or reading difficulty as well as speech fluency.
Language (O'Keefe & Kinsella-Ritter 2015; Clark et al., 2010)	Language skills of various types are included this domain and associated with the left cerebral hemisphere function. These skills involve understanding either a spoken or written language as well as to communicate efficiently by using the words in a particular order to make sense (i.e. semantics). Additionally, all words (written or spoken), must be according to specific rules as well as the application thereof (i.e. syntax).
Motor skills (Shmuelof et al., 2014)	These are inclusive of either fine-motor skills (i.e. drawing), or gross skills (i.e. jumping or running). However, all these motor skills require not only a goals or purpose but also inclusive of having knowledge pertaining to the goal/task and dependant on previous learning experiences.
Visual-spatial skills (Beurskens et al., 2012; Farran & Formby, 2012, p. 150)	This domain relates to the ability to conceptualise complex ideas and relationships, reproducing in the mind what one sees. It enables one to make sense of the visual world, interpreting the meaning of forms - albeit shapes, angles, colours, larger objects vs details of objects or figures.
Processing speed (Bherer et al., 2013; Mirelman et al., 2012; Leonard et al., 2007)	Processing speed refers to the time taken for all internal and external information to be neurologically processed. The ability to briefly hold on to information (processing capacity), while being processed, relies on the storage ability of Working memory. If received information is not processed quickly enough, it might become vulnerable to either disappear, or interfere with new incoming information. Limitations in Poor levels of Processing speed have been associated with language disabilities, slow reaction times, falls and frailty.
Executive Functions (Diamond & Ling, 2016, 2015, 2013)	Consist out of vital mental skills that allow successful and safe completion of ADL, as these activities rely on the ability to react or supress information to complete the goal of the task. Working memory and attention capacity (ability to remain undistracted from the goal) are critical role players in Executive Functions.
Attention/Concentration (Diamond, 2015)	This domain deals with the ability to maintain one's focus and/or concentration on any given stimulus or task, long enough to accomplish the goal, thereby inhibiting irrelevant information or distractions.

Most of these EFs and cognitive processes as referred in Table 2.1, occur beyond an individual's awareness. Perhaps the most noticeable age-related deficit is memory and attention (Glisky, 2007), accompanied by slower Processing speed which is associated with EF (Bherer et al., 2013). Difficulty to perform visual-spatial and dual-tasks in old age may be due to slower Processing speeds. According to Cabeza et al. (2016), in addition to studies addressing age-related deficiencies in Working - and Episodic memory, attention and slower Processing speed may be the most consistent and reliable finding across cognitive studies. The relevancy of all these domains in age-related cognitive decrements is consistently emphasised in literature (Cabeza et al., 2016). Additional cognitive skills also negatively affected by ageing, are orientation (Särkämö et al., 2014) as well as verbal and language skills (Glisky, 2007).

A chilling statement by Singh-Manoux and colleagues (2012), were based on results found during a longitudinal study of 10 years with a considerable number of participants (men: n = 5198; women: n = 2192; aged between 45 and 70 years). The aim was to estimate the onset of age-related cognitive decline. Results showed average cognitive decline occurred from as early as 45 years and was already evident in middle-adulthood (45 – 49 years). Xiao-Qi Ding et al. (2016) investigated grey matter neuronal decline in the normal ageing brain of 80 individuals (aged 20-70 years). The study reported decline was due to the reduction in grey matter volume and neuronal density. This causes a reduction in essential brain metabolites, altered cellular membrane turn-over and decreased energy metabolism. It was concluded the above-mentioned decline caused microstructural changes in cerebral white matter, as well as in the cerebellum (Xiao-Qi Ding et al., 2016). Nevertheless, there are substantial reports that these structural and/or functional alterations in the brain may have both acute and possibly prolonged influences on the ageing adult's life, as these alterations are mainly responsible for alterations found in cognitive functions (Monteiro, 2017; Cabeza et al., 2016; Xiao-Qi Ding et al., 2016; Jin et al., 2015; Bherer et al., 2013; Singh-Manoux et al., 2012).

However, cognitive decline remains a complex phenomenon and variability in cognitive decline amongst individuals has been observed (Glisky, 2007). Identifying the factors that can be attributed to the variance in rates of cognitive change, including those resilient markers, as well as ways to prevent even subtle age-related cognitive decline, needs urgent investigation (Boyle et al., 2013). It has been reported that some individuals decline rapidly or remain relatively stable, whereas some even improve due to practice and the learning effect, whereas others might exhibit a slower decline (Boyle et al., 2013). Cabeza et al. (2016) stated in accordance with Boyle et al. (2013) and Glisky (2007), that 60% of variation in cognitive decline (Boyle et al., 2013) aetiology still remained unexplained. Therefore, identification of diverse mechanisms contributing to cognitive decline is a matter of urgency (Cabeza et al., 2016), with equal importance to bring strategies into place to facilitate the prevention of late-life cognitive decline (Boyle et al., 2013).

Glisky (2007) further emphasised that cognitive decline is not equal in all areas of the brain. According to the author biological aspects, psychological aspects, health status, environment and lifestyle habits, could all attribute to inter-individual cognitive variability. Furthermore, the latter mentioned aspects, together with the differences in internal compensatory mechanisms, play a role in inter-individual cognitive variability. Healthier and stronger cognitive domains could compensate for the weaker domains (Glisky, 2007) whereas neuroplasticity of the brain involves structural and functional neuronal changes in response to changing environments (i.e. internal or external). It was concluded that compensatory mechanisms of the brain as well as the principle of neuroplasticity both play a protective role in both overall brain health and cognitive disease prevention (Glisky, 2007; May et al., 2007).

Therefore, it must be noted that there is an overlap of various cognitive processes and domains, associated skills, all interacting with one another in phenomenal and complex ways (Glisky, 2007). It seems diminished EFs play a vital and contributing role in a range of age-related global, cognitive decrements. Interventions based on sound scientific knowledge necessitate further research specifically addressing the interdependent role of EFs on Mobility, the influence on subjective well-being and HRQoL, as well as strategies to prolong the onset of EF decline caused by ageing.

2.2.1 Executive Functions

Diamond (2013) identifies three main interrelated components of EF: Inhibitory control (IC), Cognitive flexibility (CF or set-shifting) and Working memory (WM) and a co-operative relationship exists between WM and IC (Diamond 2013). Being able to change or recombine ideas, thoughts and behaviour, focus attention on a particular thought or action, an individual needs to inhibit internal (old habits) or external distractions (sounds, obstacles). However, one of the first cognitive domains to be influenced by ageing is EF, which is housed in the pre-frontal cortex and has been reported as the most vulnerable to ageing (Erickson et al., 2016; Alvarez et al., 2006).

Executive Functions specifically require a wide range of functional abilities from both subcortical and cortical regions (Alvarez et al., 2006) in the frontal lobes of the brain. This cognitive domain contributes to the variety in critical cognitive functionality and is linked to Mobility decrements in ageing (Sherlock et al., 2013). Furthermore, EF seems to control goal-directed behaviour (Friedman et al., 2016; Alvarez et al., 2006), thus playing a critical role in an individual’s independency level, dual-task (DT) ability (Mirelman et al., 2012) and QoL (Cabeza et al., 2016; Diamond, 2015; Salthouse et al., 2014) at an older age. Working memory in particular, seems to be the controlling hub of IC and CF, and is constantly being influenced by cognitive skills of Processing speed and selective attention. The former and latter statements emphasised the integrated relationship between the three main EFs and essential cognitive skills, either directly or indirectly influencing one another.

All these higher order EFs stem from high-level cognitive processes, for example reasoning, planning and creative problem-solving (Collins et al., 2012) and are responsible for controlling the lower-level cognitive processes (Friedman et al., 2016). Nevertheless, in order to grasp a clearer understanding of how EFs are concealed within Global Cognition, as well as their interdependent nature on each other (Diamond & Ling, 2016), IC, CF and WM needs individual clarification.

2.2.1.1 Inhibitory control

Inhibitory control allows for the execution of a considered response to a particular stimulus, rather than acting on it with impulse or suppressing attention to particular stimuli (Forte et al., 2015; Diamond, 2015, 2013). This particular EF prevents the individual to act on temptation, or more importantly, allow focussed movements or actions while resisting distraction (Diamond & Ling, 2016). Older adults are especially more easily distracted by irrelevant information when compared to younger adults and could be associated with poorer task-related performances (Bherer et al., 2013), for example in the execution of ADL. This may give an indication of diminishing brain function or activity in the pre-frontal cortex. The ability to walk relies on EF as it is seen as a multi-task physical activity

(Mirelman et al., 2012; Hausdorff et al., 2004). For instance, walking across a road is a specific EF challenging activity that requires the individual to use IC.

Another example where IC control comes into play is when walking alongside a road on the pavement. A variety of stimuli are received from the surrounding complex environment which may include the passing of motor vehicles, traffic noise, the surface of the walking path, stepping up or down from the sidewalk to make way for fellow pedestrians or screening for moving or static obstacles. All these internal and external stimuli received from the environment have to be scrutinised simultaneously. Some stimuli, whether auditory or visual, will have to be inhibited while walking (i.e. auditory: getting distracted from traffic noise; visual: paying too much attention to fellow pedestrians). This decision to either act upon, or inhibit a stimulus, or suppressing any irrelevant information (Diamond & Ling, 2016) relies on the individual's level of IC. However, it should be noted that IC control works in conjunction with WM and selective attention (Allen et al., 2017; Forte et al., 2015; Diamond, 2013; Nee et al., 2013), but will be discussed separately in sections to follow.

The current intervention assessed IC with a similar Walking Stroop Carpet (WSC) as originally developed by Perrochon et al. (2013). The WSC is a visual-spatial, dual-task walking test, based on the Stroop color-word test and seems to reflect the bi-directional interaction between EF and gait (Perrochon et al., 2013). The main aim behind the development of this carpet was to be able to detect MCI at very early and pre-clinical stage. Therefore, the population group (n = 49) represented young adults (20 - 30 years), older adults (64 - 74 years) and elderly adults (≥ 75 years), with or without MCI. Furthermore, Perrochon et al. (2013) concluded the WSC was able to detect early signs of diminishing EFs, providing a sensitivity of 89% and specificity of 94%. The authors found healthy participants (without MCI) performed poorer under the walking conditions that requested reading, but performed better when they had to distinguish colours.

Nevertheless, the WSC is quite unique in its design, as it requires one to adapt gait pattern whilst simultaneously navigating and inhibiting irrelevant information (i.e. as displayed in the incongruent walking conditions). The WSC could simulate walking in the natural environment (Perrochon et al., 2013), since the EF processes and skills required to navigate the carpet correspond with those required for efficient locomotion in a natural, dual-task, walking condition. For example, when walking on a pavement next to a busy road, the individual has to suppress distractive stimuli, simultaneously paying attention to objects or unequal surfaces in the walkway and quickly adapt gait patterns, if needed to avoid falling or injury. The study of Takimoto et al. (2015) used the WSC to assess fall risk in older adults with and without cognitive impairments and found the incongruent colour walking condition (similar to Condition 3 in the current study) appeared to be useful to discriminate fallers from non-fallers (Takimoto et al., 2015). Additionally, the current study suggests that the WSC could also provide an indication of levels of Processing speed, as stepping on targets (i.e. inhibition or actions) needs to be processed as quickly as possible. However, methodology and protocol with regards to the WSC are discussed in chapter four.

2.2.1.2 Cognitive flexibility (Set-shifting)

Occasionally it is expected from an individual to adjust actions due to either changing demands or priorities (Diamond & Ling, 2016). Diamond (2015), describes this EF as the ability to consider various solutions or options, pertaining to specific goals or tasks requiring execution. Therefore, should a situation, opportunity or a particular demand change unexpectedly, CF is needed to suddenly and effectively adjust and overcome these unexpected situations (Diamond, 2015; Vandierendonck et al., 2010). An example for utilising this EF would be when an individual is crossing the street and suddenly has to adapt the action of walking to either halting, changing the direction and/or speed of walking, to avoid being struck by an unexpected obstacle such as a speeding motor vehicle. A similar example of using CF would be when walking with a companion, whilst conversing. Should an unexpected object like a rock, hole or deep puddle of water suddenly be observed, it would be necessary to quickly adapt to the situation and react accordingly, to avoid injury or simply even the discomfort of wet shoes.

It seems during execution of most ADL, QoL of an individual could be determined by the general capacity to maintain an effective course of action when in the faced with interference by irrelevant stimuli (Jensen, 1968). Therefore, it is suggested that IC and CF encompass the processes of interference and facilitation, to determine differential responses in alternating situations. Functional adjustments to new or challenging situations also depend on the degree of learning and recall from past experiences where WM in particular comes into play. Working memory has been reported as the vehicle or co-ordinating hub to facilitate IC and CF (Diamond & Ling, 2016; Diamond, 2015, 2013).

Cognitive flexibility was assessed by using the Trail Making Test Part B (TMT B) which reflects both WM and CF (Sánchez-Cubillo et al., 2009; Bowie & Harvey, 2006; Arbuthnott and & Frank, 2000). In this test, 25 encircled numbers (1-13) as well as letters A to L are randomly distributed on this pen and paper test. The aim is to sequencially connect and alternate, as quickly and accurately as possible, between numbers and letters. Executive control and task switching ability is assessed. However, researchers reported TMT derived composite scores are more sensitive in specifically giving an indication of CF (Bowie & Harvey 2006; Arbuthnott & Frank, 2000; Lezak 1995). These scores diminish visual-perceptual and WM requirements, therefore allowing a better indication of CF ability (Perianez, 2007; Arbuthnott & Frank, 2000). The calculated composite scores used include the TMT difference score (TMT_D = TMT B – TMT A) as well the TMT ratio score (TMT_R = TMT B/TMT A).

2.2.1.3 Working memory (associated with updating)

Working memory has been studied for decades and found to be a necessity when co-ordinating cognitive processes, especially in tasks requiring more than one goal (D'esposito et al., 2015; Forte et al., 2015). This essential mental skill belongs to neural activation in the pre-frontal-parietal system allowing the brain to hold on to, whilst analysing information based on previous experiences or similar situations (Diamond, 2015; 2013). Incoming information gets stored briefly in WM, until processing has been completed. Leonard et al. (2007) suggests that briefly stored information is vulnerable as it may disappear or be forgotten. New incoming information might cause distraction and loss of focus, having a negative impact on planning and reasoning (Diamond & Ling, 2016). Increased WM capacity could thus allow holding onto task-specific information for longer periods, promoting the replacement of irrelevant information with task-relevant information (Miyake et al., 2000). According to Bherer et al. (2013) this conscious manipulation of information is highly age-sensitive, therefore should EF control processes (i.e. IC, WM) be required in task execution, the older adult might find it more difficult to manipulate this information if memory load increase (i.e. holding information with regards to a number of items).

i) Visual spatial Working memory and verbal Working memory

Working memory is further classified according to content (Diamond, 2013), differentiating between visual spatial WM and verbal WM. De Beni et al. (2005) explained visual spatial

WM enables an individual to keep and hold non-verbal information (i.e. tapping on a sequence of shapes or colours), whereas verbal WM is responsible for holding phonological entries (i.e. or repeating a sequence of letters or digits). Visual spatial and verbal WM work together closely and is seen as the ability to mentally remember and visualise instructions. A possible example would be receiving telephonic directions to a friend's house: *"…From Main Road: drive 2.5 km past the big entrance of the tartan covered tennis courts on you right, cross two traffic intersections, and the road works which are clearly marked with the orange cones. Once you have reached Dolphin Crescent Street, turn left, past the shopping mall with the visible, red squared logo. The party is hosted in the little park next to the shopping mall. Look out for the hostess in the bright blue dress".*
The example above contains both visual spatial and verbal WM aspects. Consider executing the above task by relying purely on memory while driving and it clearly emerges how WM, visual-spatial WM and verbal WM co-operates in harmony. Applying the entire principle of WM in its entirety thus enables the individual to make sense of current theoretical and abstract information, but also take past actions into consideration during decision-making processes (Diamond & Ling, 2016; Diamond, 2015; 2013).

Thinking about new ideas (updating), forms an integral part of all thinking and planning processes, allowing the individual to mentally explore facts, ideas or considering a variety of options or solutions pertaining to a particular situation (Diamond, 2013). Updated information or instructions are then projected into suitable actions, particular to that specific situation (Diamond, 2015). However, WM also enables an individual to react or behave in a particular way (Forte et al., 2015), even if information is not present in the immediate situation (D'esposito et al., 2015). The time taken from when a stimulus is received, to the point until an action is executed, relies on two additional vital cognitive functions, namely Processing speed and attention.

ii) Working memory and Processing speed

Processing speed refers to the amount of time it takes the brain from receiving and perceiving one or several stimuli to responding to the chosen stimulus (Leonard et al., 2007). As mentioned before, WM and Processing speed works in a co-operative way (Leonard et al., 2007). Neurological processing of both internal and external stimuli, as well as the time taken to process this information, is of essence in the safe execution of ADL. This information is only briefly stored by WM and vulnerable to be influenced by or interfered with new incoming information, hence possibly affecting task-specific goals or planning and reasoning (Diamond & Ling, 2016; Miyake et al., 2000).

Utilising the example of walking and talking with a companion (while observing a puddle of water in the immediate walkway), the individual might find himself/herself in a similar situation again. The individual decides to leap over the puddle. In this example either the distance was misjudged or muscle power or leg speed required to successfully jumping across was insufficient, therefore the decision could result in injury and the discomfort of wet shoes.

However, the interaction between WM and creativity (Lee et al, 2013; Diamond, 2013) in problem-solving comes to play in the next example. Similarly, the individual walks in a parking lot and greets a friend. Should a similar puddle of water be observed again in the immediate walkway, an appropriate, yet fast decision is again required. Working memory allows the individual to hold on to, analyse and retrieve information from the previous experience, quickly processing the current context, utilising creative problem-solving strategies. In milliseconds, the decision is made for instance to rather stop walking, complete the greeting process and find an alternative walkway. Therefore, past information has been retrieved that served as a guideline, based on the memories and consequences of the previous chosen action, even though stimuli from the external environment were completely different in the latter scenario.

Furthermore, to successfully execute any particular thought or action, an individual has to inhibit possible detrimental, internal (i.e. old habits) or external distractions (obstacles, sounds, etc.) as explained by the latter examples. However, Processing speed and selective attention were also involved during these decision-making processes, with both skills correlating with WM. The five-year longitudinal study conducted by Mirelman et al. (2012) on older adults (women: 76.4 ± 4.5 years) emphasised the importance of treatment programmes for older population groups to enhance all EFs (WM, attention, visual spatial), whereas Bherer et al. (2013) accentuated the importance of Processing speed. Nevertheless, Mirelman et al. (2012) found higher EF indexes, specifically attention scores, significantly ($P = 0.017$) predicted lower fall risk in older adults as poor levels of EF and attention significantly influenced dual-task gait performance ($P = 0.071$) in these older adults. Post-test results indicated reduced EF indexes but specifically attention test scores completed at pre-test (five years earlier), significantly ($P = 0.02$) predicted future fall risk in community-dwelling older adults. It was concluded that EFs and attention abilities underlie similar constructs (Mirelman et al., 2012).

It seems clear that both the complexity and interrelated nature of Processing speed (with all other EFs) in combination of physical ability, are at play in the walk and talk example. Processing speed is indicated in the detailed analysis of processes involved in the walk and talk example, as follows:
As the individual jumps over a puddle of water, numerous thoughts, memories, planning and reasoning takes place within milliseconds. Additionally, the brain has to handle appropriate motor-control responses to propel the individual in an upwards and forwards direction, meanwhile sending signals to adjust posture to maintain balance at both the jumping and landing spot. Simultaneously, the sudden change in gait pattern needs to be accommodated, speed and power in the muscles manipulated, whilst alternative walkway possibilities (not containing water puddles) need to be assessed. A decision regarding the best option needs to be reached, remembering the past experience of wet shoes. At the same time, conversing with the companion in a meaningful manner takes place, while processing words, thoughts and opinions based on the current conversation.

The time taken by the brain to encompass all aforementioned processes until a motor control response is executed, relies on the brain's Processing speed. Therefore, Processing speed enables an individual to respond to both internal and external stimuli, while simultaneously favouring posture and balance in order to prevent possible risk of falling and injury.

A recent study by Welmer et al. (2017) on older persons of both genders (≥ 60 years) without cognitive impairment, found slower Processing speeds, in combination of a defective EF system, significantly ($P < 0.05$) predicts injurious future falls of older persons without cognitive impairment in the long term (10 years). In another review of studies investigating the influence of resistance training on EFs, it was underlined that especially higher Processing speed and memory scores were associated with higher resistance/strength training frequencies (Chang et al., 2012). Furthermore, it was reiterated that training programmes consisting of loads between 60 – 80% One Repetition Max (1RM), two sets of seven repetitions, 2 minutes rest period between repetitions and training at least twice per week enhanced Global Cognition, information Processing speed, attention and memory performance (Chang et al., 2012).

In the current study Processing speed was not assessed specifically, however both the WSC and TMT test could give an indication of how quickly an individual processed the information. For example, in the WSC it was required to quickly process the next correct stepping target to navigate the carpet, whereas in the TMT test the next correct digit or letter to respond to, had to be processed against time (i.e. performing the task as quickly as possible).

iii) Working memory and attention

The ability to remain focussed on a task and mentally holding on to relative task-specific information for a given time, relies on the ability to hold one's attention and not become distracted by irrelevant stimuli or information. However, this ability is also interdependent on WM and IC (Diamond & Ling, 2016; Diamond, 2013). Working memory and the specific role of selective attention in WM and to regulate external information, are equally critical (Abrahamse et al., 2016). Executing everyday activities require consistent analysis of internal or external stimuli and concentrating on the current task that needs execution (Diamond, 2013).

However, this process not only necessitates the inhibition of irrelevant information but also facilitating prerequisite information in order to safely execute goal-directed actions. Therefore, the co-operative relationship between WM and IC (Diamond, 2013) as well as CF, Processing speed and attention allows the individual to experiment with ideas, adapt them, and to change behaviour in response to stimuli (i.e. memories, auditive or visual stimulation from the environment).

In conclusion, based on the views and results of studies focussed specifically on attention and WM (Kiyonaga et al., 2014; Vandierendonk et al., 2014; Vergauwe & Cowan, 2014), it can be deduced that the intricate relationship between EF domains are necessary and possibly require further investigation.

The current intervention measured both attention and WM with the Digit Span Forward (DSFW) and Digit Span Backward (DSBW) tests, respectively. These tests are both verbal in nature. The DSFW requires attention, as well as the verbal capacity (Hester et al., 2004;

Baddeley, 2000) to recall random digits in a forward order (i.e. 4, 3, 8, 2, 1, 5), whereas the DSBW measures WM specifically (Woods et al., 2001; Lezak, 1995). In the latter, digits are recalled in reverse order after the examiner read them aloud in a forward manner. Therefore, the individual has to remember the called out digits, temporarily keep this information through WM and manipulate information by verbally repeating them in reverse order (i.e. 5, 1, 2, 8, 3, 4). In addition, the WSC also required participants to selectively focus on relevant information and not be distracted by intrusive, interfering stimuli, such as either incongruent colour (Condition 3) or word (Condition 4).

2.3 EXECUTIVE FUNCTIONS AND AGEING

Normal age-related cognitive decline is associated with changes in brain and neural structure. Decay and atrophy primarily occur within the frontal, parietal, and temporal lobes (Erickson et al., 2015; Colcombe et al., 2006; Colcombe & Kramer, 2003). Therefore, it can be expected that older adults will tend to have greater difficulty with advancing age in executing complex and even everyday tasks (Beurskens & Bock, 2012). The pre-frontal cortex, hosting the EFs, is most vulnerable and first affected by the ageing process (Bherer et al., 2013; Diamond, 2013). This diminished EF functioning leads to decline in reasoning, planning and forming logical strategies to execute a predetermined plan (Beurskens & Bock, 2012). Diamond (2013) stated that EFs and the pre-frontal cortex are disproportionally affected by stress and anxiety, emotional feelings of sadness, loneliness as well as insufficient activity levels.

Functional Magnetic Resonance Imaging (fMRI), combined with longitudinal cognitive studies, have contributed extensively in understanding the effect of ageing on brain health as well as functionality. A particular study conducted by Forte and colleagues (2015) on healthy 65 - 75 year old adults, investigated the influence of EFs on mental - and physical health, as well as Health-related Quality of Life (HRQoL). The authors found that EFs predicted HRQoL. This is in accordance with another finding by Davis et al. (2010). This author stated the contribution of independent EFs on HRQoL in older women (65-75 years) was investigated, leading to the conclusion that CF, as well as WM, were independent contributors to HRQoL.

The impact of natural ageing and the magnitude of its associated EF decline on the older adult's autonomy, ADL and HRQoL will vary individually (Sherlock, 2014; Park & Reuter-Lorenz, 2009). The variance is dependent on the extent that age-related compensatory and adaptive processes can be recruited, in response to the individual magnitude and pervasiveness of structural and functional decline (Park & Reuter-Lorenz, 2009).

The relationship between these structural age-related changes and their association with EFs are highlighted in the next section. The role of exercise on EFs will be addressed in section 2.7.

2.3.1 Structural and functional alterations within the ageing brain

Natural ageing manifests not only in many structures showing atrophy, but also in cortical thinning and decreased integrity of white matter (Fjell & Walhovd, 2010; Park & Reuter-Lorenz, 2009). According to Fjell and Walhovd (2010), age-related volume decline does not necessarily indicate neuronal loss, but rather entails shrinkage of neurons. It was further stated that the length of myelinated axons can be reduced by almost 50%, with reductions in the number of synapses, especially in the grey matter. Thus, the integration and co-ordination of neural activities between various structural areas may be compromised, leading to declining EFs, Processing speed and attention (Fjell & Walhovd, 2010; Park & Reuter-Lorenz, 2009).

Age-related structural changes are largely visible in the pre-frontal and temporal cortex, whereas the cerebellum and basal ganglia comprise two major subcortical structures affected by the ageing process (Saba, 2015; Bostan et al., 2010; Fjell & Walhovd, 2010). Both subcortical structures are connected to multiple areas of the cerebral cortex via discrete, multi-synaptic loops. This integrated functional network which receives and sends information to the cerebral cortex, influences cognition, affect (mood) as well as movement (Bostan et al., 2010). Figure 2.2 depicts the neural input and output pathways between the deeper brain structures and the cortex.

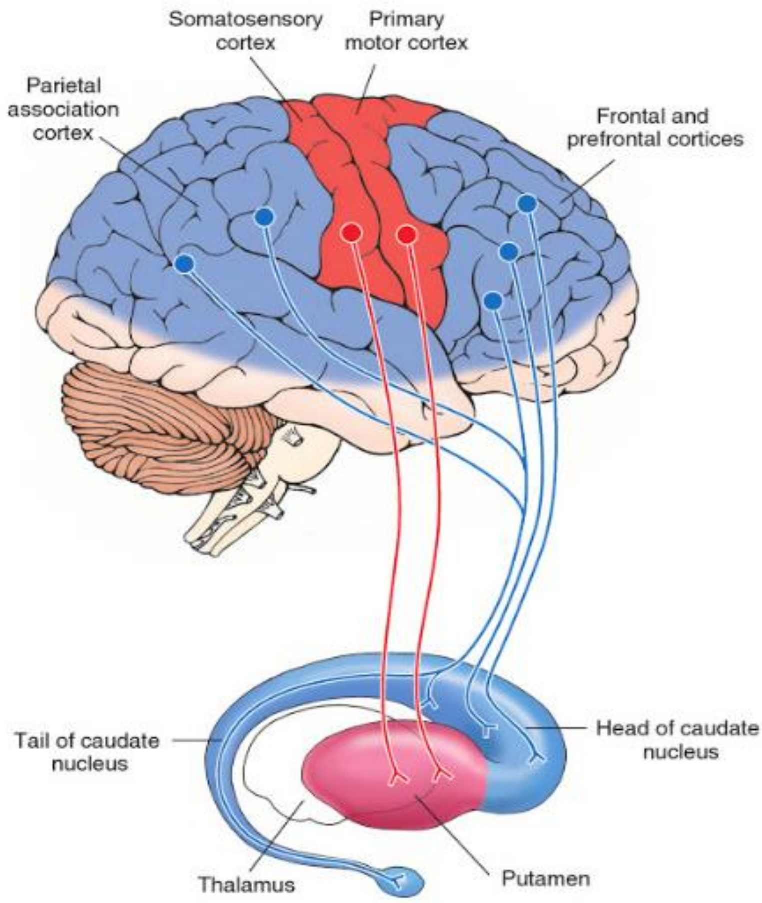


Figure 2.2 Neural input and output pathways between the basal ganglia and cortex (Siegel & Sapru, 2011; Illustration reproduced with permission).

The basal ganglia lie deep within the brain. The structures inside the basal ganglia receive input from the primary motor cortex, somatosensory cortex, pre-frontal cortex as well as the pre-frontal, temporal and parietal lobes (Figure 2.2). The three components of the basal ganglia (Bostan et al., 2010) namely the putamen, caudate nucleus and globus pallidus (refer to Figure 2.3) are fundamental to CF (Becker et al., 2016). These structures support task co-ordination and directing attentional control during task-switching activities.

Dopamine neurons in the substantia nigra extend to the putamen (Saba, 2015). The decline due to natural ageing in the volume of the putamen, which is mostly involved with the production of dopamine, is reflected in decreased regulation of attention, Processing speed, Episodic memory (Fjell & Walhovd, 2010) and response to contextual stimuli (Park & Reuter-Lorenz, 2009). Not only EFs, but also ADL and HRQoL would be affected by these age-related alterations. Park and Reuter- Lorenz (2009) emphasised the pervasive effect of the loss of dopaminergic receptors in the putamen. Perhaps these alterations in the putamen could explain increased vulnerability to depression associated with ageing.

Additionally, decreased hippocampal volume is noted with advancing age (Becker et al., 2016; Erickson et al., 2015; Rosen, 2003). A considerable decline in memory, WM included, is associated with decreased pre-frontal and hippocampal volume (Park & Reuter- Lorenz, 2009). However, decline in thalamic volume is also associated with decreased memory, comprising WM, Episodic memory or Long-term memory (Park & Reuter- Lorenz, 2009; Rosen, 2003).

The thalamus is associated with various cortical, subcortical and cerebellar structures (Fama & Sullivan, 2015). It is specifically the thalamus-pre-frontal network that enables goal directed memory acquisition, retrieval, and encoding during conscious control (Park & Reuter-Lorenz, 2009). Thus, the decline with age in these networks affects higher-order cognitive processes and EFs of WM, Processing speed, and IC (Albinet et al., 2016; Philp et al., 2014; Park & Reuter- Lorenz, 2009). Figure 2.3 highlights the location between the deeper-seated structures, connected with EFs, in relation to the lobes of the brain.

The large difference between decline in structural volume and the strength of effect it may have, varies across brain areas as well as individuals (Fjell & Walhovd, 2010; Park & Reuter- Lorenz, 2009). Some areas decline linearly from early in life, others continue to increase in volume into mid-adulthood, before deteriorating commences in later life (Fjell & Walhovd, 2010). Growth has been reported to occur in white matter volume until 40-50 years, before this volume starts to decline (Fjell & Walhovd, 2010). Structural changes in the pre-frontal cortex, temporal and parietal lobes may occur from as early as 30 years of age (Leal & Yassa, 2013; Park & Reuter-Lorenz, 2009). Additionally, annual decline of 1-2% in the hippocampus and pre-frontal cortex of individuals older than 55 years have been confirmed by Erickson and colleagues (2015).

In reference to the parabolic trajectory of EF and mobility across the life span (Figure 2.7), these changes and the resultant effect on the neural networks highlight the adverse effects on IC, CF, WM, Processing speed, attention and even Depressive Mood (Verstynen et al., 2012; Park & Reuter-Lorenz, 2009) during natural ageing. Ageing seems not to just affect the pre-frontal cortex, causing EF to decline, but also other multi-structures located deep in the brain (Siegel & Sapru, 2011).

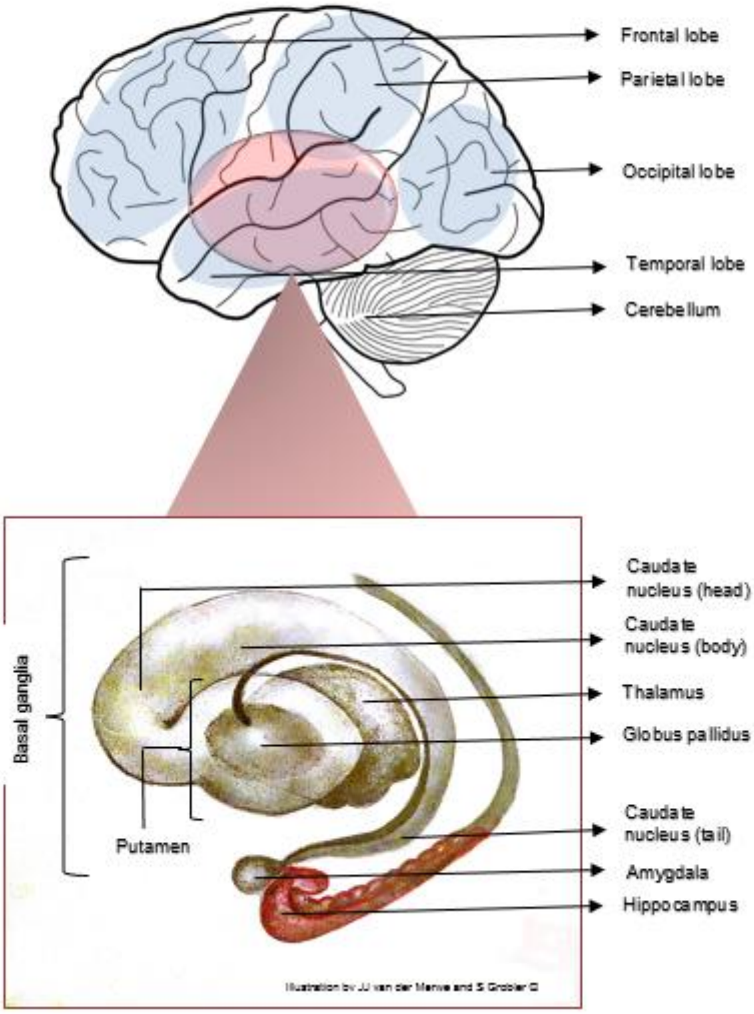


Figure 2.3 Location of deep seated structures connected to EFs, in relation to the lobes of the brain (Illustration by the author).

2.4 MOBILITY AND AGEING

Mobility and the effect of age have been studied extensively across several decades, as the loss of Mobility is predicative of disability, therefore a crucial competence for survival (Ferruci et al., 2016). Being able to move freely and easily through all planes of motions (horizontal, vertical, sagittal and oblique) could easily be taken for granted at a young age, when Mobility performances are still at peak levels (as shown in Figure 2.7). For example, while walking, most healthy individuals tend to take every step they can for granted. This is in comparison to the ageing adult who might already experience age-related Mobility and/or functional decrements, for whom walking might be a challenge. Ferucci et al. (2016, p.1184) stated that "…age-associated impairments in mobility-related physiological systems are compensated and overt limitations of mobility only occur when the severity can no longer be compensated."

According to the Oxford English Dictionary, Mobility is defined as the ability to move freely and easily. Research studies interchangeably use the terms functional ability, functional capability or functional Mobility. Forte et al. (2015) referred to Mobility as a multifaceted motor-cognitive competence which influences ADL in tangible ways, whereas Demnitz et al. (2016) described Mobility as functional capacity in all dynamic situations, whilst maintaining posture. It encompasses the ability to carry out basic ADL walking (gait), standing up or sitting down on a chair, climbing steps or maintaining postural balance to address the constant change in environmental demands (Demnitz et al., 2016). For the purpose of this study, Mobility is the capability to move all limbs and joints freely and easily, preferably without any pain or restriction, through all planes of motion. Mobility can involve static movements (for example, sitting upright in a chair, or maintaining trunk and neck stability), dynamic movements of the body as an entity (for example, rising from a prone position, walking, or executing ADLs), or an extension of individual movements of a single limb (for example, brushing one's teeth, raising a leg while maintaining balance, reaching up with the arms, or bending down during dressing activities). It is clear that the preservation and maintenance of Mobility (is vital to achieve healthy ageing, since it contributes to independency and HRQoL at later life stages (Levasseur et al., 2015; Mahishale, 2015).
Similar to the age-related trajectory path of cognitive function and EFs (Figure 2.7) caused by multifaceted physiological and structural changes, the loss in Mobility of the older adult is also ascribed to multiple deficiencies in the central nervous system (CNS), muscles, joints,

energy systems, as well as sensory physiological systems (Ferruci et al., 2016). This statement is in accordance with Sorond et al. (2015) who claimed that age-related physiological, structural, and functional changes contribute extensively to mobility limitations. The CNS plays a crucial role in facilitation and control of movements, as it continuously interacts with other cognitive, sensory, autonomic, as well as motor-control networks. Of importance are the basal ganglia, the cerebellum together with the somatosensory- and primary motor cortex. Vascular diseases, such as hypertension and age-related structural changes in both arteries and veins, are significantly linked to gait, mobility, and postural control impairments (Sorond et al. 2015).

Ferruci et al. (2016) stated that identifying molecular and/or cellular biomarkers that underlie physiological systems affected by age could indicate the time of life when maximal performance will be reached. Such biomarkers would make it possible to establish when performance decline will commence, as well as the rate of deterioration (refer to Figure 2.7). However, it is beyond the scope of this study to address all age-related physiological, cellular and molecular changes. Therefore, the focus will be on main changes in body compositions affected by ageing (i.e. muscle strength and muscle mass, bone density, skeletal and postural changes, body mass) as well as life style factors. The link between these and its effect on the older adult's HRQoL will be highlighted. Furthermore, the role of exercise in general on these changing body compositions will be expounded on in section 2.7.

2.4.1 Structural and functional decline in Mobility with ageing

a) Muscle strength

Normal ageing is associated with reduced isometric and eccentric muscle strength from the age of 40 years. Thereafter, the loss of muscle strength accelerates progressively from approximately 60 years, resulting in further reductions of biomechanical muscle quality (Chodzko-Zajko et al., 2009). According to Reid et al. (2014) ageing has a severe effect on the total loss of muscle mass (sarcopenia) of 3% - 5% per decade. Chodzko-Zajko et al. (2009) argued that lower body strength seems to decline at a faster rate, with power output declining quicker than muscle strength in comparison to upper body muscle strength (Chodzko-Zajko et al., 2009).

Age-related reductions in both size and number of type II muscle fibres are contributing to weakness in the muscle as well as power output. These deficits in both power and strength predict Mobility limitations, disability and increased risk of mortality at old age (Santilli et al., 2014; Chodzko-Zajko et al., 2009). This statement is in accordance with the findings of Cooper et al. (2014) and Feigin et al. (2016) stating that adults during midlife stages might already experience a certain degree of Mobility impairments. Such limitations may increase levels of dependency of the older adult on family members (Holtzer et al., 2016) and impact Physical Functioning and ADL (Chodzko-Zajko et al., 2009).

b) Bone density

Preserving and protecting the skeletal system could be seen as one of the gateways to independent Mobility. Skeletal diseases (i.e. osteoporosis, arthritis) have severe and adverse effects on Mobility and could decrease the ability to maintain higher-impact activities, especially for the older adult. The inability to practice weight-bearing activities, which contributes to an increase in bone density, could lead to possible bone fractures and loss of autonomy in future.

According to Chodzko-Zajko et al. (2009), total bone mass reaches its peak during the second decade of one's life and thereafter declines annually with 0.5% or more after reaching the fourth decade. Post-menopausal women seem to be affected more severely by loss in bone density (osteopenia) Chodzko-Zajko et al. (2009) reported that such women have a disproportionate loss of 2-3% per year. Furthermore, weight bearing bones and associated joints (i.e. knees, hip, and spine) are especially at risk of developing one of the most common age-related degenerative joint diseases, osteoarthritis (OA) (Fisken et al., 2015). Both women (31%) and men (20%) between the ages 65 - 75 carry the burden of OA and associated pain. These percentages rise to 40% for women and 22% for men aged over 75 years (Fisken et al., 2015). Alarmingly, Dunlop et al. (2011), found that only one in twelve women, versus to one in seven men with OA, still maintained sufficient activity levels. This tendency towards a less active life style could possibly be linked to the recent findings of an Australian study conducted by Simas et al. (2017). It was predicted that 1.6 million cases of new osteoporotic fractures and refractures will probably occur between 2012 - 2022, with women over 50 and men over 60 years of age being most affected. Although it is beyond the scope of this intervention to focus on mobility impairments prior to 50 years of age, it should be noted that Feigin et al. (2016) reported lower back and neck pain are among the top reasons of Mobility impairments. It was stated these impairments are already visible in younger adults ranging from 15 to 39 years. The necessity to identify and develop preventive strategies to combat these already evident Mobility impairments is of the utmost urgency. Serious health implications, diminished Mobility, and decreased HRQoL might await these young adults when they reach mid-adulthood (50-64 years), therefore adding to the number of already impaired and vulnerable older adults.

c) Vertebrae and posture

Ageing has been associated with changes in the vertebral column. For example, a pronounced and forward curvature (convex shape) of the spine, normally below the neck and shoulder region, is visible in older adults (Chodzko-Zajko et al. (2009). The shoulders of older adults seems to be tilted forward (anterior tilt) and indicates a stooped posture (excessive anterior tilting or bending of the upper thoracic region). These age-related changes in the vertebral column could be ascribed to structural changes within the vertebral discs. These discs are gelatine-like cartilage, and natural ageing could cause these discs to become inflexible, hardened or compressed.

The above mentioned structural changes lead to the reduction in body height. In addition, they could impair postural balance and also place increased biomechanical stress on certain areas, such as neck and lower back. This in turn may cause additional strain on compensatory or supporting muscles and/or joints, which eventually may lead to difficulty in performing ADL. Furthermore, altered posture may increase the risk of injury or falls due to the loss in postural balance. Most dynamic ADL require constant adaptation in posture and centre of gravity, for example climbing stairs, walking, carrying groceries, getting dressed. An impaired musculoskeletal system could be accompanied by a certain level of pain when executing normal ADL. The latter suggests an escalated risk of further deconditioning and diminishing HRQoL in older adults (Fisken et al., 2015).

d) Body composition (adipose tissue)

Several factors may contribute to the older adults’ increase in regional adipose tissue (fat) (Chodzko-Zajko et al., 2009). It can be hypothesised that ageing is associated with an ongoing decrease in habitual physical activities with increased sedentary life style habits. This might be attributed to the age-related changes in metabolism, decreased energy levels, and hormonal changes (Chodzko-Zajko et al. (2009).

The resulting loss of total muscle mass decreases total energy expenditure, causing metabolism to slow down. The latter in turn may cause higher and quicker fatigability (Chodzko-Zajko et al. (2009) in the older adult, which can hamper participation in habitual strenuous exercise modalities (i.e. aerobic and/or resistance training).

The adipose tissue progressively increases between 30 - 50 years (Chodzko-Zajko et al. (2009). This leads to an increased risk for developing chronic medical conditions such as type 2 diabetes, hypertension, elevated cholesterol levels, and a range of cardiorespiratory diseases. Chronic diseases and conditions are considered major culprits in cardiovascular and neurological diseases, as well as musculoskeletal weakness (Jin et al., 2015; Prince et al., 2015; Smith et al., 2012) amongst adults in mid-adulthood.

e) Lifestyle

It seems lifestyle choices made through the life span could diminish or intensify the impact of ageing on Mobility. Impairment in Mobility could be caused by sedentary or unhealthy life style habits (i.e. smoking, excessive alcohol, unhealthy eating patterns) possibly leading to obesity, diabetes and elevated cholesterol. Furthermore, not engaging in healthy sleep may also be associated with impairments in Mobility and Physical Functioning.

Although ageing itself is not a disease, it increases the older adult's vulnerability to disease (Mahishale, 2015; Park and Reuter-Lorenz, 2009). Older adults might also be exposed to additional factors, some not age-related, that could affect Mobility and overall functional performance and regular participation in a physically active lifestyle. Such factors might be an acute incident or illness (for example cancer or injury obtained through an activity, accident or fall), an underlying inflammatory or auto-immune disease (for example fibromyalgia, arthritis, rheumatoid arthritis), bone density deficiencies (osteoporosis) perhaps due to genetic factors, insufficient nutrition during younger years, highly stressful time periods (for example death of a partner, family or friend; work-related stress) which could lead to Depressive Mood, hypertension. Time constraints might further prevent the individual from participating in habitual exercise, recreational and socialisation activities. All these factors increase vulnerability of the already vulnerable neural circuitry of an older adult (Park and Reuter-Lorenz (2009).

Independent living and having the physical capacity to move around and outside the home, being able to attend to daily material needs (i.e. shopping), medical needs (i.e. visiting a doctor), maintaining social relationships, participating in recreational and cultural activities, are all aspects associated with subjective wellbeing and HRQoL (Mollenkopf et al., 2017). It is clear that multifaceted mechanisms are responsible for impairments in Mobility (Ferrucci et al., 2016). However, the marked influence of obesity and sedentary lifestyles are considered to be primarily associated with abnormalities in spatiotemporal gait parameters (Gianoudis et al., 2015; Reid et al., 2014; Sherlock, 2014; Morley et al., 2001). These changes in gait integrity will be highlighted in the next section.

2.4.2 Mobility parameters and ageing

Functional Mobility suggests that an individual's motor responses correspond sufficiently with visual spatial Processing speed, sequential timing and movement co-ordination (Sherlock et al., 2014; 2013). Most ADL are complex in nature (including walking) as it requires multiple motor-cognitive responses, whilst processing external information simultaneously (Wollesen & Voelcker-Rehage, 2013) and therefore dependent on the efficiency of EF, which will be discussed under section 2.5.

However, the basic ability to walk includes bilateral co-ordination of both upper and lower limbs of the body, postural control, and sufficient muscular strength to maintain balance (Yogev-Seligman et al., 2013; Krall et al., 2014). For example, the walking process (also referred to as ambulation or locomotion ability in some studies), mostly involves forward movement of the body as an entity at a regular or constant pace (i.e. speed of walking). A comfortable or regular walking pace indicates walking speed is therefore slower, than a brisk walking or jogging action. Furthermore, each foot is lifted and placed down alternatively on the walking surface, though both feet maintain contact with the surface and is accompanied by the swinging of arms (Figure 2.4).

Figure 2.4 Bilateral co-ordination of the limbs during walking.

Co-ordination of limb movements and accuracy in stepping patterns are not only vital to avoid falls and injuries, but also contribute to the older adults' mental and physical HRQoL (Forte et al., 2015). Alterations in spatiotemporal gait parameters have been associated with normal ageing, such as Stride length (SL) that may be shorter and could be a compensatory mechanism of the body to keep the center of gravity closer to the leading foot in its effort to maintain stability (Jerome et al., 2015; Epsy et al., 2010). A recent study by Wennberg and colleagues (2016) investigated the gait integrity of the normal and healthy ageing adults of 50 - 69 years. Significant decreases in Stride velocity (SV) ($P \leq 0.01$), Cadence (Cad) ($P \leq 0.001$) and Gait speed (GS) ($P \leq 0.01$), as well as an increase in Double support ($P < 0.01$) were found (Wennberg et al., 2016). Definitions of these gait parameters are included in the list of key terminology.

These parameters were chosen as literature reports their sensitivity in indicating age-related gait pattern alterations (Grobbelaar, 2017). These gait parameters were considered as objectively measureable parameters for Mobility by Demnitz et al. (2016) and the instrumented Timed-up-and-Go (iTUG) test is often used as an objective measurement tool to assess gait parameters and postural transitions across literature (Figure 2.5 and Figure 2.6).

These parameters could be assessed in either a single- or a dual-task setting, whether physical or cognitive in nature. These settings are explained in chapter four as Methodology.

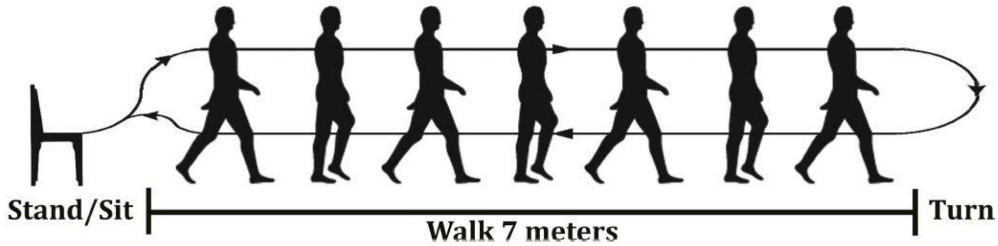


Figure 2.5 Illustration of a 7 - metre walkway (iTUG) assessing gait pattern in single-task (ST) or dual-task (DT) setting (APDM Mobility Lab ©, reproduced with permission).

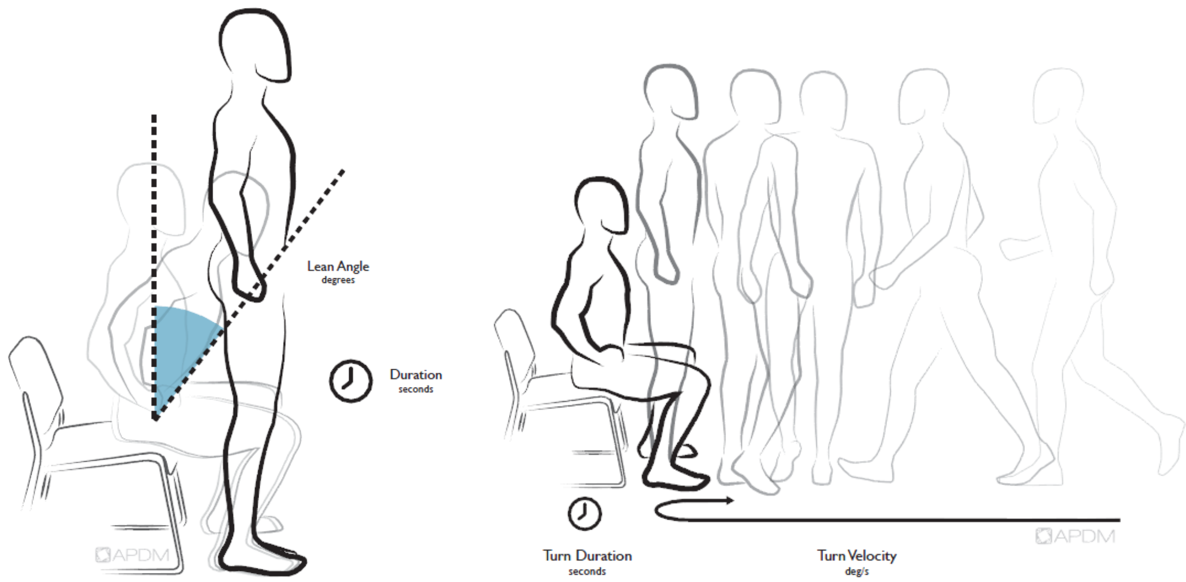


Figure 2.6 Illustration of iTUG postural transitions: Sit-to-stand analysis (left); Turn-to-sit analysis (right) (APDM Mobility Lab©; reproduced with permission).

The Six-Minute walk test (6MWT) was of particular interest in the current intervention. Gait speed (GS) and Functional Capacity (also known as cardiovascular fitness) are two variables that could give insight to overall Mobility of the older adult (Lord et al., 2002). The 6MWT was used in the current intervention to determine average GS of the older adult over a longer distance than the 7m iTUG. Martinez and colleagues (2015) assessed average GS over 10 metres only. They reported GS to be a significant ($P < 0.001$) indicator of functional autonomy, even over this shorter distance compared to the 6MWT. This finding highlights the intricate relationship between GS, Mobility, DT ability and therefore inclusive of EFs. Elaboration on this relationship follows.

Individuals exhibiting advanced levels of functional Mobility display increased performance levels in EF, memory, Processing speed as well as Global Cognition (Demnitz et al., 2016). These authors conducted a systematic review and accentuated the association of specific components of Mobility, with specific EF domains. All measures of Mobility are seemingly not equally associated with cognition and need therefore request further exploration (Demnitz et al., 2016).

Gait speed specifically was found to have stronger correlations with EFs if compared to composite measurements of grip strength, lower limb muscular strength or even postural balance (Demnitz et al., 2016). Therefore conclusion was reached that future interventions should target both Mobility and EF assessments. Additionally Demnitz and colleagues (2016) argued in favour of interventions to be combined, with the aim of examining the intricate, co-operative relationship between Mobility, EF domains and overall cognition (Demnitz et al., 2016; Clouston et al., 2013). The current intervention set out to address these suggestions, as reflected by the chosen tests, as well as the nature of the training programme.

It seems that the relationship between Mobility, the unique and dependant way how it is embodied within cognitive and sub-cognitive domains, remains elusive. Consequently, the role of IC, CF, WM and how these three crucial components relate to Mobility will be discussed.

A dysfunctional EF system predicts impaired gait patterns and even mortality at an elderly age (Gross et al., 2016; Gothe et al., 2014). Gait speed is an important measure of independence and functional status (Kearney, 2013) and is often used in research studies as a predictor for mortality (Feigin et al., 2016; Demnitz et al., 2015; Martinez et al., 2015; Clouston et al., 2013; Hardy et al., 2007). A systematic review by Demnitz and colleagues (2016) showed a high correlation between slower GS and worse Global Cognition scores

(P < 0.001), as individuals who had faster GS performed better on the Stroop test, a combination of EF tasks and the Digit Span test.

Slower GS are also associated with inefficient Processing speeds, therefore detrimentally affecting GS (Sanders et al., 2017, 2016; Welmer et al., 2016, 2014; Perrochon et al., 2013; Donoghue, et al., 2012; Finkel et al., 2007). Gait speeds were examined in a 10-year follow up study of Sanders et al. (2017) who reported that not only did slower Processing speeds predict falls in the presence of slow gait interactions and mortality before 85 years, but also indicated persistent overall cognitive decline and possible other underlying pathologies (Sanders et al., 2016). Also most neurodegenerative diseases are associated with several aspects of Mobility, especially gait instability, fall risk and fragility (Mather et al., 2016).

2.5 THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTION AND MOBILITY

Due to the interdependence of these two components, EF cannot be separated from Mobility. Lots of different manual activities are executed on a daily basis and involve the use of muscles and several body movements (i.e. moving and co-ordinating of the limbs). All manual tasks differ from one another and there is no standard manual task (Asai et al., 2014). Furthermore, these manual tasks could also involve EF processes that might require the individual to pay attention, concentrate on the planned task, or suppress irrelevant and distracting information without affecting motor-control performance. Therefore, in order to properly investigate the interplay between EF and Mobility, two or more activities have to be executed simultaneously – this is known as DT activities (Yogev-Selimann et al., 2013).

Walking and general ADL, such as bathing, dressing, walking, shopping, preparing food, or paying bills are all classified as DT activities. Their execution relies on a combination of neurocognitive health, functionality and motor-control proficiency. Motor responses have to correspond with sequential timing and movement co-ordination (Sherlock et al., 2013) including EF processes, visual-spatial Processing speed (Beurskens et al., 2012), attention and Working memory. Integration of all these aspects is considered a necessity for safe and successful DT execution (Friedman & Miyake, 2017; Miyake et al, 2000).

Older adults might already experience certain Mobility limitations or cognitive and EF deficits as mentioned previously. Executing DT activities, especially those requiring bilateral co-ordination of the limbs (Yogev-Seligmann et al., 2013) could be quite demanding on the older adult. It should not be an overwhelming task to make a cup of coffee while preparing food on the stove and simultaneously listening to the radio. However, for the older adult this might comprise too many tasks that compete simultaneously for utilisation of the same neural circuits. Therefore, attention between the tasks gets divided (Passingham, 1996; Yogev-Seligmann et al., 2013, 2008) and task execution and/or postural control might be compromised.

According to Yogev-Seligmann et al. (2013), gait (walking ability) includes two major tasks that demand attention and cognitive capacity: Bilateral co-ordination of both arms and legs, together with dynamic trunk and postural control. The ability to maintain posture while walking has been described as quite challenging, especially for older adults (Plummer et al., 2016; Al-Yahaya et al., 2010; Beauchet et al., 2009; Faulkner et al., 2007), as both these tasks are associated with higher-order cognitive and mental processes. Postural stability and motor-cognitive performance during activity execution are required, and these activities normally involve a combination of motor-cognitive responses, while simultaneously processing external information (Wollesen & Voelcker-Rehage, 2013).

In normal ageing it becomes increasingly difficult to quickly change direction or suddenly halt a movement when avoiding an obstacle or injury (Simons et al 2006). This can possibly be attributed to slower Processing speeds and motor-control reaction times, which are both associated with an increase in age. One study testified that agility is a predictor of recurrent falling (Tovin et al., 1994), whereas more recent research on healthy older adults (65-75 years) elucidated the crucial role of IC and CF on complex and DT activities (i.e. walking) (Forte et al., 2015).

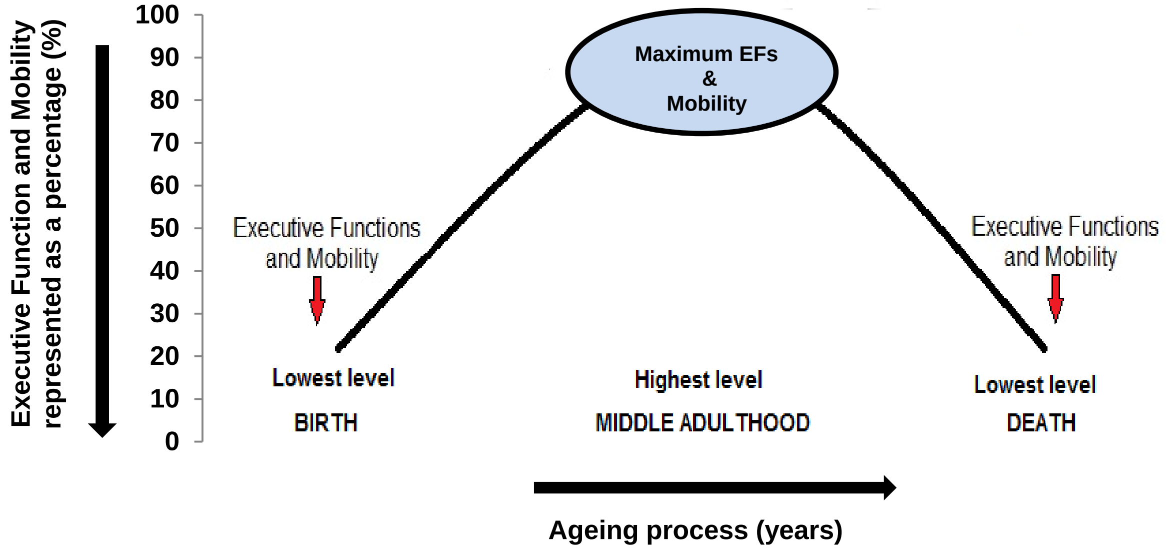


Figure 2.7 Performance levels of EF and Mobility through the life span.

Figure 2.7 illustrates the trajectory path of both EF and Mobility during the entire lifespan. The vertex seems to be reached at the approximate age of 38 to 53 years, or the approximate decade preceding elderly status. This figure coincides with literature found, stating cognivitive and mobility impairments were found to be already evident from 53 years of age however, onset of these decrements have also been found as early as 38 years of age in healthy adults (Waller et al., 2016; Cooper et al., 2014; McMahon et al., 2014; Wennberg et al., 2014; Savela et al., 2013; Strandberg et al., 2012; Chastin et al., 2011; Jeffreys et al., 2003). At birth, neuroplasticity and corresponding levels of both EF and Mobility have not yet developed to its full potential and are therefore at their lowest performance level. During the maturation, these performance levels gradually increase, reaching maximal capacity in middle adulthood (Mather, 2016). Thereafter, the age-related parabolic pathway eventually ends in death.

However, the point at which the decline in EFs and Mobility starts its downward path might be postponed to much later elderly stages. It may even remain at a high level for an increased period, expanding into later life stages. Exercise inclusive of aerobic training has been associated with an increase in EF performance (Zeng et al., 2016; Sherlock et al., 2013; Cole et al., 2011; Bielak et al., 2010), while resistance and strength training exercises have been associated with improved EFs of IC, CF, WM (Komulainen et al., 2010; Liu-Ambrose et al., 2010, 2008). According to Ferruci et al. (2016) and in reference to Table

2.2, modifiable risk factors need to be addressed to maintain and preserve Mobility in later life. Intervening on the physiological mechanisms and changes in body compositions at preclinical stages, might be the most efficient strategy to combat Mobility loss and disability during later life-stages.

Changing critical life habits associated with EF decline and consequently affecting Mobility and functional abilities, can address numerous additional factors that progressively reduce EFs. For instance, social, emotional and physical health are critical for maintaining optimal EFs, as stress, lack of sleep or exercise and even loneliness diminish EFs during one's lifespan.

Therefore, maintaining good sensorimotor integration, Processing speeds, reaction times, muscular strength and flexibility for as long as possible, could prolong the diminishing effect of ageing and are vital for both physical and cognitive health (Mollenkopf et al., 2017). The bi-directional association between cognitive and Physical Functioning (Demnitz et al., 2016) and by implication EF and Mobility, must be brought into consideration to address modifiable factors (Krall et al., 2014)

Table 2.2 Key factors that reduce Executive Functioning

RISK FACTORS ASSOCIATED WITH EXECUTIVE FUNCTION DECLINE
Obesity
Gunstad et al. (2016) “Elevated body mass index is associated with Executive dysfunction in otherwise healthy adults.”
Memel et al. (2015) “Body mass and physical activity uniquely predicts change in cognition for ageing adults.”
Bischof et al. (2015) “Obesity and ageing: consequences for cognition, brain structure, and brain function.”
Smoking
Almeida et al. (2008) “Smoking is associated with reduced cortical regional grey matter density in brain regions associated with incipient Alzheimer disease.”
Swan et al. (2007) “The effects of tobacco smoke and nicotine on cognition and the brain.”
Razani et al. (2004) “Effects of cigarette smoking history on cognitive functioning in healthy older adults.”
Unhealthy sleep patterns
Garcia et al. (2016) “Sleep and physical activity as modifiable risk factors in age-associated cognitive decline.”
Wilckens et al. (2014) “Role of sleep continuity and total sleep time in Executive Function across the adult lifespan.”
Lambiase et al. (2014) “Sleep and Executive Function in older women: the moderating effect of physical activity.”
Oxidative stress in the hippocampus and pre-frontal lobes
Wang et al. (2010) “Selective neuronal vulnerability to oxidative stress in the brain.”
Jackson et al. (2016) “Promoting brain health through exercise and diet in older adults: a physiological perspective.”
Mather et al. (2016) “The locus coeruleus: Essential for maintaining cognitive function and the ageing brain.”
Depression
Rock et al. (2014) “Cognitive impairment in depression: a systematic review and meta-analysis.”
Korten et al. (2014) “Heterogeneity of late-life depression: relationship with cognitive functioning.”
Snyder et al. (2013) “Major depressive disorder is associated with broad impairments on neuropsychological measures of Executive Function.”
Hypertension
Abraham et al. (2016) “Cardiovascular risk factors and small vessel disease of the brain: blood pressure, white matter lesions, and functional decline in older persons.”

Chuang et al. (2014) “Cardiovascular risks and brain function: a functional magnetic resonance imaging study of Executive Function in older adults.”
Zhong et al. (2014) “Pulse wave velocity and cognitive function in older adults.”
Stress and anxiety
Gamble et al. (2014) “Not just scenery: viewing nature pictures improves Executive attention in older adults.”
Areán et al. (2010) “Problem-solving therapy and supportive therapy in older adults with depression and Executive dysfunction.”
Beaudreau et al. (2009) “The association of anxiety and depressive symptoms with cognitive performance in community-dwelling older adults.”
Diabetes (Type II)
Vincent et al. (2015) “Executive Function in adults with type 2 diabetes: a meta-analytic review.”
Feinkohl et al. (2014) “Severe hypoglycaemia and cognitive decline in older people with type 2 diabetes: the Edinburgh Type 2 Diabetes Study.”
Kuo et al. (2005) “Effect of blood pressure and diabetes mellitus on cognitive and Physical Functions in older adults: a longitudinal analysis of the advanced cognitive training for independent and vital elderly cohort.”
Cerebral infarctions
Kruit et al. (2010) “Migraine is associated with an increased risk of deep white matter lesions, subclinical posterior circulation infarcts and brain iron accumulation: The population-based MRI CAMERA study.”
Schneider et al. (2003) “Relation of cerebral infarctions to dementia and cognitive function in older persons.”
Price et al. (1997) “Silent brain infarction on magnetic resonance imaging and neurological abnormalities in community-dwelling older adults.”

Healthier life styles inclusive of physical exercise, has been associated with EF, Global Cognition, functional and health benefits (Bherer et al., 2013; Erickson et al., 2013). It has a potential to reduce or ameliorate multiple risk factors associated with cognitive and EF decline that are depicted in Table 2.2.

2.6 NEUROPROTECTIVE MECHANISMS OF THE AGEING BRAIN

The varying individual degree of structural, functional and neurochemical differences (Demnitz et al., 2016; Kearney, 2013) within the brain of adults in older age, necessitates a conceptual framework to investigate and explain current knowledge and guiding future research. Four approaches identified in reviews by Park and Reuter-Lorenz (2009) and Colcombe & Kramer (2003) focussed on the cognitive decline related to older age and will be highlighted below.

There is an integral relation between cognitive function and perceptual speed. Therefore, it can firstly be postulated that variance in cognitive decline in older adults can be ascribed to decreased **information Processing speed** (Bherer et al., 2013; Park & Reuter-Lorenz, 2009; Colcombe & Kramer, 2003).

The second approach refers to the ability to consciously use controlled **memory processing**. According to Park and Reuter-Lorenz (2009), age-related decline in WM and Processing speed affects a variety of cognitive behaviours. With WM's role in short term maintenance of information and active manipulation in information processing, it is clear that compromised WM will affect EF control. This especially relates to IC that also becomes compromised with ageing. Due to ageing, the older adult might tend to direct attention to irrelevant information, causing shortfalls in other EFs such as CF (Park & Reuter-Lorenz, 2009). Therefore, during the conscious manipulation through WM, the individual has to balance maintaining the relevant, meaningful information with suppression of irrelevant, albeit meaningful information, when switching between tasks (CF). In the absence of specific instructions or environmentally supportive stimuli (i.e. WSC: Condition 2, where the colour and word are congruent) to guide selective attention, Processing speed is compromised as execution of the task becomes increasingly difficult, demanding and effortful for the ageing adult. For example, this is true for execution of incongruent tasks as done in the WSC. Attention must be regulated in order to suppress the prepotent (older, well established habits), irrelevant stimulus (IC). Simultaneously, attention needs to be maintained to be able to switch to relevant stimuli in task execution (CF).

However, Park and Reuter-Lorenz (2009) distinguish between effortful and automatic memory in the memory processing approach. The ability to consciously utilise WM-controlled processing, becomes markedly reduced with age. Automatic memory instead of effortful memory will then be utilised. This cognitive process refers to using older, established memory pathways, instead of the more effortful, controlled memory processes that facilitate recollective memory. The older adult will tend to use automatic memory in situations with an absence of explicit instructions or environmental support (i.e. incongruent tasks in the WSC). However, environmental support for example, would refer to congruent tasks in the WSC. Although memory for familiar stimuli remains relatively good with age, it becomes highly susceptible to distortion (Park & Reuter-Lorenz, 2009). Therefore the older adult might tend to revert to more familiar memories (automatic memory), strategies or previous experiences to analyse a particular situation to execute a task. However, these might not be applicable or even relevant to the current scenario. Per implication, this interference might result in incorrect responses or decisions.

The **visual spatial** approach highlights the decline in neural specialisation with age (Park & Reuter-Lorenz, 2009). It was emphasised those mechanisms and structures that were selectively used for specific cognitive processes and tasks during younger years, decline in efficiency. Therefore, a wider range of brain areas, structures, and neural circuits will be recruited and become responsive to inputs in the ageing adult. This compensatory mechanism is used to address neural and cognitive challenges when damage or age-related decline cause inefficiency in the brain and per implication, the cognitive functioning.

Integral to the **executive-control approach**, as explained by Park and Reuter-Lorenz (2009), would be the pervasive decline in IC, CF and WM due to declining brain health in ageing. The lack of attentional regulation and decreased cerebral co-ordination results in overall EF dysfunction.

The concepts of neural reorganisation of brain function in late adulthood due to biological ageing, together with intrinsic as well as extrinsic experiences, are integrated in the **Scaffolding Theory of Ageing and Cognition** (STAC) by Park and Reuter-Lorenz (2009). The main focus of this theory lies in the dynamic, adaptive and compensatory mechanisms the brain engages in. This is in response to the challenges presented by age-related decline of neural structures and their functions, to be able to maintain or optimise the brain's functioning. It further emphasises the continuity of the brain's self-regulatory processes. The brain engages in functional reorganisation and functional repair across the life span as part of the natural learning processes. This theory portrays ageing also not as an illness, which is similar to the view expressed by Mahishale (2015).

Maintenance and preserving of the brain through adaptive processes takes place throughout life. The STAC model introduces the concept of scaffolding through the life span, especially in the declining brain. Scaffolding denotes the compensatory neural pathways to bypass damaged areas or circuitry. These pathways may either be newly developed through the brain's maintenance system or they can be invoked from older pathways, resurrected from the preserved circuits of the younger years (when highly skilled levels for the task demand were still developing). Therefore, it denotes the basis of previous learning.

As the need arises for accomplishment of a task, the brain automatically responds to the challenge by assessing the task demand. Should a damaged pathway be involved, alternative circuits or areas to convey the message and complete the task will be recruited. This is in accordance with Glisky (2007) who stated that the stronger domains in the brain may compensate for the weaker ones. According to Park and Reuter-Lorenz (2009), these compensatory structures and areas are not task-specific. This enables them to be more flexible in execution of a broader spectrum of functions. Park and Reuter-Lorenz (2009) refer to this inherent process as dedifferentiation. If necessary, the brain has the ability to create new pathways in dedifferentiated areas to fulfil the task demand.

As the EFs are mostly hosted within the pre-frontal cortex, with its highly adaptive and flexible nature, this area would be especially vulnerable to the effects of ageing. However, in contrast, the pre-frontal cortex is also the primary area for scaffolding formation which may fulfil supplementary, compensatory or alternative neural circuits. Therefore, it's important to note that scaffolding is not only related to damaged pathways, but also plays an important role in enhancing EFs.

However, the pre-frontal cortex is the primary site to react positively on participation in physical activities as well (Erickson et al., 2015; Voss et al., 2011; Park and Reuter-Lorenz (2009). The utilisation of scaffolding enhances cerebral training (learning effect) and repetition provided by cognitively challenging training programmes (Diamond & Ling, 2016; Verstynen et al., 2012, Sherlock, 2013; Park and Reuter-Lorenz (2009). Sherlock (2014) emphasised the positive neurophysiological effects of exercise in an enriched environment (for example, in the water) can be related to a greater proficiency achieved in building compensatory scaffolding.

Park and Reuter-Lorenz (2009) concluded that increased bi-lateral activation of the frontal lobes, as well as associated scaffolding are especially associated with regular physical activity. In addition, the authors underscored the brain's ability to create, to renew, to maintain and preserve itself through newly created white and grey matter within the frontal lobes. As such, regular physical activity may act as a neuroprotective mechanism even in the ageing brain to realise enhanced EFs. It may lead to greater proficiency in brain maintenance and adaptation throughout life. In conclusion, the functional and structural damage caused by natural ageing, maybe slowed down or even reversed according to these authors.

2.7 EXERCISE TRAINING EFFECTS ON EXECUTIVE FUNCTIONS AND MOBILITY

The benefits of a physically active lifestyle from mid- to later life stages on functional Mobility and Global Cognition are emphasised in numerous studies (Mather et al., 2016; Cooper et al., 2014; Diamond, 2014; Bherer et al., 2013; Diamond, 2013; Hamer et al., 2013; Hillsdon et al., 2005). Physical exercise has been widely recorded to be the most successful determinant of better cognitive health and EFs (Erickson et al., 2015). It is also markedly beneficial to the physical health, even to the point of curtailing musculoskeletal disorders like osteoporosis, sarcopenia and Mobility decrements (Demnitz et al., 2016; Erickson et al., 2015; Sherlock, 2014; Graef et al., 2010; Colcombe et al., 2006). Furthermore, risk factors for EF and mobility decline (i.e. obesity, hypertension, type II diabetes, musculoskeletal weakness) could be ameliorated through participation in habitual exercise, promoting cardiovascular fitness (Sherlock, 2014). Additional benefits associated with regular and combined exercise programmes, consisting of aerobic-, resistance- and flexibility components, facilitate improved muscle strength, power output (type II muscle fibres) (Chodzko-Zajko et al., 2009) and muscular endurance (type I muscle fibres). These adaptations contribute to postural balance and the ability to execute ADL (carrying groceries, climbing of stairs, rising from seated or prone positions, bathing, etc.). Training programmes that encompass flexibility are known to increase range of motion in joints, with improvement in elasticity of tendons (Chodzko-Zajko et al., 2009). Progressive resistance training has been linked to enhanced cognitive functions, with this training modality seemingly associated with less cortical atrophy (Erickson et al., 2015). In addition, Albinet et al. (2016) investigated the efficacy of a progressive, resistance training programme with accrued fitness obtained in a water environment. These authors accentuated the connection between the pre-frontal cortex, cardiorespiratory fitness, and ultimately enhanced EFs of IC and WM. It was postulated that a structural and functional network in the Central Nervous System (CNS) links the pre-frontal cortex with cardiac activity, therefore establishing a heart – brain connection that might play a role in the increased activation of the pre-frontal cortex and associated EF processes.

To sustain functionality in neural networks of the brain (neuronal sustainability) a balance between cell death and cell replacement is required (Mahishale, 2015). One of the neuroprotective mechanisms of the brain is its inherent adaptive capability, where stronger domains or neural circuits compensate for weaker domains and their diminished cognitive functions (Glisky, 2007). Neuroplasticity involves structural and functional neuronal changes in response to challenging, changing environments (internal or external) or task demands and plays a protective role in disease prevention and overall brain health (May et al., 2007).

Pursuing a physical lifestyle during middle ($\bar{x}$ 49 years) to late adulthood can significantly decrease age-related cognitive and physical decrements in later life stages, delaying the onset of decline. (Iso-Markku et al., 2016; Hamer et al., 2013; Hillsdon et al., 2005). Advanced levels of neuroplasticity occur during physical activities of moderate- to high-intensity (Zhao et al., 2014; Kosma et al., 2016; Simmonds et al., 2016; Blondell et al., 2014; Manaf et al., 2013).

Enhanced fitness in older adults is linked to volumetric increases in the basal ganglia, hippocampus and pre-frontal cortex, facilitating the EFs associated with these structures (Becker et al., 2016; Erickson et al., 2015). Increased neuronal integrity due to exercise plays a contributory role in motor-control tasks, to allow the smooth execution of actions and sequences (Saba, 2015). The importance of bi-manual co-ordination tasks, in combination with high fitness levels, has been emphasised to realise optimal cognitive performance (Becker et al., 2016; Voelcker-Rehage & Niemann, 2013). Hippocampal volume, associated with visual-spatial WM, may be increased by 2% through aerobic exercise participation (Erickson et al., 2011). Moreover, Erickson et al. (2011) argued that this exercise modality could reverse age-related loss in volume by one to two years in late adulthood.

Both Albinet et al. (2016) and Mahishale (2015) shared the opinion of a serious shortage of research regarding the efficacy of various interventions. Previous studies aimed to address the effect of physical activity on Global Cognition and certain aspects of EF, for example WM, attention, and Processing speed (Mather et al., 2016; Diamond, 2014; Cooper et al., 2014; Bherer et al., 2013; Diamond, 2013; Hamer et al., 2013; Hillsdon et al., 2005). Nevertheless, it is still unclear whether aerobic exercise equally benefits all cognitive functions, specifically EFs, as inconsistent findings have been reported in literature (Albinet et al., 2016; Colcombe & Kramer, 2003). Therefore clarity on water-based exercise programme duration as well as training principles is still needed.

2.8 CHARACTERISTICS OF A WATER-BASED EXERCISE ENVIRONMENT

Being immersed in water with its viscous nature increases the load on the cardiorespiratory system (Sherlock et al., 2013; Cole et al., 2011), possibly enhancing EFs due to increased cerebral blood flow and cardiovascular output (Cole et al., 2011; Bielak, 2010).

The recommendation for neuroplasticity in the EF-system seems training should consist of complex (cognitively challenging) exercises that includes a variety of stimuli (Diamond & Ling, 2016; Verstynen et al., 2012; Sherlock, 2014; Sherlock et al., 2013; Park & Reuter-Lorenz, 2009). The aim is to place a cognitive demand on planning and decision-making (Sherlock et al., 2013; Bielak, 2010). Enriched and cognitively stimulating exercises have been well documented to enhance EFs (Diamond, 2015, 2013; Erickson et al., 2011; Bielak, 2010). However, executing these activities on land seems like an unnerving task to the ageing adult with possible greater fall risk.

The potential beneficial effects of a water-based exercise environment have been investigated in studies conducted by Fedor et al. (2015), Sato et al. (2015), Sherlock (2014) and Sherlock et al. (2013). Sherlock et al. (2013) hypothesised training in water could allow cognitive adaptations to take place, due to the constant change in the exercise environment. The central nervous system (CNS) recognises and perceives a variety of sensory stimuli when immersed in water and has to determine, create and apply appropriate motor responses during execution of exercises. Body position, awareness of the limbs in proportion to the body, posture and balancing requires proper sequencing, timing and motor co-ordination (Sherlock et al., 2013). Specific emphasis was placed on adding co-ordination, concentration or other cognitively demanding variables, which might result in enhanced cognitive and Executive Functions.

A water-based training environment, such as a swimming pool, has four main attributes: Density and gravity, buoyancy, hydrostatic pressure, viscosity and resistance. The biomechanical and physiological benefits of each attribute are analysed below.

2.8.1 Density and gravity

Body densities among individuals differs, therefore the amount of gravity also differs, influencing the individual's ability to maintain balance and posture in the water. Individuals entering the water are therefore uniquely challenged. This is due to variations in individuals' muscular ability, muscular strength, somatic awareness, attention and concentration abilities (Sherlock et al. 2013). These are required to execute training exercises and to maintain postural stability.

2.8.2 Buoyancy

The term buoyancy is synonymous with the feeling of weightlessness (Sherlock et al. 2013). It is ideal for adding support to weakened limbs or muscles, but also allows for a certain level of resistance according to the individual's functional limitations.

The water immersion and the resulting buoyant effect relative to density and specific gravity of individuals, could counterbalance the body mass and support weakened body structures (Cole et al., 2011). The forces of equilibrium allow postural maintenance and locomotor control (Sherlock et al., 2013). The additional perturbation (multi-directional flow of water) could increase cognitive demands during exercise and result in possible enhanced EFs.

2.8.3 Hydrostatic pressure

Sherlock et al. (2013) stated that the conveyed pressure upon the body is higher when an individual is immersed in the water. This "hydrostatic pressure" enhances venous return of blood to the heart, supports stimulation of the lymphatic system and reduces heart rate (Cole et al., 2011). Muscular blood flow doubles when immersed in water to xiphoid level

(Cole et al., 2011) and reported blood flow have measured 1.8ml/min/100g tissue when on land, compared to 4.1ml/min/100g tissue when immersed in water. Therefore, being in the water can result in increased pressure on the CNS, allowing greater availability of blood for the working tissues through increased cardiac output.

Cardiovascular system and metabolic waste removal capability of the circulatory system, seems to benefit tremendously from being in the water. As blood flow and cardiac output improves, it could lead to enhanced cerebral structural modifications that promote improved EFs (Albinet et al., 2016; Bielak 2010).

2.8.4 Viscosity and resistance

Viscosity refers to the amount of resistance or friction exerted by a liquid (Cole et al., 2011). Viscosity of water delivers higher resistance compared to the viscosity of air. Therefore, a greater force is needed to move a limb through water in comparison to movement through air during land-based exercises.

Another added force that comes to effect in a water environment is turbulence (Sherlock et al., 2013, Cole et al., 2011). This added turbulence – due to movement in the water and speed of movement being produced – leads to an even greater resistance, resulting in higher force needed to execute an exercise. It is suggested that new and more complex movements added to a water-based training regime could promote the positive effects of resistance training and aerobic training due to higher speed and force (Man et al., 2010; Klusmann et al., 2010). Each movement will be exposed to the viscous force of the water and the challenging cognitive tasks have been linked to enhanced cognitive functions and EFs.

2.9 THE EFFECT OF A WATER-BASED EXERCISE INTERVENTION (WBEI) ON EXECUTIVE FUNCTIONING OF THE OLDER ADULT

At time of writing, eight water-based intervention studies were found that focussed on components of EF. Table 2.3 summarises these studies with reference to participants, primary outcomes, methods, intervention protocol, as well as the results and findings. Only three of these studies are inclusive of individuals in the life stage prior to elderly status (Albinet et al. 2016; age range 60-75 years; Fedor et al., 2015; age range 50-80 years; Sherlock, 2014; age range 60-90 years).

Albinet et al. (2016) concluded the WBEI (21 weeks) improved all EFs (IC, CF, WM). However, IC, WM as well as CF improved at 10 weeks already. Yet, due to the nature of the CON group exercise training programme (stretching, balance, co-ordination activities), significant improvement for this group was also found on the EFs of WM and CF. Thus, only IC did not improve for the CON group at either 10 or 21 weeks. Albinet et al. (2016) ascribed the improved IC results of the water-based group to the nature of their combined exercise training programme (Refer to Table 2.3, p.59). Fedor et al. (2015) reported that even a brief WBEI of one week resulted in significant improvement in EF ($P < 0.001$), attention ($P < 0.01$), and WM ($P < 0.01$). Sherlock (2014) found only significant improvement in spatial WM ($P < 0.014$) after a WBEI spanning ten weeks.

Other WBEIs investigating cortical responses, sensorimotor cortex activation, EFs or Global Cognition, partially conducted their intervention protocols on land. The effect of sensorisomatic stimulation on aspects of EFs (Sato et al., 2015; 2013; 2012) were investigated and revealed significant ($P < 0.05$) improvements in the following: Cerebral cortical activity; sensorimotor integration and somatosensory processing; motor-cortex and spinal activity, attention, Memory, Global Cognition, Learning, Processing speed, and reaction times. Auditory dual-task performance (Schaefer et al., 2015) resulted in less listening errors when simply standing in the water at femur height. Thus, even though some investigations took place in relatively stationary positions and/or included young healthy adults, promising EF results and dual-task results were found (Sato et al., 2015; 2013; Schaefer et al., 2015). Certain aspects regarding intervention protocol could not be found in some of these studies and are referred to as unspecified in Table 2.3.

Table 2.3 Water-based interventions on Global Cognition and Executive Function

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
	(age; gender; activity status)	(Executive Functions(EF); Global Cognition)	(Setting; time-line; blinded; randomization; type)	(duration; intensity; frequency; water temperature)	(P-Values)
Fedor et al. (2015)	**Age:** 50 – 80 (n = 60) **Gender:** Healthy Male (n = 13) Healthy Female (n = 46) **Activity status:** CON significantly more active than EXP group	Effect of a brief WBEI on cognitive function and cardiovascular fitness. **Primary measurements:** ➢ Montreal Cognitive Assessment (MoCA) ➢ Adaptive rate continuous performance test (ARCPT) ➢ Frontal assessment battery (FAB); ➢ EFs of attention; TMT A, TMT B (Trail Making Test A & B); ➢ Stroop test, selective attention and mental flexibility ➢ Hopkins verbal learning test revised (HVLT-R): delayed memory recall ➢ Immediate and delayed memory recall (Rey–Osterrieth complex figure test ; ROCFT)	**Setting:** H_20 **Time:** 6 days **Blinded:** No **Randomisation:** No **Type:** 8 Cognitive tests, addressing EF and Global Cognition: 1-week high-intensity aerobic WBEI.	**Duration: 60 min** ➢ Exercise protocol not specified. **Intensity:** Moderate to high, 60%–70% of maximum heart rate **Frequency:** 6 x p/wk **Temp:** Unspecified **Depth:** Unspecified	Significant improvements for EXP in EF, attention, memory and cardiovascular fitness. EF: P< 0.001 Attention: P< 0.01 Memory: P< 0.01

Notes: EXP: Experimental group; CON: Control group; WBEI: Water-based exercise intervention; EF: Executive Function; p/wk: per week; P: P-value; n: number

…Table 2.3 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Sato et al. (2015)	**Age:** 19 – 25 (n = 10) **Gender:** Healthy Male (n = 10) **Activity status:** Unspecified	Effect of whole-hand water immersion (WI) and whole-hand water-flow (WF) stimulation, on corticospinal and intracortical excitability. **Primary measurements:** ➢ Motor-cortex and spinal activity (whole-hand immersion, no water-flow) ➢ Motor-cortex and spinal activity (whole-hand immersion with water-flow)	**Setting:** Land & H_20 **Time:** 1 day **Blinded:** Unspecified **Randomisation:** Unspecified **Type:** 3 seated conditions Static and no exercise	**Duration:** 15 minutes **Intensity:** Stationary, relaxed **Frequency:** 3 trials **Temp**: 33ºC ± 1ºC **Depth:** Whole-hand immersion	Water-flow specifically increased corticospinal and intracortical circuits' activity during immersion. Whole-hand WF modulates activities associated with motor-movements. Increased activation in the motor-cortex regulating planning and executing voluntary movements. Motor-cortex and spinal activity with WF: $P < 0.05$
Sato et al. (2015)	**Age:** 69-86 (n = 21) **Gender:** Healthy Male (n = 4) Healthy Female (n = 17) **Activity status:** Unspecified Two water groups Normal Water Exercise group **Nor-WE** Cognitive Exercise group **Cog-WE**	Comparing the effects of a WBEI with and without cognitive stimulation on cognitive and physical functions. **Primary measurements:** ➢ Attention ➢ Processing speed ➢ Executive Function ➢ Memory ➢ Physical function (Refer to Table 2.4)	**Setting:** Land & H_20 **Time:** 10 weeks **Blinded:** Single-blind **Randomisation:** Yes **Type:** 5 Cognitive tests (in Japanese):	**Duration Nor-WE: 60 min** ➢10min walk (Land) ➢30min strength & stepping (H_20) **Duration Cog-WE: 60 min** ➢10min walk (H_20) ➢30min cognitive – motor DT (H_20) (Refer to tables' footnote) **Intensity:** Borg's scale in Japanese used: (very light - very hard; 6 – 20); (RPE: 11). **Frequency:** 1 x p/wk **Temp**: 31.5ºC **Depth:** 1 metre	Elderly adults could benefit from personalised WBEI. Cognitive functions improved in both groups. Significant improvement in stepping reaction time, attention, Memory, learning and Total (Global) cognition scores, aspects of Physical Functioning (Refer to Table 2.4). Stepping reaction time: $P < 0.01$ Attention: $P < 0.01$ Memory: $P < 0.01$ Global Cognition scores: $P < 0.01$ Learning: $P < 0.05$

Notes: WBEI: Water-based exercise intervention; DT: dual-task; p/wk: per week; RPE: Rate of Perceived Exertion; P: P-value; n: number

…Table 2.3 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Sato et al. (2013)	**Age:** 19 – 26 (n = 15) **Gender:** Healthy Male **Activity status:** Unspecified	Effect of WI on long- and short term intracortical and afferent inhibition as well as intracortical facilitation. **Primary measurements:** ➢ Sensorimotor integration ➢ Somatosensory processing	**Setting:** H_20 **Time:** 1 day **Blinded:** Unspecified **Randomisation:** Unspecified **Type:** 3 seated conditions Static and no exercise	**Durtion:** 15 minutes **Intensity:** Stationary, relaxed **Frequency:** 12 trials **Temp**: 30ºC	WI modulates sensorimotor integration and changes in somatosensory processing. WI may decrease pain and accommodate movement limitations. Sensorimotor integration & somatosensory processing: $P < 0.05$
Sato et al. (2012)	**Age:** 21 – 26 (n = 9) **Gender:** Healthy Male **Activity status:** Unspecified	Effect of WI at femur level on cerebral cortical activity. **Primary measurements:** ➢ Sensory-and motor-cortex activation	**Setting:** H_20 **Time:** 1 day **Blinded:** Unspecified **Randomisation:** Unspecified **Type:** 5 standing conditions Static and no exercise	**Duration:** 15 minutes **Intensity:** Stationary **Frequency:** Once **Temp**: 34ºC **Setting:** H_20 (standing) **Depth:** Femur height	WI could improve the efficacy of physical therapy due to increased sensory-and motor-cortex activation. Cerebral cortical activity: $P < 0.05$
Sherlock, (2014)	**Age:** 60 – 90 (n = 34) **Gender:** Heterogenic **Activity status:** Seemingly active 3x p/wk	Effect of Aquatic Exercise on parameters of EF in the ageing population. **Primary measurements:** ➢ Battery of EF focused tests (CANTAB testing battery ➢ 6MWT (Six-Minute Walk Test) ➢ Quality of Life	**Setting:** H_20 **Time:** 10 weeks **Blinded:** No **Randomisation:** Yes **Type:** Progressive exercise overload with adult educational concepts.	**Duration:** 50 minutes **Intensity:** 45 – 70% of HRR (Heart rate reserve) Heart rate monitors used **Frequency:** 3 x per week **Temp**: Unspecified **Depth:** Unspecified	WBEI revealed no significant global effects on cognitive function or for physiological parameters. Significant improvements in spatial Working memory (SWM) and Diastolic blood pressure (DPB). WBEI positively affected selective components of EF, cardiovascular fitness, and wellness. Positive behavioural change: Chronic exercisers due to physical improvements and perceived accessibility to the exercise environment. Spatial Working memory : $P < 0.014$ Diastolic blood pressure: $P < 0.014$

Notes: WBEI: Water-based exercise intervention; WI: Water-intervention (not necessarily associated with exercise); EF: Executive Function; p/wk: per week; P: P-value; n: number

…Table 2.3 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Schaefer et al. (2015)	**Age:** 24 – 25 (n = 22) Note: One healthy female (73 years) with MCI included for age comparison reasons. **Gender:** Healthy Male (n = 12) Healthy Female (n = 10) **Activity status:** Unspecified	Effect of WI on DT performance: Implication on auditive cognitive errors, postural sway and balance on land. **Primary measurements:** ➢ Listening errors Single-task (ST) ➢ Listening errors Dual-task (DT) ➢ ST & DT Postural sway on land and water (Refer to Table 2.4)	**Setting:** Land & H_20 **Time:** 1 day **Blinded:** No **Randomisation:** Quasi-experimental crossover **Type:** DT Cognitive task: (letter repetition while standing); DT Motor task: (observing postural sway during repetition).	**Duration:** Cognitive: 90 seconds Motor: 90 seconds **Intensity:** Unspecified **Frequency:** Once **Temp**: 30ºC **Depth:** Seated: Xiphoid depth	Auditory cognitive errors were less while seated and immersed water to the xiphoid. This suggests less interference in the water environment, comparing to the same cognitive task performed on land. Postural sway results are mentioned in Table 2.4. ST listening errors in water: 42% less compared to listening errors on land DT listening errors in water: 45% less compared to listening errors on land
Albinet et al. (2016)	**Age:** 60 – 75 (n = 36) **Gender:** Healthy Male (n = 10) Healthy Female (n = 26) **Activity status:** Sedentary	Effect of aerobic exercise in a water-based environment on EFs, cardiorespiratory fitness, cardiac vagal control and psychological variables. **Primary measurements:** ➢ EFs of IC, WM, CF ➢ Cardiorespiratory fitness (VO_{2max}); Heart rate variability ➢ Depression, self-efficacy ➢ Decisional balance	**Setting:** H_20 **Time:** 21 weeks **Blinded:** Unspecified **Randomisation:** Randomised control trial **Type:** Combined programme according to guidelines of the ACSM for the older adult (Aerobic, resistance, flexibility components included). CON group (Stretching)	**Duration:** 60 minutes Warm up: 10 min Session: 40 min Cool down: 10 min **Intensity:** 40 – 65% of individual heart rate (moderate – vigorous) Karvonen formula used **Frequency:** Twice per week **Temp**: Unspecified **Depth:** Unspecified	Significant improvements were found for all Primary measurements for the EXP group. The EXP group improved in all primary measurements. The CON group only improved in WM and CF, but not in IC. However, overall the WBEI led to improved EFs. Inhibitory control (IC): ($P < 0.05$; at 10 & 21 weeks) Working memory (WM): ($P < 0.05$; at 10 & 21 weeks) Cognitive flexibility (CF): ($P < 0.05$; only at 10 weeks) Cardiorespiratory fitness: ($P < 0.05$) EXP & CON Heart rate variability: ($P < 0.05$) EXP Depression, self-efficacy: ($P < 0.05$) EXP & CON

Notes: WBEI: Water-based exercise intervention; WI: Water-intervention (not necessarily associated with exercise); EF: Executive Function; IC: Inhibitory control; WM: Working memory; CF: Cognitive flexibility; MCI: Mild cognitive impairment p/wk: per week; P: P-value; n: number

A possible explanation for the lack of research in the mid-life age group (50-64 years) could be the trend in past decades to focus on the elderly (≥ 65 years) who are known to exhibit higher incidences of impaired cognition and Mobility. However, decrements in these functions are often already identifiable in middle adulthood (Cooper et al., 2014; Feigin et al., 2016). The necessity of extensive research to determine higher neural responses due to water immersion and exercise is emphasised by Schaefer et al. (2015).

2.10 THE EFFECT OF WATER-BASED EXERCISE INTERVENTIONS ON MOBILITY

The positive relationship between exercise and Mobility is indisputable. Walking ability, gait symmetry, muscle strength, postural control during execution of ADL and cardiovascular endurance can all be obtained and positively modified through exercise. Higher physical activity levels prior to 65 years of age are associated with higher levels of Mobility after reaching the age of 75 years (Tikkanen et al., 2012).

Zhao et al. (2014) stated it is quite inexpensive to maintain the sufficient degree of Mobility and also effective to limit global cognitive impairments, physical dependency and frailty. Exercise and a physically active life style have to be sustainable, implying that this exercise environment should let the individual feels safe and protected from risk of injury. This is especially true for the older adults (≥ 50 years) that might already experience a declining trajectory in EF, Mobility and DT execution. The unique properties of water, as a safe exercise medium, could contribute especially to enhancement of Mobility. These qualities of a water-based exercise environment are discussed in section 2.7.

Table 2.4 summarises the eleven water-based exercise interventions (WBEI) and the significant ($P < 0.05$) findings pertaining to Mobility (stepping reaction time, voluntary stepping time, proprioception, muscle strength, flexibility, postural balance, gait interaction, as well as cardiovascular endurance and body mass reduction).

Table 2.4 Water-based interventions on Mobility

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
	(age; gender; activity status)	(Executive Functions(EF); Global Cognition)	(Setting; time-line; blinded; randomization; type)	(duration; intensity; frequency; water temperature)	(P-Values)
Sato et al. (2015)	**Age:** 69-86 (n = 21) **Gender:** Healthy Male (n = 4) Healthy Female (n = 17) **Activity status:** Unspecified	Comparing the effects of a WBEI with and without cognitive stimulation on cognitive and physical functions. **Primary measurements:** ➢ Physical functionality ➢ Body Mass Index (BMI) ➢ Walking ability ➢ Lower leg muscle strength (Single- task condition) ➢ Cognitive functions (Refer to Table 2.3)	**Setting:** Land & H_20 **Time:** 1 day **Blinded:** Single-blind **Randomisation:** Yes **Type:** 5 Cognitive tests (in Japanese): attention, Processing speed, Executive Function, and Memory	**Duration Nor-WE: 60 min** ➢10min walk (Land) ➢30min strength & stepping (H_20) **Duration Cog-WE: 60 min** ➢10min walk (H_20) ➢30min cognitive motor-DT (H_20) **Intensity:** Borg's scale in Japanese used: (very light - very hard; 6 - 20). Participant's RPE: 11 **Frequency:** 1 x p/wk **Temp**: 31.5ºC **Depth:** 1 metre	Significant improvement in both EF (Table 2.3), aspects of physical functioning and BMI reduction. The Nor-WE dramatically improved in walking ability and lower limb muscle strength. Body Mass Index (BMI): $P < 0.01$ Walking ability: $P < 0.00$ Lower limb, muscle strength: $P < 0.04$

Notes: WBEI: Water-based exercise intervention; Nor-WE: Normal water exercises; Cog-WE: Cognitive water exercises; RPE: Rate of Perceived Exertion; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…					
	Participants	**Primary outcomes**	**Methods**	**Intervention protocol**	**Results, findings**
Schaefer et al. (2015)	**Age:** 24 – 25 (n = 22) Note: One healthy female (73 years) with MCI included for age comparison reasons. **Gender:** Healthy Male (n = 12) Healthy Female (n = 10) **Activity status:** Unspecified	Effect of WI on DT performance: Implication on auditive cognitive errors, postural sway and balance on land. **Primary measurements:** ➢ Postural sway on land and water (Single-task condition) ➢ Postural sway on land and water (Dual-task condition) Single and dual-task Listening errors (cognitive) on land and water (Refer to Table 2.3)	**Setting:** Land & H_20 **Time:** 1 day **Blinded:** No **Randomisation:** Quasi-experimental crossover **Type:** DT Cognitive task: (letter repetition while standing) DT Motor task: (observing postural sway during repetition).	**Duration:** Cognitive task: 90 seconds Motor task: 90 seconds **Intensity:** Unknown **Frequency:** Once **Temp**: 30ºC **Depth:** Seated/Standing: Xiphoid depth Intervention protocol set out in Table 2.3	Significant environmental factor observed; postural sway was in water greater compared to land and Postural sway during ST conditions in water was more, compared to DT conditions. Postural sway (Environmental factor): P = 0.002 Postural sway in water: P < 0.001 Postural sway ST conditions: P < 0.03

Notes: MCI: Mild cognitive impairment; WI: Water-intervention (not necessarily associated with exercise); ST: Single-task; DT: Dual-task; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Martinez et al. (2015)	**Age:** 69-86 (n = 26) **Gender:** **WBEI** Healthy women (n = 16) **Gender:** **CON** Non-exercising; Healthy women (n = 10) **Activity status:** Excluded those participating in routine-based exercise, 6 months prior to intervention.	Determining the effect of a periodized WBEI on functional autonomy in elderly women. Primary measurements ➢ Latin-American Development for Maturity Postural stability (functional autonomy test) ➢ 10 meters walk test ➢ Getting up from seated-position (GSP), ➢ Getting up from the prone position (GPP), ➢ Getting up from a chair & moving around the house (GCMH), ➢ Putting on & taking off a shirt (PTS). ➢ Formula: Functional Autonomy & General GDLAM index (GI): GI = [10MWT+GPP+GSP+TS)*2] + GCMH/4	**Setting:** H_20 **Time:** 12 weeks **Blinded:** Unspecified **Randomisation:** Yes **Type:** High frequency WBEI according to age-specific percentages of of Heart Rate Reserve (HRR)	**Duration:** 50 minutes **Intensity:** 40 – 60% of HRR; heart rate monitors used: Week 1 – 6: 40-50% of HRR Week 7-12: 50-60% of HRR **Frequency:** WBEI group: 5 x p/wk **Temp:** Unspecified **Depth:** Unspecified **WBEI Setting:** H_20 Warm-up (10 min) ➢ Unspecified protocol Aerobic component (30 min); (water-based) ➢ Realising rhythmic-gymnastic activities in a water-based setting. ➢ Intensity progression (see intensity) ➢ Unspecified sets & repetitions Warm-up (10 min) ➢ Unspecified protocol	Periodized water exercise training programme was able to enhance 10 metre walk test and (GI) however, future studies are required investigating functional autonomy improvements due to WBEI. 10 meters walk test (10MWT): P = 0.001 GDLAM index (GI): P = 0.012

Notes: WBEI: Water-based exercise intervention; CON: Control group; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Elbar et al. (2012)	**Age:** 64-88 (data analysis (n = 34) **Gender:** **WBEI (n=17)** Men (n= Unspecified) Women (n= Unspecified) **Gender:** **CON (n=18)** Men (n= Unspecified) Women (n= Unspecified) A-status: Excluded those participating in physiotherapy, hydrotherapy, or attended community exercise classes six months prior. Included participants taking medications.	Exploring the efficacy of a WBEI (that includes perturbation training) to improve voluntary stepping speed and postural stability in older adults. **Primary measurements** ➢ Voluntary step test ➢ Postural stability (Berg Balance Score)	**Setting:** H_20 **Time:** 12 weeks **Blinded:** No **Randomisation:** Concealed, randomised controlled cross-over design. **Type:** Progressive balance function and strength training. Included gait specific exercises. Seemingly low aerobic intensity.	**Duration WBEI group A:** 40 min **Duration WBEI group B:** 40 min (Cross-over design) **Intensity of :** ➢ Seemingly low (RPE / Heart rate monitoring unspecified) **Frequency WBEI and CON group:** Participants in both groups attended activities 2 x p/wk. **Temp:** Unspecified **Depth:** Unspecified **WBEI Setting:** H_20 Progression training (12-weeks) Five progression levels: challenging balance, postural control exercises and stepping response with exercises. Warm-up & Cool-down (Unspecified min/ protocol) Balance (Unspecified min); (H20; with/without equipment; noodles; unstable balls) Levels 1 and level 2 exercises ➢ Stand and reach, displacing body's Centre of Mass (COM) through water motion/ turbulence	**Both WBEI groups**: Water-based, progressive perturbation training results in reduced voluntary stepping time. Higher central processing speed due to training, contributed to reduced step-initiation phase. Step initiation phase (m/s): P = 0.05 Foot-contact time (m/s): P = 0.003 Leg swing phase & Step-execution-initiation (m/s): P = 0.002 Berg Balance scale scores did not improve for the current study but significant improvements reported in certain postural stability variables. Postural stability – eyes open: Medial-lateral postural sway: P = 0.05 Sway area (mm^2): P = 0.04 To be continued on the next page…

Notes: WBEI: Water-based exercise intervention; CON: Control group; RPE: Rate of Perceived Exertion; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Elbar et al. (2012)				➢ Standing on equipment (balls and noodles); reaching in multi-directions. Levels 3 and level 4 exercises ➢ Incorporated gait exercises. ➢ Create disturbance in water, increase resistance, motion and turbulence act to perturb the COM (i.e. simulating tripping) Level 5 exercises Perturbation activities provided by instructors or fellow-participants to evoke balance-recovery stepping reaction against water-resistance.	Postural stability – eyes closed: Medial-lateral postural sway: P = 0.02 Anterior-lateral postural sway: P = 0.02 Sway area (mm^2): P = 0.03 **Limitations** Possibly including participants with relatively good balance deemed as quite independent, classifying the group as low-risk. Suggestion: Exploring water-based perturbation effects in higher-risk population groups.

Notes: COM: Centre of Mass; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Hale et al. (2012)	**Age:** 55-65 (data analysis (n = 35) **Gender:** **WBEI (n=23)** Men (n=6) Women (n=17) **Gender:** **CON (n=16)** Men (n=4) Women (n=12) **Activity status:** Included participants taking part in exercise programmes not aiming to improve balance or strength and taking 8-10 types of medications. **Note:** Aerobically active (walking) participants could have been included.	Exploring a WBEI efficacy of a WBEI, to reduce fall risk by improving physical function (gait) in older adults with lower-extremity (mild-moderate) osteoarthritis. CON group: (time-matched education; computer skilled training and computer games, no exercise but social engagement). **Note:** Two CON participants (uninterested in computer-training) completed other social, seated activities, provided by the local organisation catering for older adults. (Card-making and Mahjong) **Primary measurements** ➢ Falls risk (short-form Physiological Profile Assessment; PPA) ➢ Contrast sensitivity ➢ Reaction time (computer and mouse test) ➢ Proprioception ➢ Strength ➢ Postural sway (anterior-posterior; medial-lateral) ➢ Step test ➢ TUG (number of steps)	**Setting:** H_20 **Time:** 12 weeks **Blinded:** Unknown **Randomisation:** Randomised controlled trial. **Type:** Low-intensity aerobic, progressive balance training, muscle strength and resistance components included. Progression: Execution of exercises commenced initially at xiphoid level (1310mm). Towards the end of the intervention, execution at depth of 940mm.	**Duration WBEI:** Week 1 – 9 (20 – 25 min) Week 4 – 6 (30 – 35 min) Week 7 – 12 (45 – 60 min) **Duration CON group:** Week 1 -12 (60 min) **Intensity of WBEI Group:** ➢ Seemingly low (RPE / Heart rate monitoring unspecified) **Frequency WBEI and CON group:** Participants in both groups attended activities 2 x p/wk (Attendance records) **Temp:** 28 ºC. **Depth:** Xiphoid level to waist level **WBEI Setting:** H_20 Main characteristic: progressively more challenging balance exercises (eyes open vs eyes closed; single leg balancing vs support on both legs). Warm-up & Cool-down (unspecified min); (H_20) ➢ Stretching (quadriceps, hamstrings, shoulders, triceps muscles) ➢ Walking forward, backward, sideways ➢ Calf and toe raises	Step Test: changed significantly in both WBEI group and the CON group. No statistically significant between-group differences were found for the primary outcome or any of the secondary outcomes measured. Fall risk ratio improved for CON group, possibly due to "getting out of home regularly and into community". Intriguing results. Future studies seemingly need to incorporate computers and computer training. **WBEI group**: Step test & step change (left leg) : P = 0.000 Step change (right leg): P = 0.004 **CON group**: Step test & step change (left leg): P = 0.002 Step change (right leg): P = 0.017 Reaction time: P = 0.03 Contrast sensitivity: P = 0.05 To be continued on the next page…

Notes: WBEI: Water-based exercise intervention; CON: Control group; TUG: Timed-up-and-Go test; RPE: Rate of Perceived Exertion; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Hale et al. (2012)		➢ Self-reported physical function questionnaire ➢ Physical, social, emotional well-being questionnaire ➢ Balance confidence and fear of falling when performing functional activities (self-report balance questionnaire),		Balance (unknown min); (H20; with/without equipment) and included: ➢ Cross-country skiing, (progress from reaching to jumping) ➢ Single and double leg jumping jacks, walking, leg swings etc.)	**Limitations** Possibly including non-sedentary individuals (selection bias). Not tracking participation of the participants in other physical activities-possibly contaminating results (self-reported questionnaires). Possible measurement error on PPA-scores.
Bocalini et al. (2008)	**Age:** 62 – 75 (n = 50) **Gender:** Healthy Elderly women **Activity status:** Sedentary for 3 months prior to intervention	Comparing the effectiveness of WBEI and land-based exercise on muscle strength, flexibility and functional capacity (fitness). **Primary measurements** ➢ Muscle strength (Knee extension & knee flexion) ➢ Grip strength testing; 3RM Strength testing; ➢ Muscle power (vertical squat jumps), Flexibility trunk flexion); lower leg muscle strength, chair-rise, walking stability (TUG-test).	**Setting:** Land & H_20 **Time:** 12 weeks **Blinded:** Unspecified **Randomisation:** Unspecified **Type:** Similar to Takeshima et al. (2002) but slight modifications. Aerobic and resistance components included.	**Duration:** 60 minutes **Intensity:** Moderate: 70% of HR_{max} week 1-12 for both groups. Resistance manipulated with movement velocity. The land-based group executed the same warm-up and cool-down protocol except, walking was land-based 70% $HR_{max.}$ **Frequency:** WBEI group: 3 x p/wk (resting days between training days) Land-based group: 5 x p/wk **Temp:** 29ºC **Depth:** Xiphoid or near xiphoid level	WBEI and land-based group significantly improved in maximum aerobic power ($VO2_{max}$). However, the WBEI group's values were significantly higher than Land-based group. Only the WBEI group significantly improved in RHR. More neuromuscular parameters significantly improved for WBEI-group, comparing to land-based and considered more powerful to induce changes in physical fitness. To be continued on the next page…

Notes: WBEI: Water-based exercise intervention; TUG: Timed-up-and-Go; HR_{max}: Maximum Heart rate; RHR: Resting Heart Rate; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Bocalini et al., 2008				**WBEI Setting:** H_20 Warm-up (10 min) & Stretching:(H20) ➢ Warm-up movements (H20) Endurance (45 min); (H20); All exercises: (1 Set; 10 – 15 repetitions) ➢ Races, arm & leg movements with water-resistance products (soft-cushioned hand-bars, leg pads and aqua-tubes. ➢ Dumbbell- and barbell-type devices for upper body resistance exercises (chest press, biceps curl, and lumber rotation). ➢ Leg pads for lower body exercises (knee extension, knee flexion, leg press, leg curl, calf press, leg abduction and adduction	**WBEI-group** A curl test: $P< 0.001$ Sit-to-stand-test: $P< 0.001$ 8-foot up and go test: $P< 0.001$ Sit and reach test: $P< 0.001$ Maximum aerobic power: $P < 0.001$ **Land-based group** Sit-to-stand-test $P< 0.001$ 8-foot up and go test: $P< 0.001$ Sit and reach test: $P< 0.001$ Maximum aerobic power: $P < 0.001$

Notes: WBEI: Water-based exercise intervention; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Tsourlou et al. (2006)	**Age:** 68 – 69 (n = 22) **Gender:** Healthy Elderly women **Activity status:** Sedentary to low activity	Investigating 24-week WBEI on muscle strength, flexibility and functional mobility. **Primary measurements** ➢ Aerobic and resistance components included. ➢ Muscle strength (hydraulic-resistance machine), ➢ Grip strength testing, ➢ 3RM Strength testing, ➢ Muscle power (vertical squat jumps), ➢ Flexibility trunk flexion), ➢ Lower leg muscle strength, ➢ Chair-rise test, ➢ Walking stability (TUG-test).	**Setting:** H_20 **Time:** 12 weeks **Blinded:** Unspecified **Randomisation:** Unspecified **Type:** Aerobic and resistance components included.	**Duration:** 60 minutes **Intensity:** Moderate to high: 65% of HR_{max} week 1-4; 80% of HR_{max} week 5 -24: (RPE 11.8 ± 1.2); Week 12: Music tempo of 100 – 140 b/min^{-1} (Aerobic); Resistance components performed with music (60 b/min^{-1}). **Frequency:** 3 x p/wk **Temp:** 30ºC **Depth:** Xiphoid to axillary region **WBEI Setting:** H_20 Warm-up (10 min) & Stretching:(H20) ➢ slow-pace walking, with rhythm and direction change (H20) Aerobics (25 min); (H20); large muscle –groups: ➢ lateral traveling, long-lever pendulum-like movements of extremities, ➢ forward and backward jogging with arms pushing, pulling, pressing & leaps, ➢ kicks, leg crossovers, hopping movements – multiple direction travel & jumps	WBEI produced significant improvements in muscle strength; body fat and functional mobility. Type of training (supervised setting) has a high degree of safety. Lean body mass: $P < 0.0125$ Peak isometric torque of knee flexors: $P < 0.0125$ Grip strength: $P < 0.0125$ Dynamic strength parameters: $P < 0.0125$ Flexibility: $P < 0.0125$ TUG-test: $P < 0.0125$ Trunk flexion & extension: $P < 0.0125$ To be continued on next page…

Notes: WBEI: Water-based exercise intervention; TUG: Timed-up-and-Go; HR_{max}: Maximum Heart rate; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Tsourlou et al. (2006)				Resistance (10 min); ($H_2$0) ➢ Water-equipment (noodles etc.). ➢ Week 1-2: No resistance & familiarisation; week 2-24; 2 sets of 12-15 reps): ➢ knee extension-flexion, hip-extension-flexion with extended knee, double knee lifts, & side- press kicks.) Progression: Equipment, reps, sets, velocity manipulation.	
Broman et al. (2006)	**Age:** 69.0-69.8 (n = 24) **Gender:** Healthy Elderly women **Activity status:** Unspecified	Is deep water running, with a wet vest, safe for elderly exercise and does the high-intensity programme improve aerobic power? **Primary measurements** ➢ Maximal oxygen uptake (cycle ergometer); ➢ Submaximal exercise test (cycle ergometer); ➢ Wet vest training to accommodate mobility limitations, pain, poor balance (Nemcek 1988). ➢ RHR with monitors	**Setting:** $H_2$0 **Time:** 8 weeks **Blinded:** Unspecified **Randomisation:** Yes **Type:** Walking, running (interval training) **Note:** WBEI: 5 drop-outs, due to demanding testing protocol, influenza and rheumatological disorder.	**Duration:** 60 minutes **Intensity:** High (Perceived exertion scale used (CR-10 scale). 75%-79% of maximal HR **Frequency:** WBEI group: 2 x p/wk **Temp:** 27ºC **Depth:** Xiphoid or near xiphoid level **Control group Setting:** ➢ Unspecified protocol **WBEI Setting:** $H_2$0 Warm-up (7 min) ➢ Unspecified protocol Interval training (30 min); ➢ **Note:** Running technique taught prior to intervention;	WBEI group significantly improved in submaximal work capacity, maximal aerobic power, and maximal ventilation with effects transferable to land-based activities (P-values: $P < 0.01$). The testing values for the control group remained unchanged. To be continued on next page…

Notes: WBEI: Water-based exercise intervention; RHR: Resting Heart Rate; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Broman et al. (2006)				➢ Consisted of three periods (10min each) and 2 min rest between periods. ➢ Shortest exercise interval was 15 sec; longest exercise interval was 3minutes. Cool-down (7 min) ➢ Unspecified protocol	
Lord et al. (2006)	**Age:** 71-76.5 (n = 85) **Gender WBEI (n=85):** Men (n = 18) Women (n = 6) **Notes: Baseline age differences:** (WBEI: $\bar{x}$ 71.8; Con: $\bar{x}$ 76.5; P<0.01) Medical conditions included (i.e. Stroke diabetes, blood pressure, osteoarthritis, balancing issues, fall risk individuals etc.).	Effectiveness of WBEI Physical functioning in older people. **Primary measurements** ➢ Water confidence improvement, ➢ Flexibility of entire body ➢ Postural awareness, balance & co-ordination improvement ➢ Reaction time, ➢ Maximise enjoyment and enhance social contacts	**Setting:** H_20 **Time:** 22 weeks **Blinded:** No (reported as a limitation) **Randomisation:** Yes **Drop-outs (n = 37):** Due to poor health (n=11), hospitalization (n=5) and dislike for pool environment (too cold; reaction to chlorine, shower facilities) (n = 7). **Type:** Combination of aerobic, resistance and flexibility exercises.	**Duration:** 60 minutes **Intensity:** Not specified: ("standard exercise warm-up, conditioning, cool-down"). Instructed to work at own pace if Mobility limitation is present. **Frequency:** WBEI group: 1 x p/wk (resting 2 weeks mid intervention) **Temp:** Different pools 25ºC - 29ºC **Depth:** Unspecified protocol **WBEI Setting:** H_20 ➢ Warm-up (Unspecified duration) & Stretching major muscle groups and joints: (H_20).	WBEI significantly improved in maximum balance range test, showed higher co-ordinated stability and less errors and increased shoulder range of motion errors. Author acknowledges: ➢ Programme intensity seemed insufficient or ➢ Wrong programme modality caused no improvement in reaction time. To be continued on the next page…

Notes: WBEI: Water-based exercise intervention; Con: Control group; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Lord et al.(2006)	The WBEI group reported higher prevalence of osteoarthritis, took musculoskeletal and psychoactive medications). **Gender Control group: (n=44):** Men (n = 7) Women (n = 37) **Activity status:** Sedentary / walking < 15min/day			Conditioning (Unspecified duration) ➢ Balancing/co-ordination: stand on one leg; moving arms & opposite leg. ➢ Multi-directional weight transference/reaching activities. ➢ Upper body resistance: Flexible knee-boards held with both hands. ➢ Hip, knee & ankle ROM: Hold on to pool side / each other in circle format – balancing exercises. ➢ Aerobic: Kicking legs holding kick-board hop and jump in circle formation, paired games and team games. ➢ Cool-down (5 – 10 min) ➢ Stretching, deep breathing and floating with assistance if needed. **Control Setting:** Unspecified	Small but non-significant improvements in quadriceps strength and reaction time. Programme emphasis was on balance-related exercises, therefore no strength gains were observed. **WBEI-group** Maximal balance range test: $P< 0.01$ Co-ordinated stability: $P< 0.05$ Shoulder ROM (degrees): $P< 0.05$

Notes: WBEI: Water-based exercise intervention; ROM: Range of motion; p/wk: per week; P: P-value; n: number

…Table 2.4 continue…

	Participants	Primary outcomes	Methods	Intervention protocol	Results, findings
Takeshima et al. (2002)	**Age:** 60 – 75 (n = 45) **Gender:** Healthy Males **Activity status:** Sedentary	Investigating physiological responses of elderly women participating in a well-rounded. **Primary measurements** ➢ Muscle power (vertical jumps), ➢ Muscle strength (hydraulic-resistance machine), ➢ Agility (side-stepping test), ➢ Flexibility (trunk flexion & extension). ➢ Physiological tests (i.e. RHR, BP, VO2max, Cholesterol, Lactate etc.),	**Setting:** Land & H_20 **Time:** 12 weeks **Blinded:** Unspecified **Randomisation:** Unspecified	**Duration:** 70 minutes **Intensity:** Moderate: 67% of HR_{max} while walking and 65% of HR_{max} while dancing during week 1 and 78% of HR_{max} while walking and 71% of HR_{max} while dancing during week 12. Week 1-11: (RPE 11.8 ± 1.2); Week 12: (RPE 13.5 ± 1.4) **Frequency:** 3 x p/wk **Temp:** 30ºC **Depth:** Xiphoid Warm-up (20 min) ➢ Stretching: (land-based) ➢ slow-pace walking, with rhythm and direction change (water-based) Endurance (30 min) ➢ walking and dancing (water-based) Resistance (10 min) ➢ Water-equipment (pads, foam dumbbells etc.). Move through full movement range, as fast as possible (water-based) ➢ Exercise type lower body (1 set of 10-15 reps): ➢ Knee flexion & extension; leg press & leg curl, calve press, leg abduction & adduction) ➢ Exercise type upper body (1 set of 10-15 reps): ➢ Chest press, biceps curl, lumber rotation	WBEI produced significant improvements in cardiorespiratory fitness, muscle strength; body fat and total cholesterol. Skin-fold thickness (mm): $P < 0.05$ Vertical jump (cm): $P < 0.05$ Side step (steps 20 s^{-1}): $P < 0.05$ Cholesterol and blood lipids: $P < 0.05$ Knee extension: $P < 0.05$ Knee flexion: $P < 0.05$ Chest press and pull: $P < 0.05$ Trunk flexion & extension $P < 0.05$

Notes: WBEI: Water-based exercise intervention HR_{max}: Maximum Heart rate; RHR: Resting Heart Rate; BP: Blood pressure; RPE: Rate of Perceived Exertion; p/wk: per week; P: P-value; n:

2.11 SUMMARY

The intricate and phenomenally interwoven ways of the EF system, operating within Global Cognition through essential higher order cognitive skills of Processing speed, selective attention, and visual spatial information processing, are often underestimated. Further clarifying research is clearly essential. These neurocognitive domains, with their multi-construct contributions to overall brain health and Mobility (in both ST and DT activities), are vital to safe execution of ADL.

The extent of damage being done to neuronal health, cognition and Mobility by mentally and physically unhealthy lifestyle choices are acute and everlasting. However, through exercise, damaged neural pathways in the brain could be bypassed or even repaired across the life-span.

Decrements in EF and Mobility increase loss of autonomy and a might place an extensive burden on supporting family members and the public health sector (Forte et al., 2016; Holtzer et al., 2016; Mahishale, 2015). Additionally, the ways in which external factors, such as loneliness, depression, asocial behaviour, stress, or anxiety on one hand, and creativity and sense of belonging on the other hand, may affect EF and Mobility (specifically gait patterns and DT-activities) are severely underestimated.

Nevertheless, although natural ageing is not a disease, it remains a challenge to the older adult. The inherent, dynamic ability of the brain allows for functional reorganisation and repair throughout the life span. To maintain itself and adapt in response to neural challenges, new, compensatory or alternative neural circuits may be developed and recruited, especially in the pre-frontal lobes of the ageing brain. This process of scaffolding allows the circumvention of damaged and faulty pathways associated with inefficient EF performance, as well as fulfilling a supportive role throughout life.

The pre-frontal lobes are the most sensitive to the effects of exercise, especially those relating to enhanced EFs. Therefore, the adaptation of a habitual exercise programme that entails components of aerobic and resistance training, together with co-ordination of limbs, can address and ameliorate modifiable risk factors. Natural ageing does not have to be a threat. Due to the unique properties of a water-based exercise environment, it might be ideal for the older adult in which to exercise safely and optimally address these training principles.

CHAPTER 3
PROBLEM STATEMENT

3.1 EXISTING LITERATURE

Existing literature addressing Executive Function (EF) and Mobility, heightens the matter of urgency in: finding methods to slow down or prevent age-related cognitive decline (Mahishale, 2015); or ways to improve cognitive functions, general health as well as Functional Mobility, specifically in adults aged 50 years and older (Cooper et al., 2014; Gothe et al., 2014; Zhao et al., 2014; Bherer et al., 2013; Hamer et al., 2013; Hillsdon et al., 2005; Cooper, 1997). The research conducted by Jin and colleagues (2015) placed emphasis on the implementation of strategies, specifically aiming to address disease prevention in these older adults (≥ 50 years). The aim of these interventions was to avoid future health-impaired elderly, whom are in need of long term care (Bloom et al., 2015; Mahishale, 2015). Mirelman et al. (2012) in particular, emphasised the need of physical training programmes, with the specific aim to preserve EF and attention to prevent dual-task (DT) gait variability and falls in elderly people.

Ageing causes an inevitable, natural decline in cognitive function and Mobility (Gothe et al., 2014; Zhao et al., 2014). Executive Functions, especially Processing speed, are vital in the execution of all DT activities, healthy Physical Functioning and Mobility (Diamond and Ling, 2016; Diamond, 2015, 2013; Gothe et al., 2014; Bherer et al., 2013; Lahman et al., 2012). Furthermore, EFs and Mobility, including gait functionality (Mirelman et al., 2012; Hausdorff et al., 2004), are interlinked (Lahman et al., 2012) and crucial for independency and overall Quality of Life (QoL) (Cooper, 1997).

Adults aged between 53 and 64 years who lead insufficient active life styles, are sedentary or only obese during this mid-life stage, are especially at high risk for EF decline, functional disability and mortality even before reaching the age of 65 years (Cooper et al., 2014). Twenty-three percent of the ageing population in general from 60 years of age were identified as suffering from the burden of chronic diseases. Cardiovascular and neurological diseases, together with musculoskeletal weakness and disease are considered as major culprits (Jin et al., 2015; Prince et al., 2015; Smith et al., 2012).

Of importance to the older adult, is the vast amount of research underlining the benefits of an active lifestyle. Emphasis is placed on the role of habitual exercise to reduce the risk of mild cognitive impairment (MCI) which could lead to dementia and Alzheimer's disease (AD). Exercise may also lower the incidence and prevalence of chronic diseases i.e. cancer, diabetes and coronary heart disease (Alhurani et al., 2016; Bherer et al., 2013; Ratey et al., 2011). These physical barriers could prevent or limit the individual from engaging in any physical activities, contributing towards a probable disease-filled future, depression and mortality.

Emphasis is placed on the need to include both aerobic and resistance components in future training programmes to conserve Global Cognition (Bherer et al., 2013). Aerobic exercises of high-intensity, with a combination of resistance training, bi-manual coordinated moves across the midline of the body and requiring sequential learning, seem to be most beneficial to enhance EFs (Diamond 2015; Verstynen et al., 2015; Diamond 2013; Perrochon et al., 2013).

Considering how adults in the preceding decade prior to elderly status (≥ 65 years) are already experiencing age-related physical and cognitive decrements, it follows that aerobic and resistance training according to these suggestions, would require the individual to be exceptionally well-conditioned in a land-based exercise environment. Therefore, the supportive, safe nature of a water-based exercise environment could be ideal (Waller et al., 2016; Fedor et al., 2015, Sato et al., 2015, 2013; Sherlock, 2014; Sherlock et al., 2013; Haley et al., 2012) for these adults, holding long term health and wellness benefits as individuals continue into later stages of life.

To the knowledge of the researcher at time of writing, this is the first water-based-exercise-intervention study, in accordance to the suggestions of Waller et al. (2016), Diamond (2015) and Sherlock et al. (2013), addressing the relation between EFs as an entity, Functional Mobility and DT ability. In general, limited water-based intervention programmes addressing EF and Mobility exist to date. One study explored the differential effects of a water-based intervention programmes on Global Cognition and found positive results (Sato et al., 2015). Two water-based intervention studies further explored EFs with focus on healthy elderly (Sherlock et al., 2013; Sherlock, 2014). These studies propose that similar benefits could be predicted for healthy older adults between 50 to 64 years of age. Results from both studies confirmed a water-based intervention to positively influence EF and Mobility in healthy elderly. Sherlock et al. (2013) explored EFs in both land and water environments, focussing on the comparison between the aerobic and anaerobic effects on EF. In the follow-up study of 2014, Sherlock specifically focussed on the effect of a water intervention programme on Global Cognition, inclusive of EF, in healthy elderly. Both studies identified the necessity for more water-based interventions with regard to cognitive functioning. Fedor et al. (2015) explored the effects of a one week water intervention programme on Global Cognition and cardiovascular fitness in apparently healthy older individuals. Positive results for EF, i.e. Working memory (WM) and attention, were reported. However, this particular study had a few limitations, lacking randomisation, since participants could choose to be either in the intervention or control group. The sample size was small, limiting statistical power due to the exclusion of participants who experienced impaired cognition at baseline testing.

3.2 MOTIVATION AND PURPOSE

Water provides a safe, therapeutic environment that eliminates the concern for falling (Sherlock et al., 2014). Hydrostatic forces, constant resistance, buoyancy and reduced gravity are synonym to a water environment. The current intervention aims to contribute to research by designing an effective and safe water intervention programme which includes an aerobic and resistance training component, specifically intended to enhance EF and Mobility. Exercising in this environment could be an inexpensive, non-pharmaceutical way to successfully address the cognitive and Mobility degeneration phenomenon in older individuals, as well as contributing to enhanced independency and Health-related Quality of Life HRQoL.

It is postulated that EFs and Mobility of older adults (50 – 64 years) could possibly benefit from a water-based exercise intervention (WBEI) programme. In addition, this study may hopefully also contribute as preliminary intervention to future longitudinal or prospective studies that could further research to determine whether a WBEI could reduce, delay and possibly prevent cognitive impairment in adults aged 50-64 years.

The researcher hypothesised that the influence of an 8 - week WBEI may enhance EF and Mobility of apparently healthy older individuals more in comparison to non-exercising individuals, who received no water intervention and participated in relaxation and educational activities.

3.3 RESEARCH QUESTION

The primary aim was to determine if an 8 - week WBEI of high-intensity will influence EF and Mobility, in apparently healthy older individuals in the Western Cape, South Africa. The secondary aim set out to assess the changes in older adults' perceived HRQoL and whether improvements in activities of daily living (ADL) took place.

3.3.1 Research objectives

To address the above-mentioned aims, the following objectives were categorised into primary and secondary, which also incorporated possible confounding variables. Primary objectives, including testing measures used, are addressed first.

3.3.1.1 Primary objectives

The two primary objectives (EF and Mobility) with testing measurements used are indicated below.

a) Executive Function

i) Attention and Working memory was obtained with the Digit Span Forward (DSFW) and Digit Span Backward (DSBW) respectively

ii) Cognitive flexibility measured with the Trail Making Test (TMT) part A (TMT A) and part B (TMT B)

iii) Inhibitory control as determined with the Walking Stroop Carpet (WSC)

b) Mobility

i) Functional Capacity was obtained with the Six-minute walk test (6MWT) as well as Gait speed

Spatiotemporal gait variables, Turning variables and Postural transitions as set out in detail in chapter four (Methodology), was measured at pre-and post-test to assess gait under single and dual-task walking conditions. In addition, Gait speed was determined under both latter walking conditions:

ii) *Single-task Mobility was assessed with the instrumented Timed-Up and Go (iTUG) test*

iii) *Dual-task Mobility and Dual-task Cost (DTC%) were obtained with a cognitive Timed-Up and Go (iTUG) test*

3.3.1.2 Secondary objectives

The secondary objectives were to assess the following changes pre- and post-intervention in the two groups i.e. on:

a) *Global Cognition with the Montreal Cognitive Assessment (MoCA)*

b) *Depressive Mood through the Patient Health Questionnaire (PHQ - 9)*

c) *Self-perceived Health-related Quality of Life with the 36 - Item Short Form Health Survey (SF - 36)*

d) *Self-perceived Physical Functioning with the 10 - item Physical Functioning subscale (PF - 10).*

3.3.2 Descriptive characteristics and variables

Descriptive characteristics included age, gender, height, body mass, body mass index (BMI), and activity status (RAPA: Rapid Assessment of Physical Activity) whereas certain variables were identified that could influence EF, Global Cognition, Mobility and HRQoL.

3.3.2.1 Independent variables

The 8-week WBEI for the Experimental group (EXP) and the non-exercising activities (8 weeks) for the Control group (CON) were both classified as independent variables.

3.3.2.2 Dependant variables

Dependant variables were EFs (Inhibitory control, Cognitive flexibility, Working memory) and Mobility i.e. spatiotemporal gait parameters of: Total duration (TD), Gait speed (GS), Stride length (SL), Stride velocity (SV), Cadence (Cad), Double support (DS), Turning variables (Turning duration, Peak turning velocity, Number of steps during turn) and Postural transitions (Sit-to-stand: STS; Turn-to-sit: TTS), inclusive of Functional Capacity or aerobic endurance.

3.3.2.3 Confounding variables

Level of education, Global cognitive impairment (MoCA), Depressive Mood (PHQ-9) and self-perceived HRQoL are the identified confounding variables.

In order to control for the above-mentioned confounding variables, participants achieving scores < 20 in the MoCA and > 9 in the PHQ-9, were excluded from the study. Global Cognition scores of 26 are considered normal, whereas scores < 20 indicates severe cognitive dysfunction. Additionally, severely depressed individuals were excluded (PHQ-9 scores of ≥ 10).

CHAPTER 4
METHODOLOGY

4.1 INTERVENTION DESIGN

The group-based, 8-week intervention programme followed a single-blind randomised control trial. Figure 4.1 illustrates the division of participants into an experimental (EXP) group that followed a water-based exercise intervention (WBEI), and a non-exercising control (CON) group who performed time-matched-attention (TMA) activities. The TMA programme consisted of relaxation and educational activities. Recruitment commenced in the Western Cape (South Africa) after approval was obtained from the *Research Ethics Committee* of Stellenbosch University (SU-HSD-002062; Appendix B). The intervention took place between the 1st of May and the 21st of July 2016. Pre- and post-test (over a 2-week period) occurred before and after the 8-week period.

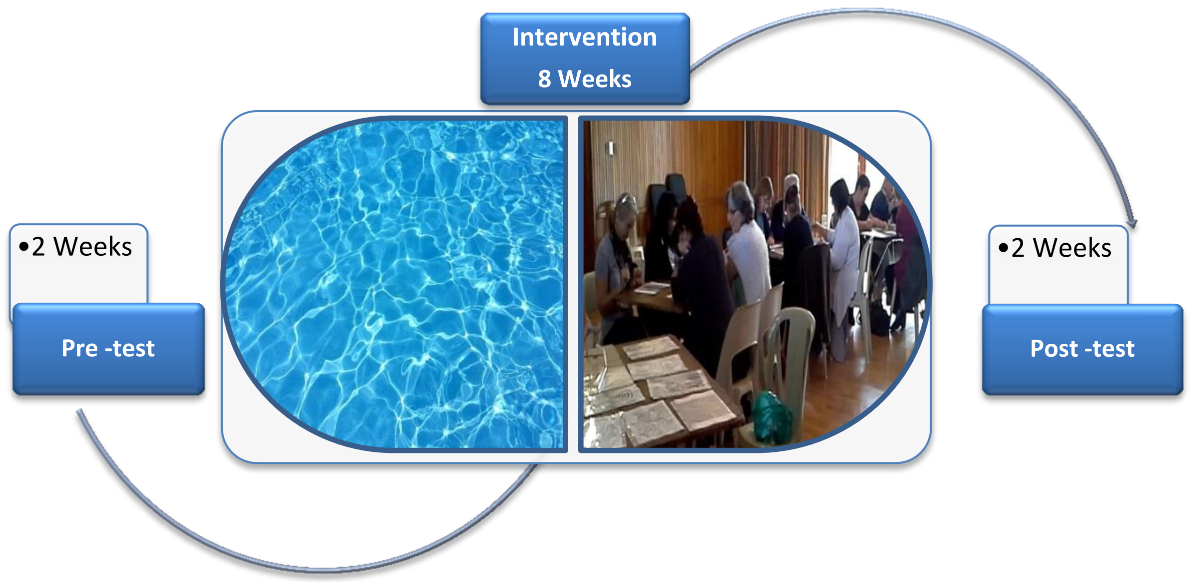


Figure 4.1 Schematic design of the 8-week research project testing periods.

A water-based exercise trial (WBET) phase, done prior to pre-test, consisted of ten sessions of 45 minutes each. Neither physical, nor pen- or paper tests were completed during the trial phase. The focus pertained to the water-based exercise protocol only. Appropriate exercise combinations and modifications to be presented during the WBEI were developed, adapted and overseen by a qualified exercise specialist. The final exercise programme was based on a trail phase (10 sessions; 45 minutes each). None of the participants in the trial phase were involved in the 8-week intervention or had any contact with eligible, randomised participants.

Once the intervention began, no changes were made to the exercise sessions. The sample size necessary to reach a statistical power of 80% ($\alpha < 0.05$) and a moderate size effect ($d > 0.40 – 0.75$), required a minimum of 40 participants (Cohen, 1992).

Verbal and written informed consent (Appendix E) was obtained prior to the initiation of pre-testing. Concealed randomisation was executed by an offsite, uninvolved individual with an initial allocation of 27 (EXP) : 29 (CON) (refer to Figure 5.1 in chapter five). Therefore, none of the participants were aware throughout the intervention whether they were allocated to either an EXP group or CON group. Furthermore, the success of blinding was ensured since: no information was divulged to either group that might influence intervention results directly or indirectly; sessions of both groups took place at completely different locations and at different times of the day; none of the participants were aware of the true purpose of the study; and lastly, both groups participated alternatively in exactly the same activities. No harm due to the intervention has been reported.

4.1.1 Recruitment and participants

Sixty eight apparently healthy volunteers aged between 50 and 64 years were recruited in April 2016 through advertisements in the local newspaper and social media (Appendix C & D). The initial screening process was only done verbally and not physically (i.e. testing if participants were able to complete ADL's). Therefore, prospective participants had to verbally confirm the following: they were independently living within the community; were apparently healthy; walked without assistive devices and were independent in the execution of activities of daily living (ADL).

Orthopaedic, musculoskeletal, cardiovascular, neurological conditions or injuries that could limit their participation in the intervention, six months prior to recruitment, led to exclusion. Individuals with none to probable mild cognitive impairment (MCI) on the Montreal Cognitive Assessment (MoCA: Global Cognition score ≥ 20) (Edwards et al., 2016; Lister et al., 2016; Zheng et al., 2016; Nasreddine et al., 2005) and a depression score ≤ 9 (Patient Health Questionnaire: PHQ-9) (Simon et al., 2013) were eligible for participation. A total attendance score of 80% was required for inclusion, while an absence of more than two consecutive sessions would disqualify participants. An attendance register was updated at each session. Table 5.1 outlines the descriptive and clinical characteristics of participants at pre-test.

4.1.2 Setting

An indoor venue with appropriate requirements was utilised for pre- and post-test (suitably levelled floor space, adequate lighting and all equipment necessary). A second, similar venue was used for the CON group activities.

The WBEI was simulated in two similar indoor swimming pools (Temperature: 31ºC – 33.5 ºC). Pools ensured comfortable standing, with depth (1.2 – 1.8 metre) to reach participants' sternum height. Both pools were easily accessible with general safety features (surrounded by anti-slip, rubberised features, stepped water entry with hand-railing). A safety bar, lengthwise at water-level, was an addition to safety.

4.1.3 Intervention

The principal researcher conducted all sessions of the WBET phase, followed by the WBEI, as well as TMA sessions. Guest speakers presented five of the educational and relaxation activities to the latter group.

4.1.3.1 Water-based exercise intervention (WBEI)

Participants attended 24 sessions, training three times per week on every alternative day. The total session duration was 45 minutes, including a 7-minute warm-up and cool-down period respectively. The WBEI of progressively higher intensity included cardiovascular and resistance training according to the American College of Sports Medicine (ACSM) exercise guidelines for older adults, (Sparling et al., 2015; Sari 2011; Nelson et al., 2007). The exercise protocol was based on reviews of previous research, with an overview provided in Table 2.3 and Table 2.4 of water-based studies that focussed on EF and Mobility.

During the sessions, participants utilised the Category Ratio 0 – 10 Rate of Perceived Exertion (RPE) scale to evaluate their perceived cardiovascular exertion. Instructions fully explained the application of the self-perceived RPE (Table 4.1; Appendix F). Additionally, participants were continuously and individually monitored by the exercise specialist for effective use and compliance (RPE score 7 – 8; high-intensity) during each exercise session. Use of participants' self-reported RPE scores is valid and reliable to successfully evaluate perceived exertion in exercise intensity, rehabilitation, aerobic and resistance training (Herman et al., 2006; Day et al., 2004; Foster et al., 2001).

Table 4.1 Category Ratio 0 – 10 Rate of Perceived Exertion Scale

RATE OF SELF-PERCEIVED EXERTION SCALE (0 – 10)			
0-1	No exertion at all (i.e sleeping).	2	Absolute barest exertion (i.e. sitting/ lying down).
3	Comfortable light activity, breathing starting to increase, yet still very easy. No sweating.	4	Light activity and start breaking sweat. Conversations maintained easily. Can maintain for hours.
5	Moderate activity induce and conversations maintained easily. Will be able to maintain intensity for at least 60 min.	6	Moderate activity and sweating (can still speak without difficulty and could maintain intensity for a while).
7	Experience shortness of breath, can still speak one sentence ; high-intensity	8	Can only speak one/two words and not a sentence high-intensity. Won't be able to maintain for long periods. (maximum intensity reach for maximum 20sec: during interval training)
9	Very hard activity	10	Maximal exertion and cannot push any harder

Notes: The colour-coded RPE version - used as a poster on the wall (1.5 x 1m) - during the intervention, can be viewed in Appendix F)

a) *WBEI training protocol*

Cardiovascular and resistance training in a water environment can be especially appropriate and beneficial to the older adult, due to the unique properties of this exercise environment (Sherlock, 2014; Sherlock et al., 2013; Graef et al., 2010; Takeshima et al., 2002). Buoyancy reduces stress on joints and enhance postural support (Lord et al., 2006), whereas the multi-directional flow and viscosity of water leads to increased resistance and muscle strength (Graef et al., 2010; Tsourlou et al., 2006).

The aerobic exercise protocol included bi-manual exercises, limb-coordination movements frequently crossing the midline of the body (Diamond, 2015; Williams and Lord, 1997), rhythmic exercises (Martinez et al., 2015) and sequential learning (Sherlock et al., 2013). Previous studies reported an increase in complexity and neurocognitive demands could contribute positively to enhanced EFs (Schaefer et al., 2015; Sato et al., 2013, 2012; Elbar et al., 2012), thereby facilitating Functional Mobility (Graef et al., 2010; Tsourlou et al., 2006; Takeshima et al., 2002). Cardiovascular (Broman et al., 2008) in combination of resistive training components are beneficial to increase healthy, independent Functional Mobility as well as EF (Albinet et al., 2016).

The exercise programme (Appendix G) was designed in accordance with the views, findings and suggestions of the above-mentioned water-based studies and previous research focussed on EF and Mobility specifically. Basic sequential movements in a block formation were executed. One movement lasted between 8-16 counts before slight variation of movement (i.e. expansion of limbs) or direction occurred. The aim was to maintain averaged self-perceived intensity levels ($\bar{x}$ 7.5 ± 0.3). Intensity progressively increased (week 1 – 8) through manipulation of speed and complexity of movement, interval training duration (10 – 20 seconds), as well as frequency of interval training. The warm-up and cool-down exercises, as well as the time allocated for it, remained unchanged throughout the intervention.

4.1.3.2 Time-matched-attention (TMA) activities protocol (Appendix H)

The CON group attended 24 sessions of group-based time-matched-attention (TMA) activities to address motivation and attention as possible confounding variables. Session duration was kept at 45 minutes, thrice weekly for an 8-week period, similar to the WBEI (Hale et al., 2012). Rate of Perceived Exertion scores were verbally obtained from each individual at the end of each TMA session, as these sessions did not contain any physical activities that could cause physical fatigue. The content of the TMA programme was derived from two WBEI studies. Similar to the protocols from both Hale et al. (2012) and Sherlock (2014), the TMA programme included relaxation sessions, educational presentations, creative activities and social engagement amongst group members and the presenter. For ethical purposes, a complementary water-exercise programme, similar to the WBEI, was presented to the CON group after Post-test.

4.1.4 Measurements and Tests

Data collected at pre-and post-test reflected descriptive, primary and secondary outcomes. Testing procedures during pre- and post-test sessions, i.e. clothing and footwear of participants remained unchanged. Time of day at Post-test was scheduled to correspond within a two hour period of the pre-test. Testing time per participant ranged between 80 – 90 minutes. Figure 4.2 shows the testing sequence for all tests during both pre- and post-test sessions. All physical tests, including cognitive pen-and-paper tests and questionnaires mentioned below, were conducted or completed in the participants' language of choice (Afrikaans and English). The principal researcher is fluently bilingual and professionally trained with regards to administering protocol of all tests. Post-tests were administered in the exact consecutive order, in the same way conducted at pre-test.

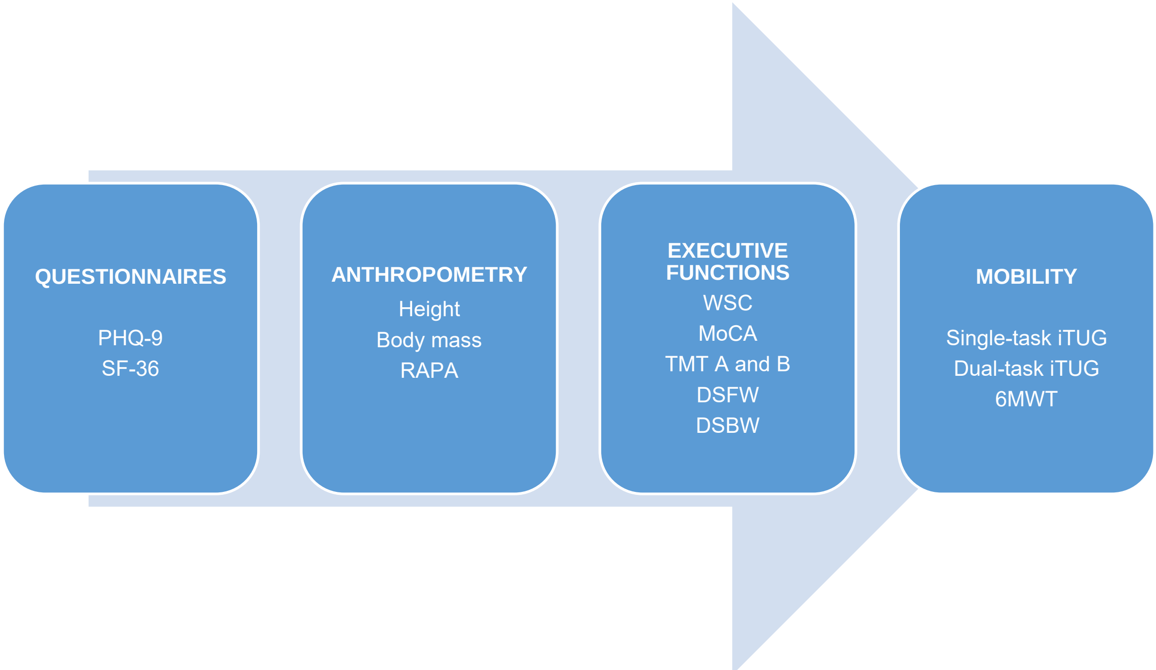


Figure 4.2 Sequence of testing procedure during pre- and post-test sessions.

All self-reported questionnaires were completed with guidance from the principal researcher. Participants verbally confirmed understanding instructions pertaining to the completion of the questionnaires.

Anthropometrical data (height: m; body mass: kg; BMI: $kg.m^{-2}$), as well as demographic characteristics of age, gender, education, Global Cognition (MoCA) and Depressive Mood (PHQ-9) were collected at pre- and post-test. These tests were used as screening instruments pertaining to inclusion criteria and were included as covariates in the analyses if a difference between groups was observed at pre-test. The RAPA was used in addition to determine the level and intensity of physical activity.

Outcomes related to the research objective are briefly listed, before a more detailed discussion follows, with primary outcomes addressed first. The two primary outcome variables were identified as Executive Function (EF) and Mobility. Secondary outcome variables included Global Cognition (MoCA), Depressive Moods (PHQ-9), HRQoL (SF-36), Physical Functioning (PF-10), Body mass index (kg.m-2), body mass (kg).

Executive Function performance was determined in terms of attention and Working memory (WM), Cognitive flexibility (CF) and Inhibitory control (IC). The outcome measurements for EF, in consecutive order, included the following: attention and WM were measured with the Digit Span Forward (DSFW) and Digit Span Backward (DSBW), respectively; CF was measured with Trail Making tests A and B (TMT A and TMT B), whereas the Walking Stroop Carpet (WSC) measured IC.

Mobility performance on the other hand, was examined in terms of Functional Capacity, spatiotemporal gait and transitional parameters under single-task (ST) and cognitive dual-task (DT) conditions, together with dual-task cost (DTC).

Mobility was assessed with the following outcome measurements: Functional Capacity was assessed with the 6MWT. Therefore, participants completed a sub-maximal 6MWT following the protocol determined by Ko et al. (2013) to give an indication of Functional Capacity and Gait speed, reflecting walking ability. Additionally, the iTUG was used to assess the spatiotemporal gait parameters of

Total duration (TD), Gait speed (GS), Stride length (SL), Stride velocity (SV), Cadence (Cad), Double support (DS), Turning variables (Turning duration, Peak turning velocity, Number of steps during turn) as well as Postural transitions (Sit-to-stand: STS; Turn-to-sit: TTS). All gait parameters, including transitional movements, were completed without interference of a secondary task (single-task: ST) and with interference of two cognitive dual-task (DT) walking conditions. The two cognitive tasks - alphabetical letter generation and serial subtraction - were performed at preferred walking-speed and measured motor -and cognitive costs.

Of the physical tests, the WSC was executed first to control for cognitive fatigue and slower Gait speeds. Four trials with the iTUG were followed by the 6MWT. A sufficient resting period (approximately 10 minutes) with refreshments (water) was given prior to execution of seated cognitive testing. Participants indicated verbally when they were well rested to pursue seated cognitive pen-and-paper testing of the MoCA, TMT A, TMT B, DSFW and lastly DSBW test.

However, for methodological purposes, description of all above-mentioned test -and measurement protocols are discussed in consecutive order pertaining to chapter five (Results). Protocol regarding anthropometrical data collection is discussed first, followed by primary variables and lastly, secondary outcome variables.

4.1.4.1 Anthropometrical measurements and activity status

Two measurements were performed on participants at pre- and post-test and instruction was given to wear the same clothing at both testing occasions. Participants gave an indication of their current activity status, by completing the Rapid Assessment of Physical Activity (RAPA) questionnaire. Participants were barefoot during anthropometry assessments of height and body mass. Protocols are briefly highlighted below.

a) Height

A tape measure glued against a vertical wall and a steel ruler was used. Participants were positioned with their backs against the tape measure and wall. They were instructed to look straight ahead, stood with feet together, arms hanging relaxed at the sides of the body. Heels, buttocks and upper backs had to be in contact with the tape measure against the wall. The steel ruler was placed horizontally on the highest point of the scull (vertex), measuring the maximum distance from the floor to the vertex. Height was measured in meters (m) and recorded to the nearest 0.01m.

b) Body mass and Body Mass Index

Participants' body mass was determined using a calibrated electronic scale and recorded to the nearest 0.1 kg. The scale was zeroed on a level floor surface prior to measurement. Body mass was distributed evenly without support, by standing in the centre of the scale and looking straight ahead. Body mass index was calculated offsite. A standardised metric formula gave an indication of body mass (kg) in relation to the participant's height and expressed in kg/m^2: BMI = weight (kg) / $height^2$ (m^2).

c) Rapid Assessment of Physical Activity (RAPA; Appendix I)

According to Topolski et al. (2006), the RAPA is an easily administered, valid and reliable interpreted questionnaire of self-perceived levels of general physical activity for adults > 50 years. This nine item questionnaire assesses components of strength, flexibility as well as intensity levels of physical activity. The questionnaire contains instruction for completion, including a brief description and graphic illustrations of types of activities. Three levels of physical activity are identified as light, moderate or vigorous, requiring only a yes or no response. The initial seven items are scored according to these points (1 = sedentary, 2 = underactive, 3 = regular underactive (light activities), 4 = regular underactive, and 5 = regular active). Strength training and flexibility items are scored separately, with one point allocated for strength training, two for flexibility and three if both items are marked positive. However, the user of the questionnaire is encouraged to supplement the information gained from it with a brief conversation regarding their current levels of physical activity (Topolksi et al., 2006).

4.1.4.2 Primary outcome variables

4.1.4.2.1 Executive Functions

a) Attention and Working memory: Digit Span Forward (DSFW) and Digit Span Backward (DSBW) (Appendix J)

Both the DSFW and DSBW have been widely used as a screening tool in EF and cognitive performance testing (Hester et al., 2004). The phonological loop or verbal capacity is assessed with DSFW (Baddeley, 2000), while information processing, manipulation thereof and temporary storage of that information in the Working memory, is assessed with the DSBW test (Julayanont et al., 2012). Therefore, the ability to retain and recall auditory stimuli, followed by verbal expression of the information necessitates attention, which is measured by the Digit Span Forward (DSFW) (Julayanont et al., 2012). The reverse reporting in the Digit Span Backward (DSBW) requires an active, conscious process to manipulate digits in reverse order before articulation.

In both tests, digit span length is measured by recalling digit sequences ranging from two digits to nine. Therefore the maximum amount of digits to be recalled is nine and eight in the DSFW and DSBW respectively (Woods et al., 2001). In each test, the examiner reads digits out aloud at a rate of one digit per second, in a clear monotonous voice, without any phonological variance or emphasis placed on particular numbers (i.e. DSFW span size of 6: “4, 3, 8, 2, 1, 5”). Failing to accurately report any digit within the sequence, allows for a second change of recalling another digit list of similar length. Failing two consecutive trials ends the test. Maximal list length (span size) reached are recorded (Hester et al., 2004). Protocol for the DSBW is similar, except the digits read out by the examiner have to be repeated in reverse order by the participant (i.e. DSBW Span size of 6: “5, 1, 2, 8, 3, 4”).

b) Cognitive flexibility: Trail Making Test (TMT) part A (TMT A) and part B (TMT B) (Appendix K)

The TMT A and B is a seated pencil-and-paper test, measuring CF (Arbuthnott and Frank, 2000), selective attention and information Processing speed (Bowie and Harvey, 2006). In TMT A, encircled numbers from one to 25 were randomly placed, whereas encircled numbers (1-13) alternating with letters A to L, are randomly distributed in TMT B. Participants are required to sequentially connect circles as quickly and accurately as possible (Perianez et al., 2007). Errors and corrections are pointed out, resulting in increased total duration (seconds). Direct scores represent time required to complete TMT A and B respectively. Two indirect scores (difference score: TMT B – TMT A and ratio score: TMT B : TMT A) calculated interference, executive control and task switching ability (Perianez et al., 2007; Bowie and Harvey, 2006). Perianez et al. (2007) as well as Arbuthnott and Frank, (2000) confirmed reliability as well as validity of the TMT A and B test. It has been widely used as an effective neurocognitive tool, to assess EF (specifically Cognitive flexibility) in healthy and cognitively impaired individuals, within young to elderly age groups.

c) *Inhibitory control: Walking Stroop Carpet (WSC; Appendix L & M)*

The original WSC was developed and used by Perrochon et al. (2013), who underscored the use of the WSC as a method for early detection of mild cognitive impairment (MCI) in younger adults (20 – 30 years), older adults aged 64 - 75 and onwards. In the study conducted by Takimoto et al. (2015), the WSC was effective in detecting fall risk in adults (65 - 91 years). Spatiotemporal gait parameters in the studies of both Takimoto et al. (2015) and Perrochon et al. (2013) were recorded by using the GAITRite® system. This system is a portable walkway, containing built-in pressure activated sensors, measuring temporal (timing) and spatial (two dimension geometric position) parameters during gait (i.e. Total duration, Stride length, Stride velocity, Double support).

In the current intervention, this unique gait specific carpet assessed gait ability, requiring a combination of cognitive-motor tasks. It aims to assess mainly EF of Inhibitory control (IC). However, successful navigation of the WSC necessitates other EFs (i.e. CF, WM) and associated higher-order cognitive skills, for example, information Processing speed, selective attention and visual spatial information processing (Perrochon et al., 2013). All of the aforementioned EFs and cognitive skills are required in the dual-task (DT) walking environment. Therefore, this suggests that slower navigation performance on the WSC not only gives an indication of poorer IC, but also indicates a possible shortfall in the other higher-order cognitive skills. This might lead to alterations in the spatiotemporal gait parameters (i.e. increased navigation times (Total duration), increased Double support as well as a decrease in Stride velocity (Perrochon et al., 2013).

Nevertheless, the WSC used in the current intervention was slightly adapted. Figure 4.3 and Figure 4.4 (a; b) provides both schematic illustrations and photographs of the adapted WSC. However, the few structural adaptations and additions that have been made, will only be explained after detailing structural characteristics of the original WSC, as used by Perrochon et al. (2013) and Takimoto et al., (2015). Thereafter, stepping protocol as used in the original WSC will be highlighted and compared with the protocol used for the adapted WSC. Motivational reasons behind all structural adaptations and modifications pertaining to protocol will be provided.

The original WSC

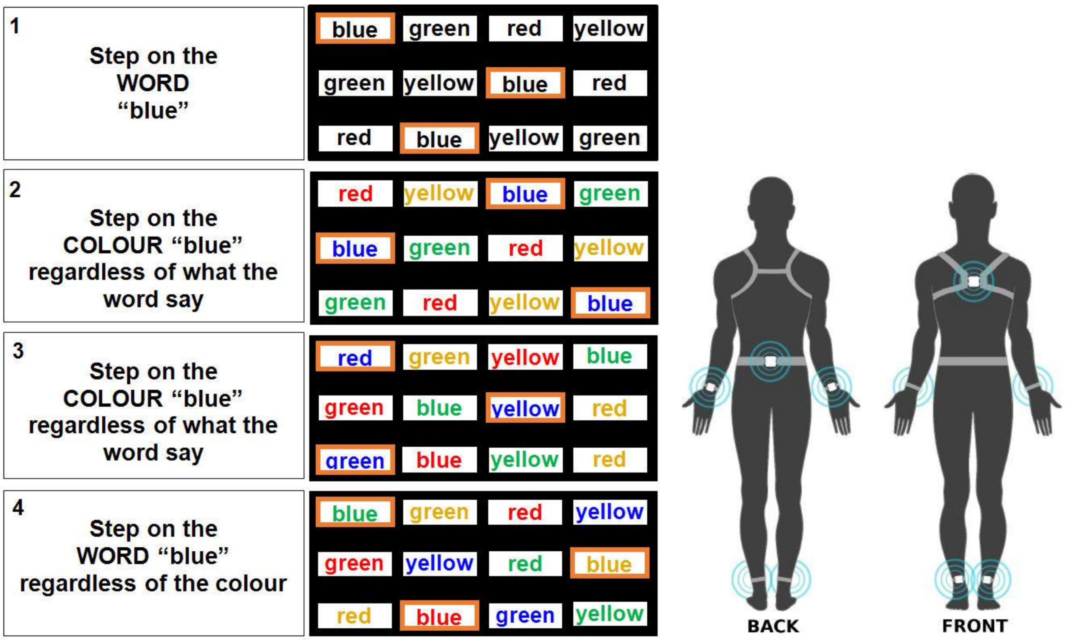
The WSC, as developed and used by Perrochon et al. (2013) as well as Takimoto et al. (2015), was 5m long, 1m wide, consisted of four stepping targets arranged laterally per row, and placed 10 rows lengthwise. Distances between rows measured 45cm. Text was printed directly on either a white background (monochromatic neutral condition) or a black background (incongruent condition). These stepping targets spelled the words “Red”, “Blue”, “Yellow” and “Green” and were randomly placed in the matrix of horizontal -and lengthwise rows. However, only two carpets were used for three Stroop-walking conditions.

The first carpet had monochromatic targets (white background with black text). Participants had to step on targets displayed in black ink. On the second carpet (black background) none of the colours of the text corresponded with the name of the colour (i.e. ‘red’ could be printed in either blue, yellow or green ink). Participants had to step on targets, focussing on the colour of the ink, whereas in the second incongruent walking condition, participants had to step on the text, regardless of the colour the text is displayed in.

The adapted WSC

As mentioned, the current intervention produced an adapted version of the original WSC, meaning a few structural adjustments together with walking adaptations were made to the original WSC. One congruent walking condition was added, based on the views of Perrochon et al. (2013) and the computerised version of the Stroop test of Lucas et al. (2012).

However, Stroop guidelines as set out by Jensen et al. (1968) were taken into consideration and adhered to during the design and development of the carpet. Protocol instructions applicable to each condition are detailed in Appendix L).



Notes: Stepping target is indicated by the orange square

1: Condition 1 (Neutral); 2: Condition 2 (Congruent); 3: Condition 3 (Incongruent colour); 4: Condition 4 (Incongruent word): Illustration of APDM© sensor placements used with permission.

Figure 4.3 Schematic illustrations of the Stroop walking conditions and gait sensor placements (from left to right, respectively)

The WSC in this study was 7.35m in length and 1m in width, therefore providing a longer walkway for data collection. The removable white targets on the black cloth background were placed to form 16 rows lengthwise, with four targets per row. Text on the targets spelled either ‘Red’, ‘Blue’, ‘Yellow’, or ‘Green’ with each word occurring once per row. Stepping target randomisation (Appendix M) was achieved using the computer-based Excel (Microsoft) programme and removability ensured repeat randomisation at Post-test to avoid a possible learning effect.

The distance between rows, measured from the centre of a target to the consecutive target centre (45 cm). Participants in the current study were bilingual (Afrikaans and English speaking). Therefore, each walking condition (n = 4) had a separate walking carpet which could simply flip over to reveal the language of choice. Figure 4.4a below depicts the carpet used during the congruent Condition 2, for an Afrikaans speaking participant. This congruent walking condition was added to the original three conditions used by Perrochon et al. (2013) as well as Takimoto et al. (2013)

and is also part of the computerised Stroop test used by Lucas et al. (2012) and Puren (2015).

The photograph (Figure 4.4a) on the left clearly shows placement of stepping targets, inclusive of the distance between rows (only 7 out of 16 rows are visible). On the right, the comfortable Stride lengths (45cm) during walking are shown. Wearing of socks was compulsory for hygienic reasons. Participants had to attempt each trial as quickly and accurately as possible.

One particular difference in protocol used, compared to “normal walking” as executed in Perrconhon et al., 2013 and Takimoto et al., 2015, was the requirement of stepping with both feet on a target (step-together action), to avoid fall risk. It remains unclear if participant’s were allowed a familiarisation phase in the study conducted by Takimo et al. (2015). However, in Perrochon et al. (2013) participants had a 2m familiarisation phase, of which data was not collected. Therefore data was obtained over 3m only whereas in the current study, the familiarisation of 2m (four rows) was additional to the 7.35m walkway (16 rows lengthwise).

In the current study, spatiotemporal gait parameters of Total duration and Stride velocity while walking on the WSC were obtained for four walking conditions (Control; n=1; Congruent; n=1; Incongruent; n=2) using APDM Mobility Lab^{TM} software. Data streamed wirelessly through these gait sensors which were placed on the trunk, lumbar region and ankles (Figure 4.3; Figure 4.4 b).

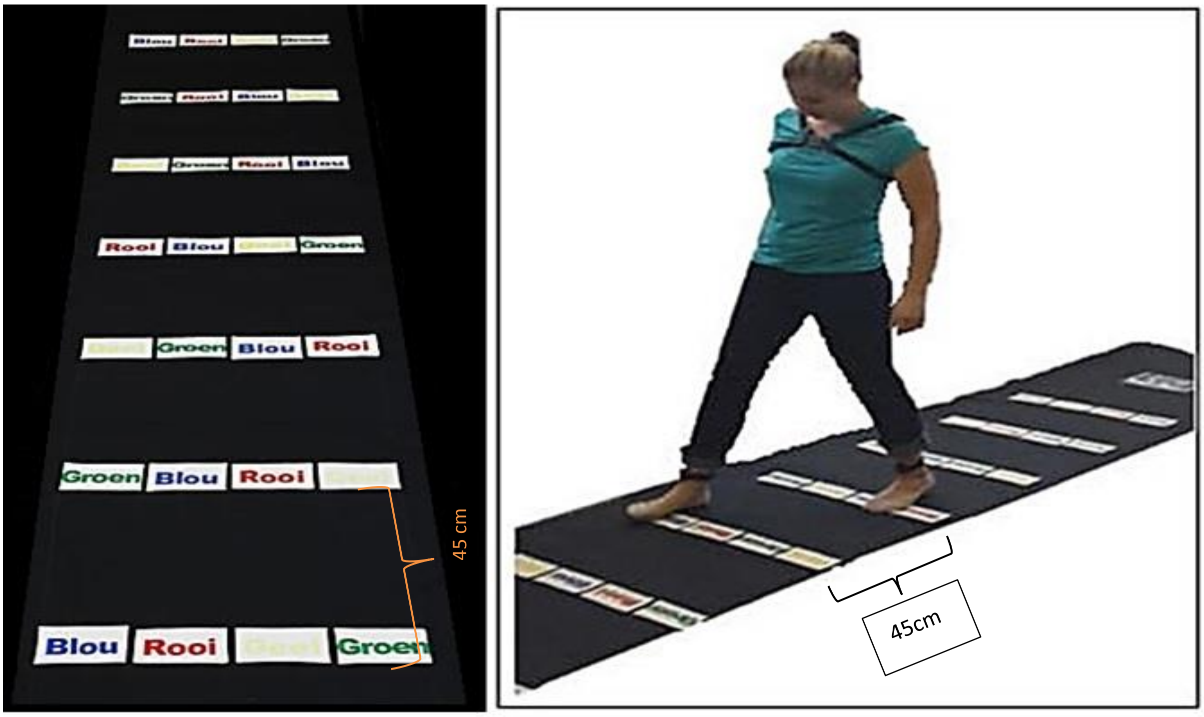
In accordance to the studies of Perrochon et al. (2013) and Takimoto et al. (2015), Interference, Ratio and Facilitation calculations were applied for each walking condition on gait parameters of Total duration (TD: seconds) and Stride velocity (SV: % of stature, cm / seconds). Formulas used to obtain derived scores for the two incongruent walking conditions, included Interference ratio (IR); Interference over time (Interference.Time) and Facilitation over time (Facilitation.Time):

$$IR = \left(\frac{Congruent}{Incongruent}\right);$$

$$Interference.Time = (Incongruent - \ Congruent);$$

$$Facilitation.Time = (Congruent - Incongruent)$$

a.



b.

Figure 4.4 Afrikaans version of the congruent Condition 2 (a); APDM Mobility Lab^{TM} gait sensors (b) used. Gait sensors from left to right: ankle, trunk and lumbar sensor. Permission granted to publish illustrations from APDM Mobility LabTM©.

Each walking condition was verbally explained in the language of choice and demonstrated by the evaluator. The test and walking conditions were always presented in the same order (familiarisation; neutral; congruent; incongruent-colour; incongruent-word) (refer to Figure 4.3). As mentioned earlier, of all the cognitive tests completed, the WSC test always commenced first. Data collection of each walking condition only commenced upon participants' verbal agreement, protocol and aims were fully understood. These true trials always included the 4-lines used during the familiarisation phase. After familiarisation and prior to the true trial (16 rows), the examiner randomly allocated either a colour or a word to each condition, using the stepping target randomisation sheet. Should the word or colour “Green” appear as the randomly chosen option (similar to the familiarisation), an additional randomisation was done. However, this only occurred twice. Each participant was familiarised with each walking conditions, prior to its execution. The explanation was always followed by a demonstration by the examiner which was repeated until the participant fully understood the task.

The true trial was timed on the account “begin” and stopped on the APDM software programme, as soon as either a part, or the entire foot (with a leg of their choosing) stepped on the instructed, target.

The aim of each walking condition was to step-together as quickly and accurately as possible. In case of hesitation or an incorrect response, participants simply continued walking. However, incorrect responses were recorded with a portable video camera (Samsung Galaxy tablet, GT-N8000, Android version 4.1.2) and hesitations would cause increased TD(s) scores.

Protocols revolving around each walking condition pertaining to the adapted WSC are briefly summarised in consecutive order. Refer to Appendix L for detailed walking instructions and protocol used, together with Figure 4.3 for the schematic illustration.

i. **Familiarisation:** Each walking condition had a familiarisation phase. The first four lines were always used for familiarisation and participants were always instructed to step on either the word or colour “Green”. Participants practiced on these initial four lines until they were comfortable with the walking technique, protocol and aim of the test. No data was collected during familiarisation.

ii. **Neutral (Condition 1):** In the neutral condition, words (i.e. ‘Blue’) were printed in black on the white squared targets.

iii. **Congruent (Condition 2):** In the congruent condition, ink of the text corresponded to name of the colour (i.e. ‘Blue’ was printed in blue ink).

iv. **Incongruent colour (Condition 3):** This was the first incongruent condition to be executed. Words did not necessarily correspond to the coloured ink (i.e.

text 'Blue' could be printed in red, yellow or green ink). The aim was to concentrate and step on the colour of the ink, regardless what the text spelled.

v. **Incongruent word (Condition 4):** In the second incongruent condition, words also did not correspond to the coloured ink and seem similar to Condition 3. However, the aim was to concentrate on the text only and ignoring the colour ink used to print the text.

4.1.4.2.2 Mobility

a) Functional Capacity: Six-Minute walk test (6MWT)

Participants were required to walk, as fast as possible, between the identified markers (15m apart) to obtain a maximum distance covered, reflecting true aerobic Functional Capacity. The protocol was explained thoroughly and understood by all participants. A timer started on the examiner's account "begin" and both were stopped on 6 minutes. Distance covered was measured in meters. Resting periods were allowed during the walk and reflected by an increase in the duration of the test. Familiarisation was only done verbally to avoid possible fatigue.

Additionally, the 6MWT were utilised to calculate average Gait speed (m/s) (GS: Total distance (m) / time (s) and gave an indication of functional gait performance. Gait speed obtained with the 6MWT were compared to GS found over the 7m distance of the instrumented Timed-up and Go (iTUG) test. Measurements and protocol regarding the iTUG follows below.

b) Single-task and dual-task Mobility: instrumented Timed-Up and Go (iTUG) test

Single-task (ST) and dual-task (DT) gait parameters of Total duration (TD), Gait speed (GS), Stride length (SL), Stride velocity (SV), Cadence (Cad), Double support (DS) including Turning variables (Turning duration: s; Peak turning velocity: °. s-1; Number of steps during a 180° degree turn: *f*) and Postural transitions (Sit-to-stand duration: STS; Turn-to-sit duration: TTS) were obtained with the iTUG (Refer to Figure 2.5, p.36).

Walking distance, as obtained with the iTUG, was 7 metres (m), whereas the same gait sensors as mentioned in the WSC (Fig 4.4b) were used for the iTUG under both

ST and cognitive DT. Protocols revolving around ST -and cognitive dual-task (DT) conditions are briefly discussed.

Protocol for single-task (ST) Mobility: (iTUG) test

Participants were seated comfortably in the armless chair, arms on their legs and back against the seat. A count-down period (3 counts) allowed participants to prepare themselves for the test. On the examiners account "begin" which corresponded with the Mobility Lab^{TM} software, participants had to rise from the chair without using their arms (i.e. "… ready? In 3, 2, 1, Begin). Should the participant be unable to rise from this position, the test was reset and usage of the arms was allowed followed by walking normally. Participants completed a familiarisation trial followed by the ST walking condition.

The walking pace was self-selected, comfortable, with no interference and the walking distance was 7m. The 180° turning point was clearly marked with an orange cone. Participants walked towards the cone, around it, and returned to their original seated positions which completed the test. Data obtained during this condition, provided baseline data to compare dual-task data with.

Protocol for cognitive dual-task (DT) Mobility: (iTUG)

Exactly the same protocol was used for the two cognitive DT conditions, inclusive of all the main gait parameters, Turning variables and Postural transitions. The initial alphabetical natured cognitive task had four pre-determined variations. Participants recited letters from the alphabet (dual-task word: DT_{word}). Participants randomly chose between four variations which were equally difficult or easy.

The second cognitive dual-task had a numeric nature, similar to the DT test in Bergamin et al. (2014). Participants chose a random number from 63 to 73 and were asked to subtract either in 7's, 5's, and 3's (Dual-task number: DT_{number}). No instruction was given to allow preference to either gait or the cognitive tasks. Answers were recited verbally while walking the required distance. Values were reflected as a percentage. The averages between DT_{word} and DT_{number} were obtained as well ($DT_{Ave\ (word\ +\ number)}$).

c) Dual-task Cost (DTC%)

Dual-task cost average (DTC% Ave $_{(word+number)}$) between the two cognitive dual-task activities were calculated for main gait parameters, Turning variables and Postural transitions.

Formulae utilised to obtain DTC% and average dual-task scores were:

$$DTC\% = 100 \text{ x } [\frac{\text{ST minus } (DTword\ OR\ DTnumber)}{\text{ST}}]$$

$$DTC\%\ average(DTAve) = 100 \text{ x } [\frac{(DTword + DTnumber)}{2}]$$

4.1.4.3 Secondary outcome variables

a) Global Cognition: Montreal Cognitive Assessment (MoCA; Appendix N)

The Montreal Cognitive Assessment (MoCA), 30 point pen-and-paper test, also utilised as a screening tool for levels of cognition (refer to inclusion criteria), is considered a valid and reliable test to screen for Global Cognition as well as to detect mild cognitive impairment (MCI) in older adults (Julayanont and Nasreddine, 2017; Edwards et al., 2016; Zeng et al., 2016). Multiple cognitive domains of EF, visual-spatial skills, memory, language, calculation, abstraction ability, attention, concentration and even orientation are assessed within approximately 10 minutes.
Considering the age-bracket of participants and the possibility of MCI, cut-off scores for inclusion were set as ≥ 20. Therefore, individuals with none to probable MCI were included, similar to other authors (Edwards et al., 2016; Zeng et al., 2016; Lister et al., 2015; Nasreddine et al., 2005). Obtained scores of ≥ 26 were considered normal (Nasreddine et al., 2005).
Additionally, the MoCA assesses levels of education, therefore allowing negating the effect of fewer years of education as a confounding variable. An additional point was assigned to Global Cognition scores if participants indicated they did not have additional tertiary qualifications (≤ 12 years) and deemed as low educated or illiterate (Julayanont and Nasreddine, 2017).

b) Depressive Mood: Patient Health Questionnaire (PHQ-9; Appendix O)

This self-reporting questionnaire indicates the presence of depressive symptoms as well as characterises the severity of depression. It consists of nine questions scored from 0 (not at all) to 3 (nearly every day) (Kroenke et al., 2001). These scores indicate the frequency of occurrence within the last 14 days, portraying a total score of 27. Scores obtained between 0-9 indicate none to mild depression, not requiring treatment, or warranting clinical judgement should symptoms persist (Carey et al., 2014). Therefore, only participants obtaining scores ≤ 9 were deemed eligible.

c) Quality of Life: 36-Item Short Form Health Survey (SF-36; Appendix P)

The SF-36 is used to assess aspects related to self-perceived Health-related Quality of Life (HRQoL) of adults >18 years. The 36 questions not only capture participants' perception of their general health, but also provide two summary measures of health-related QoL (HRQoL) (Hooker, 2013), namely the Physical Component Summary (PCS) as well as a Mental Component Summary (MCS) (White et al., 2011). Additionally, these questions are sorted into multi-item scales that assess eight concepts. Participants had to report the degree to which their self-perceived physical and mental health limits them from being functional during basic activities of daily living (ADL). The effect these limitations had on Physical Functioning, as well as social-, emotional- or mental functioning, was reported. The raw scores obtained are summed up and converted to a 0-100 scale (0 = worst health possible; 100 = best possible health). Higher scores indicate improved perceived health status (White et al., 2011). The eight subscales of the SF-36 follows (Ware, 2000; Ware and Sherbourne, 1992) inclusive of a brief explanation are provided in Appendix I.

4.1.5 Statistical analysis

Data are presented as percentages (%), frequencies (*f*), mean ($\bar{x}$) and standard deviation (±SD), unless otherwise specified. A repeated-measures planned analyses of variance (ANOVA) (STATISTICA version13, Statsoft®, Tulsa, OK, USA) was used to assess the relation between the within-subject factor i.e. time and the between-subject factor i.e. intervention type (water vs. educational sessions) for each dependent variable. Post Hoc Fisher exact LSD was applied to further evaluate specific influences at each time point including Cohen's effect sizes for practical significance, with 0.2 equals small, 0.5 indicates medium and 0.8 equals large effect (Thalheimer and Cook, 2002). Sample size was determined as the number of participants necessary to reach a statistical power of 80% ($\alpha < 0.05$), with an estimated moderate effect size ($d = 0.50$) (Cohen, 1992).

CHAPTER 5

RESULTS

5.1 OVERVIEW

The following chapter reports on the results of the investigation. First the descriptive characteristics of the participants are portrayed, then the main outcome variables and concluding with the secondary outcome variables.

5.2 PARTICIPANTS

In total, 68 people responded to the newspaper articles and information left on social media pages. Fifty-six, of the respondents, met the inclusion criteria and were enrolled in the study, i.e. 27 randomised in the Experimental group (EXP; 23 women) and 29 in the time-matched-attention (TMA) activities, Control group (CON; 26 women). Twenty-two participants from the EXP group completed the water-based exercise intervention (WBEI) and final testing, whereas 19 from the CON group completed the study (Figure 5.1). Five participants withdrew from the EXP group (Men: n = 1; Women: n = 4) due to family and work commitments. The only man from this group withdrew due to work committments. Three women reported time-constraints associated with work commitments and one reported family commitments as the main reason. Dropout from the CON group (Men: n = 1; Women: n = 9) was quite large, with a variety of reasons given: work-related injury (Men: n = 1); work commitments (Women: n = 4); family commitments (Women: n = 2); time constraints (Women: n = 1); relocation (Women: n = 2). None of the withdrawals were due to harm or injury due to the intervention.

Table 5.1 outline the descriptive characteristics of participants at pre-test (baseline). Only age differed significantly between the two groups at pre-test. The EXP group was ~ 4 years younger than the CON group ($P < 0.01$); however, additional analysis of covariance showed that the age differences between the two groups did not significantly influence the primary outcome variables ($P > 0.05$).

Even though the groups didn't differ significantly in years of education, seventy-seven percent (n = 17) of participants in the EXP group (2 men, 15 women) and 47% (n = 9) of participants in the CON group (1 man, 8 women) had 13 years and more education.

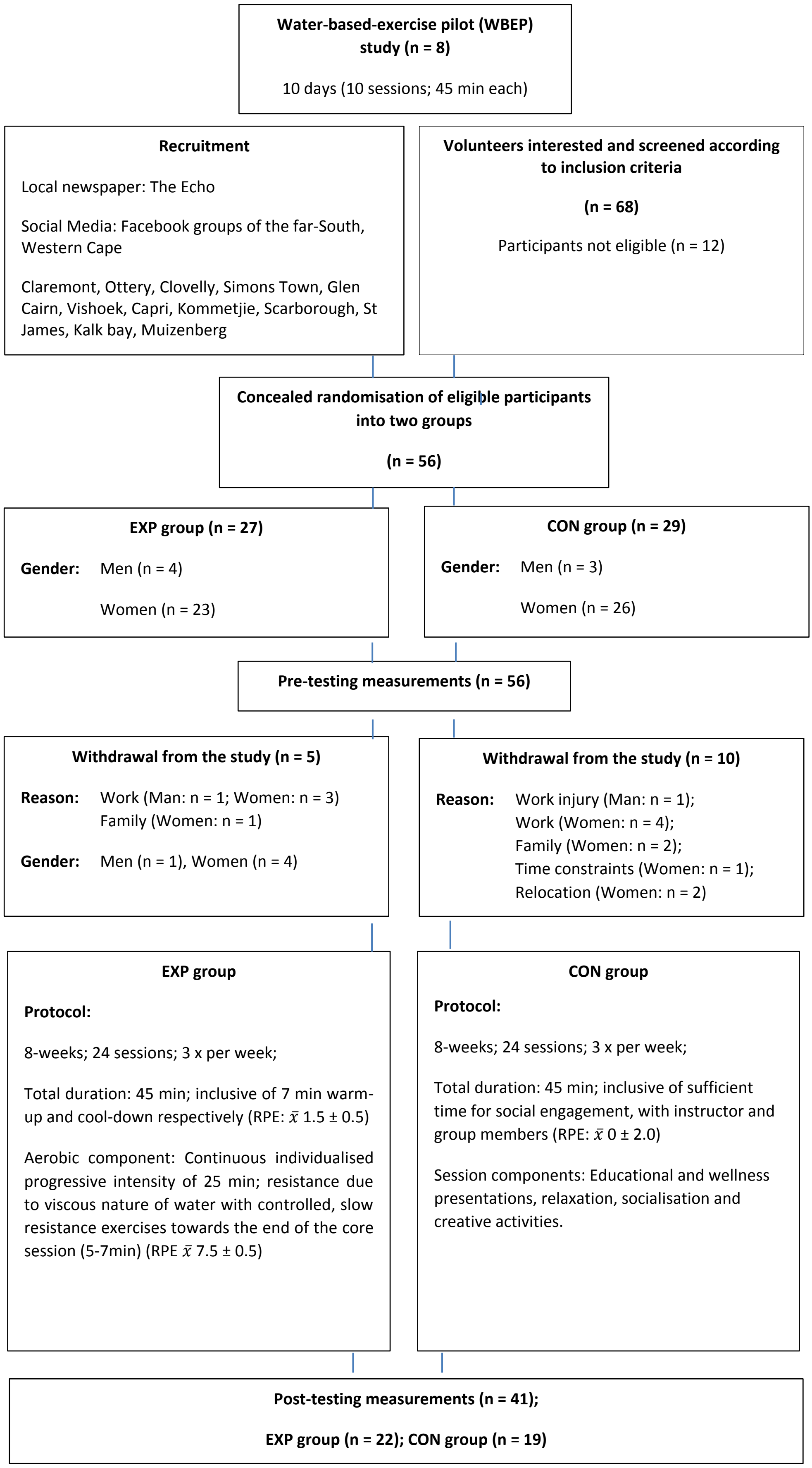


Figure 5.1 Flow diagram of intervention phases and participant allocation.

Pre-test Body mass index (BMI) and body mass did not differ between the groups (Table 5.1). The 8-week intervention significantly reduced the EXP group's body mass and BMI scores, with a multi-factorial ANOVA showing a Time ($P < 0.01$) and Treatment effect ($P < 0.001$) for both descriptive variables. The EXP group reduced their body mass by 3.6%, ($P < 0.00001$; $d = 0.20^{S}$) while the CON plateaued with 0.5% change over time ($P = 0.60$; $d = 0.02^{N}$). This was also reflected in the EXP group's BMI 4% reduction ($P < 0.001$; $d = 0.15^{S}$). Post-test results did not indicate a significant difference between EXP and CON group for both BMI ($P = 0.60$; $d = 0.17^{S}$) and body mass ($P = 1.00$; $d = 0.01^{N}$).

The results of the Rapid Assessment of Physical Activity Questionnaire (RAPA) at pre-test revealed that 27% of the participants in the EXP group (n = 6) indicated that they were under active and only participating in light activities, 59% (n = 13) indicated that they were underactive, but participating in some moderate activities, while only 14% of the EXP indicated that they were active (n = 3). In the CON group, none of the participants indicated that they were active. Fifty-eight percent (n = 11) rated themselves as under active but participating in some moderate activities, 21% (n = 4) as under active and only participating in light activities and 11% (n = 2) as underactive and another 11% as sedentary (n = 2). There was no significant difference between the two groups in terms of physical activity status. Figure 5.2 demonstrates change in self-perceived RAPA scores over time.

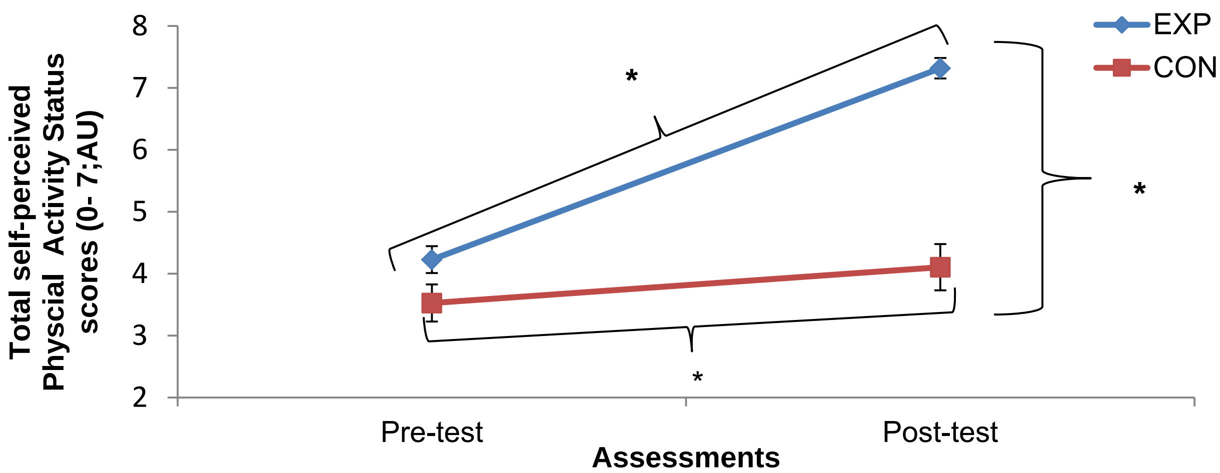


Figure 5.2 Change in RAPA scores between EXP and CON group over the 8 weeks ($\bar{x}$ ± SEM; $P < 0.05$ *).

Results reveal significance in Time, Group and Treatment effect (P < 0.0001). Post-test showed 73% increase in self-perceived physical activity level for the EXP group (P < 0.001; *d* = 3.48[H]), compared to 16% increase for the CON group (P = 0.04; *d* =0.40[M]). There was a 17% difference at pre-test between groups (P = 0.07; *d* = 0.62[M]; 17%), while at Post-test there was a significant 44% difference (P < 0.001; *d* = 2.64[H]).

Figure 5.3 illustrates changes in Functional Capacity (aerobic or endurance) of both groups over the 8-week study period. Multifactorial ANOVA analysis indicated significant Fixed effects (Time: P = 0.0003; Group: P = 0.02; Treatment: P = 0.004), whereas post-hoc analysis revealed participants in the EXP group was able to cover a greater distance (m) within the 6-minute time period at Post-test (P < 0.0001; *d* = 0.69[M]; 10 %). Average Functional Capacity of the CON group did not show significant change (P = 0.52; *d* = 0.15S; 1%). Groups did not differ at pre-test (P = 0.28; *d* = 0.33[S]; 4%), but significantly differed at Post-test with 13% (P = 0.002; *d* = 0.53[M]).

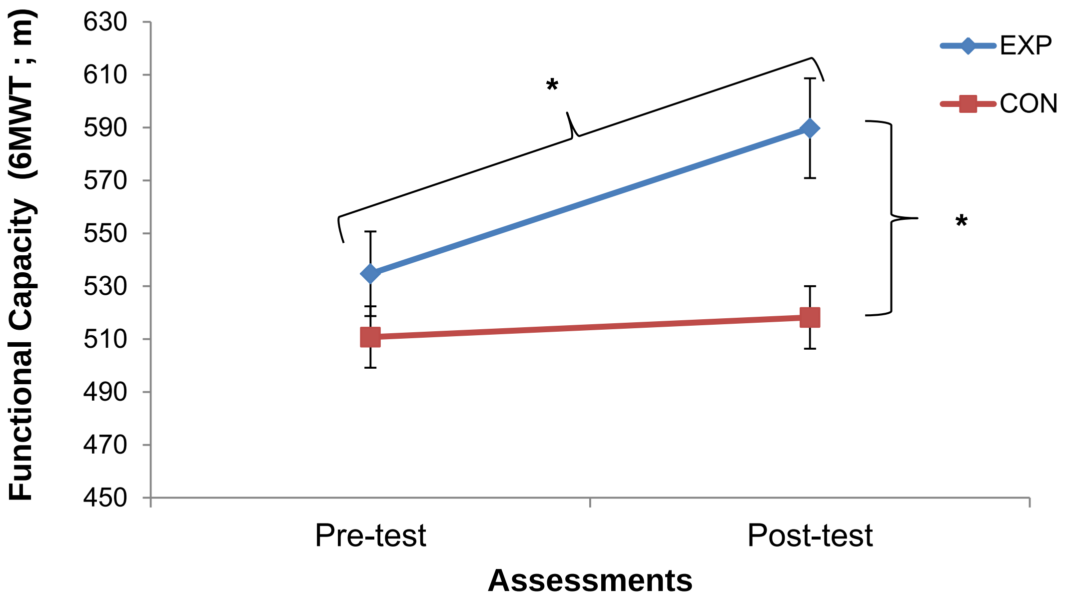


Figure 5.3 Functional Capacity (as indicated with submaximal 6MWT) between EXP group and CON group over 8 weeks ($\bar{x}$ ± SEM; P < 0.05 *).

Table 5.1 Descriptive statistics for the Experimental (EXP) and Control (CON) groups at pre-test (n = 41; $\bar{x}$ ± STD).

Characteristic	EXP (n = 22)		CON (n = 19)		
	$\bar{x}$ ± STD	Range	$\bar{x}$ ± STD	Range	P-value; Effect sizes
Age (years)	55.23 ± 4.37	50.00 - 65.00	59.05 ± 4.09	52.00 - 65.00	**0.01***; d = 0.92^{L}
Height (cm)	163.32 ± 12.13	125.00 -189.00	165.47 ± 6.02	150.00 - 181.00	0.47; d = 0.23^{S}
Body mass (kg)	81.59 ± 15.05	58.00 - 110.00	78.48 ± 20.38	55.00 - 135.00	0.58; d = 0.18^{S}
BMI (kg.m^{-2})	31.11 ± 8.08	21.14 - 55.04	28.61 ± 6.85	19.54 - 47.27	0.29; d = 0.34^{S}
Education (years)	14.75 ± 2.83	8.00 - 20.00	13.42 ± 3.82	6.00 - 19.00	0.08; d = 0.41^{M}
Activity status (RAPA)	4.55 ± 1.50	3.00 - 8.00	4.47 ± 2.09	1.00 - 7.00	0.07; d = 0.05^{N}
Global Cognition (MoCA)	25.59 ± 2.63	20.00 - 30.00	26.21 ± 2.66	20.00 - 30.00	0.48; d = 0.24^{S}
Functional Capacity (6MWT; m)	534.73 ± 88.51	330.00 - 720.00	510.79 ± 51.61	431.00 - 606.00	0.23; d = 0.33^{S}
Depressive Mood (PHQ-9; AU)	4.18 ± 2.65	0.00 - 9.00	4.05 ± 2.09	0.00 - 7.00	0.88; d = 0.06^{N}

Notes: EXP: Experimental group; CON: Control group; BMI: Body Mass Index; MoCA: Montreal Cognitive Assessment; PHQ-9: Patient Health Questionnaire; 6MWT: Six-Minute walk test; RAPA: Rapid Assessment of Physical Activity; AU: Arbitrary units; *d*: Effect sizes; ^{N}: Negligible; ^{S}: Small; ^{M}: Medium; ^{L}: Large;
P < 0.05*

5.3 INTERVENTIONS

On average, the EXP group had a 98% (*f* = 23) attendance while the CON group attended 82% (*f* = 20) of the sessions (EXP: $P < 0.05$; CON: $P > 0.05$). Figure 5.4 illustrates the average weekly RPE scores of the two groups for the 24 sessions over the 8 weeks.

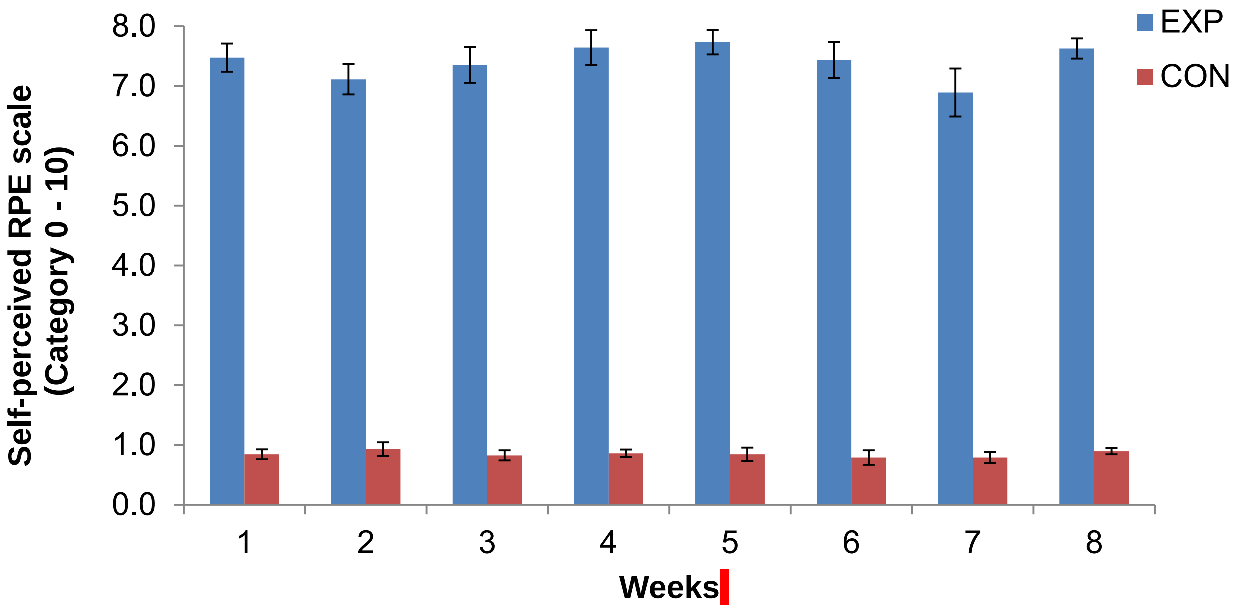


Figure 5.4 Average RPE scores per week ($\bar{x}$ ± SEM).

5.4 OUTCOME VARIABLES

The following section first reports findings of the main outcome variables i.e. Executive Functioning (EF) and Mobility followed by the secondary outcome variables.

5.4.1 Primary outcome variables

Executive Functioning is described collectively by the results of the Digit Span, Trail Making Test A & B as well as the Stroop Carpet tests; while Mobility is inferred from spatiotemporal gait as well as transitional parameters during single and dual-task conditions.

5.4.1.1 Executive Functions (EF)

Table 5.2 summarises the Main (i.e. Time as well as Group) and Treatment (Group x Time) effects for the EF main outcome variables.

Table 5.2 Main and Treatment effects for primary EF outcome variables

Variables	Main effects		
	Time effect (Δ)	Group effect	Treatment effect
Updating: (Digit Span)	**Maximum Span (*f*)**		
Attention (DSFW)	P = 0.99	P = 0.65	P = 0.81
Working memory (DSBW)	P = 0.45	P = 0.59	P = 0.77
Set-shifting: (Trail Making Test)	**Total duration (Response time; s)**		
Visual attention (TMT A)	P = 0.64	P = 0.11	P = 0.15
Cognitive flexibility (TMT B)	**P = 0.001****	P = 0.07	P = 0.33
Cognitive flexibility TMT_D	**P = 0.002****	P = 0.07	P = 0.17
Cognitive flexibility TMT_R	**P = 0.01***	P = 0.24	P = 0.08
Inhibitory control: (WSC)	**Total duration (Response time; s)**		
Interference Ratio (IR)	**P = 0.02***	P = 0.13	P = 0.11
Interference Score	**P < 0.001****	P = 0.12	P = 0.06
Facilitation Score	P = 0.17	P = 0.72	P = 0.52
Inhibitory control: (WSC)	**Stride velocity (Response time; m/s)**		
Interference Ratio (IR)	P = 0.20	**P = 0.02***	**P = 0.03***
Interference Score	**P < 0.0001****	P = 0.07	**P = 0.03***
Facilitation Score	**P = 0.0004****	P = 0.49	P = 0.47

Note: Δ: Change over time, WSC: Walking Stroop Carpet; DSFW: Digit Span Forward; DSBW: Digit Span Backward, TMT A: Trail Making Test part A; TMT B: Trail Making Test part B; IR: Interference ratio; TMT_D: TMT B - TMT A (TMT Difference); TMT_R: TMT B / TMT A (TMT Ratio); cm: centimetre; s: seconds; P < 0.05 *; P ≤ 0.01**

a) Attention and Working memory: Digit Span Forward (DSFW) and Digit Span Backward (DSBW)

Figure 5.5a illustrates the unchanged scores for both groups over time (P > 0.05; *d* < 0.10^N) for the Digit Span Forward. Groups did not differ at Pre-test (P = 0.78; *d* = 0.10^N; 2%) or Post-test (P = 0.61; *d* = 0.16^S; 3%). Similar, the Digit Span Backwards (DSBW) did not improve for either EXP (P = 0.74; *d* = 0.09^N; 2%) or CON group (P = 0.47; *d* = 0.13^N; 4%) as shown in Figure 5.5b. There was a non-significant 3% and 6% difference between groups at Pre-test (P = 0.73; *d* = 0.13^N) and Post-test (P = 0.53; *d* = 0.18^S), respectively.

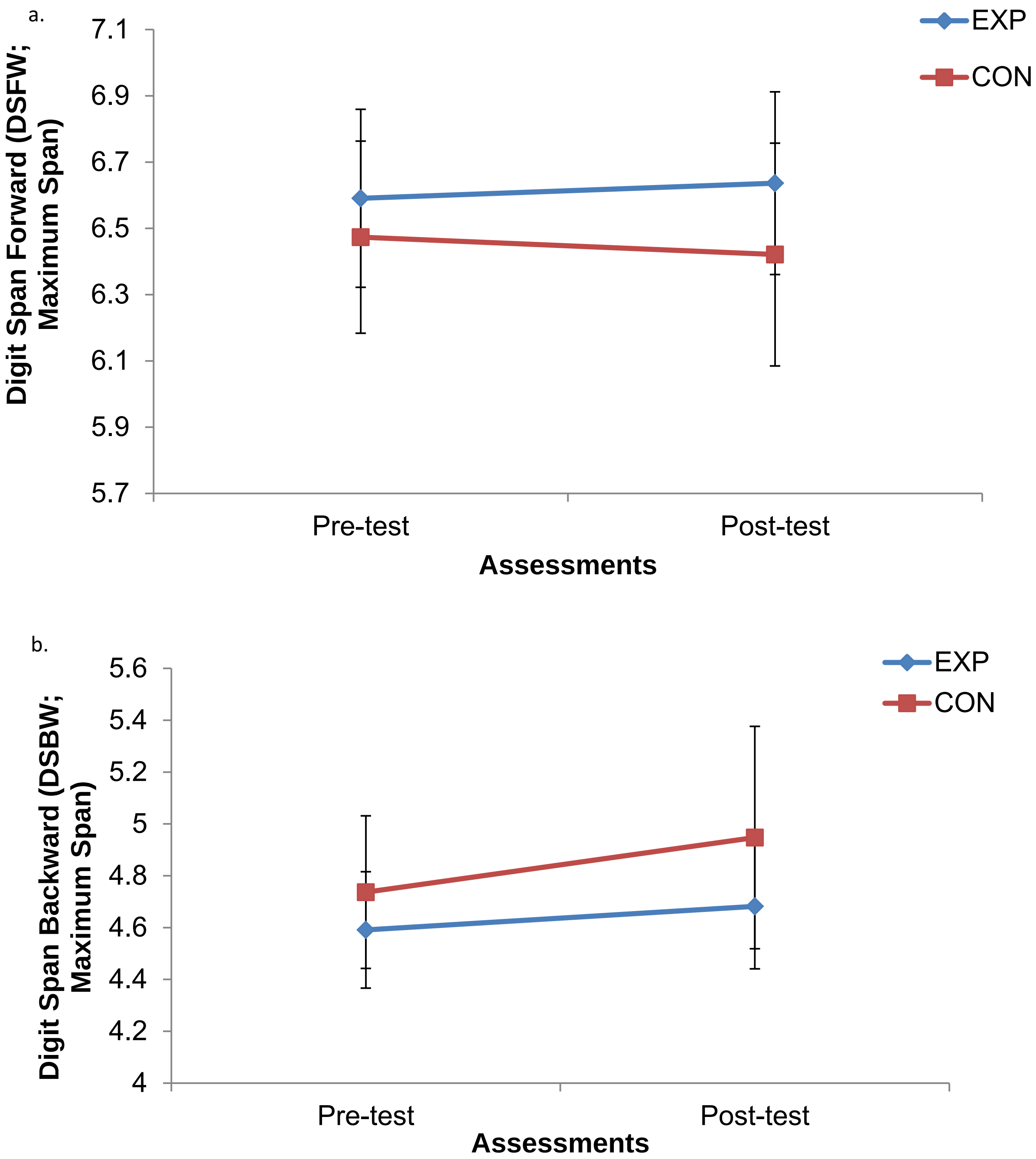


Figure 5.5 Digit Span Forward (a) and Backward (b) length achieved over time between groups ($\bar{x}$ ± SEM; $P < 0.05$ *).

b) Cognitive flexibility: Trail Making Test (TMT) part A (TMT A) and part B (TMT B)

Figure 5.6 depicts the ratio (TMT_R = TMT B / TMT A) and difference (TMT_D = TMT B – TMT A) between TMT B and TMT A between groups at pre-or post-test.

Post-hoc analysis showed total duration (s) to perform the TMT A test decreased with 9% for the EXP group (P = 0.16; $d = 0.40^{M}$), compared to the 4% change of the CON groups (P = 0.50; $d = 0.12^{N}$), yet both performances were considered insignificant. Only a small difference of 8% (P = 0.44; $d = 0.27^{S}$) was visible between groups at pre-test, followed by a significant 24% difference between the two groups' post-test results (P = 0.04; $d = 0.65^{M}$).

In contrast to TMT A results, both groups performed better in the TMT B test over time, although only the CON groups' performance was significant. A 21% performance improvement, with a medium effect size ($d = 0.49^{M}$), in favour of the CON group (P = 0.004) were reported. The EXP group's 16% performance inmprovement was non-significant (P = 0.07) accompanied with a medium effect size ($d = 0.51^{M}$). A significant difference of 31% was observed between groups at pre-test (P = 0.04; $d = 0.60^{M}$) (refer to Figure 5.6b) and a non-significant difference of 21% at post-test (P = 0.21; $d = 0.50^{M}$; 22%).

Derived TMT scores (TMT B - TMT A and TMT B/TMT A) is illustrated in Figure 5.6c & d, respectively.

Post-hoc analysis for TMT difference (TMT_D) revealed CON group significantly improved with 33% (P = 0.003; $d = 0.62^{M}$) in comparison to the EXP group (P = 0.16; $d = 0.45^{M}$; 20%). There was a 45% difference at pre-test between the groups (P = 0.03; $d = 0.62^{M}$) and a non-significant difference at post-test (P = 0.40; $d = 0.36^{S}$; 21%).

With regards to TMT ratio (TMT_R) scores the EXP group changed by 6% (P = 0.53; $d = 0.22^{S}$). However, the CON group improved with almost one standard deviation from pre -to post-test, resulting in a percentage difference of 25% (P = 0.004; $d = 0.77^{L}$). The groups did differ significantly at pre-test (P = 0.04; $d = 56^{M}$; 22%) but not at post-test (P = 0.80; $d = 0.10^{N}$; 3%).

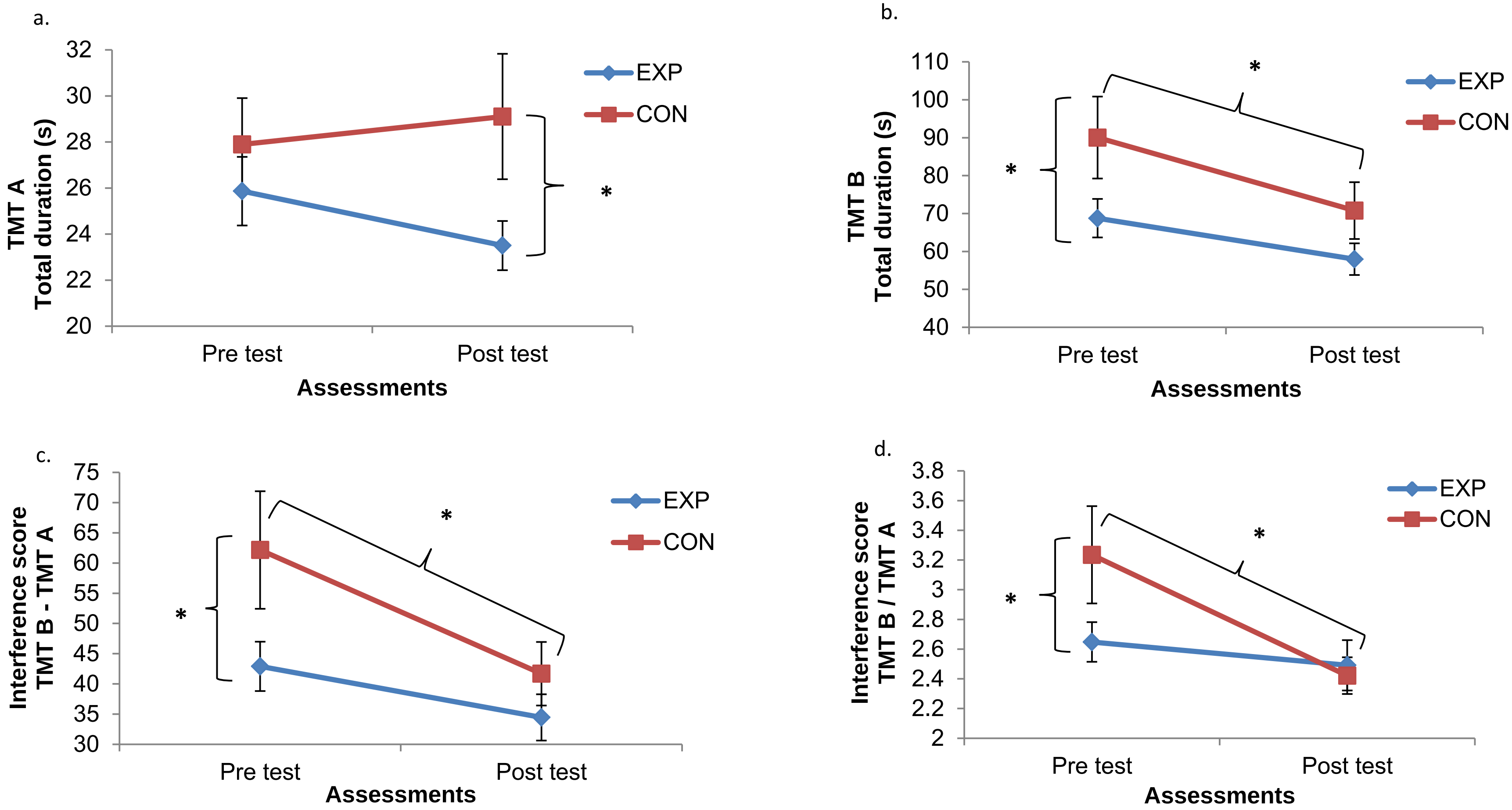


Figure 5.6 TMT A and B direct scores including derived scores between EXP and CON over 8 weeks ($\bar{x}$ ± SEM; $P < 0.05$ *).

c) Inhibitory control: Walking Stroop Carpet (WSC)

The Walking Stroop Carpet (WSC) predominantly assess Inhibitory control (IC) amongst other cognitive functions. A Stroop Interference Ratio score, for the two incongruent walking conditions (Condition 3; Condition 4), was calculated from the averages between the two incongruent conditions. The Interference Ratio (IR) score is derived from deviding the average incongruent conditions by the congruent (Condition 2). While, the difference between Control (Condition 1) and Condition 2 stimuli refers to the Facilitation score, whereas the difference between Control and incongruent (average of Condition 3 and 4) is called the Interference score. Collectively these composite scores, i.e. Facilitation score, Interference score and IR, are the main IC variables.

Fixed effects for calculated composite scores of IC variables are reported in Table 5.2. Fixed effects The WSC TD gait variable showed a significant Time effect for the IR and Interference score variables ($P < 0.05$), with only a tendency for a Treatment effect ($P = 0.06$) for the Interference score. The WSC SV gait variable on the other hand revealed statistical significant Time effects for the Interference and Facilitation scores, but only the IR and Interference score demonstrated Treatment effects ($P < 0.05$). None of the WSC's IC composite TD and SV variables differed significantly between groups at Pre-test ($P > 0.05$). Post-hoc analysis (Table 5.4a & b) disclosed significant changes for the EXP group over time, as well as Post-test differences for IR and Interference scores in TD and SV variables ($P < 0.05$). However, the only significant changes observed in both groups was the change over time in Facilitation scores ($P < 0.05$) for the SV variable (Table 5.4b).

The Fixed effects for the gait parameters, i.e. Total duration (TD) and Stride velocity (SV), for each of the four walking conditions and the average incongruent variable are reported in Table 5.3. Total duration and SV, pertaining to the Stroop walking conditions and group's IC performances are shown in Table 5.4a and 5.4b, respectively. This will be reported on in the following subsections.

Table 5.3 Main and Treatment effects for gait parameters obtained in the Walking Stroop Carpet test

Variables	Main effects		Interactions
	Time effect (Δ)	Group effect	Treatment effect
WSC	**Total duration (Response time; s)**		
Condition 1: Control	**P = 0.01 ***	P = 0.31	P = 0.99
Condition 2: Congruent	**P < 0.001 ***	P = 0.41	P = 0.54
Condition 3: Incongruent colour	**P < 0.001 ***	P = 0.08	P = 0.05
Condition 4: Incongruent word	**P < 0.001 ***	P = 0.16	P = 0.34
Average Incongruent	**P < 0.001 ***	P = 0.09	P = 0.059
WSC	**Stride velocity (Response time; m/s)**		
Condition 1: Control	P = 0.32	P = 0.50	P = 0.59
Condition 2: Congruent	P = 0.08	P = 0.71	P = 0.32
Condition 3: Incongruent colour	**P = 0.004***	P = 0.11	P = 0.11
Condition 4: Incongruent word	**P = 0.04***	P = 0.15	P = 0.41
Average Incongruent	**P = 0.003***	P = 0.09	P = 0.17

Note: Δ: Change over time, WSC: Walking Stroop Carpet Condition $1_{\text{black \& white/neutral}}$; Condition $2_{\text{colour/congruent}}$; Condition $3_{\text{incongruent colour}}$; Condition $4_{\text{incongruent word}}$; s: seconds; m: meter; P < 0.05 *

i) WSC Conditions for Total duration (TD):

The EXP and CON groups did not differ significantly in any of the Pre-test WSC's Total duration (TD) walking condition variables (P > 0.05; Table 5.4a).

There was a Time effect for all conditions as well as the average composite score, with only Condition 3 revealing a high tendency to a Treatment effect (P = 0.05; Table 5.3), while the average score for the two incongruent conditions alluded to a tendency for a Treatment effect (P = 0.06) as well.

Post-hoc analysis indicated an average improvement of 10.6% (P < 0.05) in Total duration within the EXP group over time for all conditions, except the 4% change overtime in Condition 1 which was only a tendency (Table 5.4a). The CON group on the other hand also showed 5% and 6% improvements in Condition 2 and 4, respectively (P < 0.05). The EXP group outperformed the CON group after the intervention period during Conditions 3 & 4, as indicated with the average incongruent score, reflecting ~9% faster WSC speeds (P < 0.05).

Table 5.4a WSC Total duration reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19) for each condition and composite scores.

Variables (s)	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values; Effect sizes (*d*); (% difference / △)		
Condition 1: Control	27.44 ± 3.41 (21.83 - 34.42)	26.36 ± 2.75 (22.44 - 32.83)	28.33 ± 3.01 (23.24 - 32.56)	27.25 ± 3.19 (21.72 - 33.52)	$P^1 = 0.07$ $P^2 = 0.09$ $P^3 = 0.36$ $P^4 = 0.37$	$d^1 = 0.36^S$ $d^2 = 0.36^S$ $d^3 = 0.28^S$ $d^4 = 0.31^S$	(4%) (4%) (3%) (3%)
Condition 2: Congruent	27.10 ± 2.96 (21.39 - 32.21)	25.23 ± 2.72 (21.29 - 33.02)	27.53 ± 2.34 (23.30 - 30.95)	26.16 ± 3.50 (19.70 - 32.91)	**$P^1 = 0.001$**** **$P^2 = 0.02$*** $P^3 = 0.64$ $P^4 = 0.32$	**$d^1 = 0.67^M$** **$d^2 = 0.47^M$** $d^3 = 0.16^S$ $d^4 = 0.31^S$	(7%) (5%) (2%) (4%)
Condition 3: Incongruent	28.70 ± 4.12 (22.66 - 39.65)	25.69 ± 2.49 (21.20 - 30.80)	29.53 ± 3.72 (24.68 - 36.39)	27.66 ± 4.03 (22.41 - 35.63)	**$P^1 < 0.0001$**** $P^2 = 0.37$ $P^3 = 0.47$ **$P^4 = 0.03$***	**$d^1 = 0.91^L$** $d^2 = 0.50^M$ $d^3 = 0.22^S$ $d^4 = 0.61^M$	(10%) (6%) (3%) (8%)
Condition 4: Incongruent	32.37 ± 4.01 (25.02 - 40.41)	28.25 ± 3.02 (20.67 - 34.55)	33.19 ± 3.64 (27.15 - 38.44)	31.32 ± 4.82 (24.69 - 41.26)	**$P^1 < 0.0001$**** **$P^2 = 0.03$ *** $P^3 = 0.51$ **$P^4 = 0.02$***	**$d^1 = 1.19^{VL}$** **$d^2 = 0.45^M$** $d^3 = 0.22^S$ **$d^4 = 0.80^L$**	(13%) (6%) (3%) (11%)
Average Incongruent	30.53 ± 3.54 (24.30 – 37.14)	26.97 ± 2.41 (23.08 – 31.19)	31.36 ± 3.28 (26.57 – .7.03)	29.49 ± 4.05 (23.55 – 36.9*7)	**$P^1 = 0.002$**** **$P^2 = 0.01$*** $P^3 = 0.44$ **$P^4 = 0.02$***	**$d^1 = 1.20^{VL}$** **$d^2 = 0.52^M$** $d^3 = 0.25^S$ **$d^4 = 0.79^L$**	(12%) (6%) (3%) (9%)
Interference Ratio	0.89 ± 0.06 (0.79 – 1.01)	0.94 ± 0.07 (0.82 – 1.14)	0.88 ± 0.07 (0.76 – 1.00)	0.89 ± 0.07 (0.72 – 0.99)	**$P^1 = 0.005$**** $P^2 = 0.62$ $P^3 = 0.69$ **$P^4 = 0.03$***	**$d^1 = 0.79^{VL}$** $d^2 = 0.15^S$ $d^3 = 0.16^S$ **$d^4 = 0.73^M$**	(6%) (1%) (1%) (5%)
Interference Score	3.09 ± 2.10 (-0.52 –7.29)	0.61 ± 1.74 (-2.20 – 3.68)	3.03 ± 2.05 (-1.24 – 6.39)	2.24 ± 2.48 (-2.55 – 5.61)	**$P^1 = 0.01$*** $P^2 = 0.62$ $P^3 = 0.69$ **$P^4 = 0.03$***	**$d^1 = 1.32^{VL}$** $d^2 = 0.36^S$ $d^3 = 0.03^N$ **$d^4 = 0.79^L$**	(80%) (26%) (2%) (276%)
Facilitation Score	- 0.34 ± 2.43 (- 5.53 - 5.51)	- 1.13 ± 2.17 (- 6.25 - 2.70)	- 0.81 ± 2.44 (- 8.80 - 2.02)	-1.09 ± 1.77 (- 4.43 - 1.63)	$P^1 = 0.14$ $P^2 = 0.61$ $P^3 = 0.51$ $P^4 = 0.96$	$d^1 = 0.35^S$ $d^2 = 0.13^N$ $d^3 = 0.20^S$ $d^4 = 0.02^N$	(232%) (35%) (138%) (2%)

Notes: EXP: Experimental group; CON: Control group; WSC: Walking Stroop Carpet; s: seconds; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

ii) WSC Conditions for Stride velocity (SV):

Table 5.4b shows that none of the WSC's Stride velocity (SV) walking condition variables differed significantly between groups at pre-test ($P > 0.05$).

The Fixed effects only revealed significant Time effects in the incongruent walking conditions for Stride velocity ($P < 0.05$; Table 5.3). Taking a closer look at the individual assessment points and group differences (Table 5.4b), only the EXP group improved by ~13% over time for Conditions 3, 4 and the average incongruent score ($P < 0.05$). This resulted in group differences of about ~13% at post-test for Condition 3 and the average incongruent score, where the EXP group out performed the CON group ($P < 0.05$).

Table 5.4b WSC Stride velocity reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19) for each condition and composite scores.

Variables ($m.s^{-1}$)	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values	Effect sizes (*d*)	(% difference / △)
Condition 1: Control	0.61 ± 0.16 (0.36 – 1.04)	0.58 ± 0.13 (0.35 – 0.79)	0.57 ± 0.10 (0.46 – 0.77)	0.56 ± 0.16 (0.35 – 0.96)	P^1 = 0.26 P^2 = 0.75 P^3 = 0.40 P^4 = 0.69	$d^1 = 0.21^S$ $d^2 = 0.08^N$ $d^3 = 0.30^S$ $d^4 = 0.14^N$	(5%) (2%) (7%) (3%)
Condition 2: Congruent	0.59 ± 0.14 (0.39 – 1.01)	0.61 ± 0.13 (0.39 – 0.89)	0.56 ± 0.12 (0.39 – 0.77)	0.61 ± 0.19 (0.38 – 1.13)	P^1 = 0.59 P^2 = 0.06 P^3 = 0.43 P^4 = 0.95	$d^1 = 0.15^S$ $d^2 = 0.32^S$ $d^3 = 0.23^S$ $d^4 = 0.00^N$	(3%) (9%) (5%) (0%)
Condition 3: Incongruent	0.85 ± 0.15 (0.32 – 0.89)	0.64 ± 0.14 (0.40 – 0.92)	0.53 ± 0.13 (0.32 – 0.57)	0.56 ± 0.16 (0.36 – 0.92)	**P^1 = 0.04*** P^2 = 0.32 P^3 = 0.51 P^4 = 0.09	**$d^1 = 0.42^M$** $d^2 = 0.21^S$ $d^3 = 0.26^S$ $d^4 = 0.55^M$	(10%) (6%) (9%) (13%)
Condition 4: Incongruent	0.48 ± 0.12 (0.31 – 0.83)	0.56 ± 0.12 (0.26 – 0.86)	0.45 ± 0.10 (0.31 – 0.64)	0.48 ± 0.13 (0.27 – 0.76)	**P^1 = 0.001**** P^2 = 0.30 P^3 = 0.46 **P^4 = 0.03***	**$d^1 = 0.68^M$** $d^2 = 0.27^S$ $d^3 = 0.28^S$ **$d^4 = 0.66^M$**	(17%) (7%) (6%) (14%)
Average Incongruent	0.53 ± 0.12 (20.73 – 48.46)	0.60 ± 0.12 (22.42 – 49.05)	0.49 ± 0.11 (19.53 – 42.94)	0.52 ± 0.13 (19.31 – 44.42)	**P^1 = 0.002**** P^2 = 0.25 P^3 = 0.33 **P^4 = 0.04***	**$d^1 = 0.60^M$** $d^2 = 0.29^S$ $d^3 = 0.36^S$ **$d^4 = 0.66^M$**	(12%) (6%) (8%) (13%)
Interference Ratio	1.13 ± 0.12 (0.88 –1.50)	1.02 ± 0.14 (0.72– 1.42)	1.15 ± 0.18 (0.77 – 1.46)	1.18 ± 0.16 (0.96 – 1.54)	**P^1 = 0.01*** P^2 = 0.50 P^3 = 0.71 **P^4 = 0.002****	**$d^1 = 0.86^L$** $d^2 = 0.18^S$ $d^3 = 0.14^N$ **$d^4 = 1.10^{VL}$**	(10%) (3%) (2%) (16%)
Interference Score	-0.08 ± 0.08 (-15.38 – 2.80)	0.02 ± 0.06 (-5.64 – 8.06)	-0.08 ± 0.06 (-13.37 – 0.18)	-0.04 ± 0.08 (-13.58 –3.18)	**P^1 < 0.001**** P^2 = 0.10 P^3 = 0.95 **P^4 = 0.01***	**$d^1 = 0.87^L$** $d^2 = 0.58^M$ $d^3 = 0.00^N$ **$d^4 = 0.29^S$**	(75%) (50%) (0%) (100%)
Facilitation Score	- 1.02 ± 5.01 (14.43 ± 5.26)	1.60 ± 3.29 (-5.63 ± 8.29)	- 0.84 ± 4.91 (-10.73 ± 12.27)	2.91 ± 3.27 (-2.46 ± 10.18)	**P^1 = 0.03 *** **P^2 = 0.004 **** P^3 = 0.89 P^4 = 0.33	**$d^1 = 0.63^M$** **$d^2 = 0.92^L$** $d^3 = 0.04^N$ $d^4 = 0.41^M$	(257%) (446%) (18%) (82%)

Notes: EXP: Experimental group; CON: Control group; WSC: Walking Stroop Carpet; s: seconds; m: meter; [1]: EXP within group; [2]: CON within group; [3]: Pre-test between groups; [4]: Post-test between groups; *d*: Effect sizes; [N]: negligible; [S]: small; [M]: medium; [L]: large; [VL]: Very large; P < 0.05*; P < 0.01**; △: Change

5.4.1.2 Mobility

Mobility was inferred from gait and transitional variables. Gait speed (GS) was obtained during the 6MWT and instrumented Timed-Up and Go (iTUG) test as an indication of walking ability. From the iTUG test other gait variables were obtained i.e. Total duration (TD), Stride length (SL), Stride velocity (SV), Cadence (Cad) as well as Double support (DS).

Gait, as well as transitional movements was measured under single-task (ST) and cognitive dual-task (DT) conditions. Dual-task cost (DTC) was calculated from these variables and is reported as well.

In this section, the Mobility Fixed effects (calculated by a multifactorial ANOVA) are first summarised before data is divided into: gait variables (section a) and transitional variables (section b). Table 5.5a and b summarises the Main (i.e. Time as well as Group) and Interaction (Group x Time) effects for the gait and transitional variables (i.e. ST, DT and %DTC), respectively. Results for ST, DT and absolute DTC (%) gait variables are summarised in Table 5.6a, 5.6b and 5.6c, respectively.

Table 5.5a Main and Treatment effects for single-task, dual-task gait parameters, including Dual-task Cost (%)

Variables	Main effects		Interactions
	Time effect (Δ)	Group effect	Treatment effect
Single-task (ST)			
Total duration (s)	**P = 0.003****	P = 0.22	P = 0.92
Gait Speed ($m.s^{-1}$) in 6MWT	**P < 0.001****	**P =0.02***	**P = 0.003****
Gait Speed ($m.s^{-1}$) in iTUG	**P = 0.001****	P = 0.24	P = 0.99
Stride length (% of stature)	P = 0.37	P = 0.63	P = 0.82
Stride velocity (cm/s)	P = 0.06	P = 0.39	P = 0.98
Cadence ($steps.min^{-1}$)	P = 0.30	P = 0.43	P = 0.85
Double support (% of GCT)	P = 0.36	P = 0.57	P = 0.61
Dual-task (DT)			
Total duration (s)	**P = 0.006****	P = 0.10	P = 0.66
Gait Speed ($m.s^{-1}$) in iTUG	**P = 0.005****	P = 0.11	P = 0.76
Stride length (% of stature)	P = 0.25	P = 0.16	P = 0.56
Stride velocity (cm/s)	P = 0.07	P = 0.09	P = 0.53
Cadence ($steps.min^{-1}$)	**P = 0.050***	P = 0.15	P = 0.43
Double support (% of GCT)	P = 0.22	P = 0.23	P = 0.93
Absolute % Dual-task Cost (DTC; %)			
Total duration	P = 0.80	P = 0.34	P = 0.54
Gait Speed in iTUG	P = 0.93	P = 0.42	P = 0.84
Stride length	P = 0.41	P = 0.23	P = 0.27
Stride velocity	P = 0.29	P = 0.36	P = 0.62
Cadence	P = 0.89	P = 0.26	P = 0.72
Double support	P = 0.19	P = 0.65	P = 0.52

Notes: Δ: Change over time; 6MWT: Six minute walk test; iTUG: instrumented Timed-Up and Go; ST: Single-task; DT: Dual-task: DTC %: Dual-task Cost (%); s: seconds; cm; centimetre; min: minute; P < 0.05*****; P ≤ 0.01******

Table 5.5b Main and Treatment effects for Single-task, Dual-task transitional parameters, including Dual-task Cost (%)

Variables	Main effects: Time effect (Δ)	Main effects: Group effect	Interactions: Treatment effect
Transitional Movements (ST)			
Turning duration (s)	P = 0.73	P = 0.41	P = 0.73
Peak turning velocity (°. s^{-1})	P = 0.84	P = 0.29	P = 0.94
Number of steps (*f*)	P = 0.28	P = 0.55	P = 0.60
Sit-to-stand duration (s)	P = 0.35	P = 0.70	P = 0.33
Turn-to-sit duration (s)	**P = 0.046***	P = 0.14	P = 0.09
Transitional Movements (DT)			
Turning duration (s)	P = 0.07	P = 0.13	P = 0.44
Peak turning velocity (°. s^{-1})	P = 0.40	P = 0.59	P = 0.74
Number of steps (*f*)	**P = 0.03***	P = 0.75	P = 0.52
Sit-to-stand duration (s)	P = 0.41	P = 0.60	P = 0.17
Turn-to-sit duration (s)	P = 0.88	**P = 0.04***	P = 0.92
Transitional Movements (absolute DTC; %)			
Turning duration	P = 0.07	P = 0.25	P = 0.80
Peak turning velocity	P = 0.47	P = 0.35	P = 0.74
Number of steps	P = 0.84	P = 0.83	P = 0.43
Sit-to-stand duration	P = 0.33	P = 0.50	P = 0.70
Turn-to-sit duration	P = 0.58	P = 0.64	P = 0.38

Notes: Δ: Change over time; iTUG: instrumented Timed-Up and Go; ST: Single-task; DT: Dual-task: DTC %: Dual-task Cost (%); s: seconds; cm; centimetre; min: minute; *f*: frequency; (°. s-1): degrees/s; %: Percentage; P < 0.05*

a) Gait Variables

The EXP and CON groups did not differ statistically significant in any of the pre-test gait variables for ST or DT ($P > 0.05$). There were however weak tendencies for the two groups to differ by about ~9.5% at pre-test for DT Total duration and Stride velocity (Table 5.7a).

During ST conditions, the iTUG (7m) Total duration and Gait speed (Gait speed $_{(iTUG)}$) showed a Time effect ($P < 0.05$; Table 5.5a). Post-hoc analysis indicated a similar improvement in Total duration and Gait speed within the EXP and CON groups, respectively ($P < 0.05$) (Table 5.6a). However, with the longer distance covered during the 6MWT (Figure 5.3) (Gait speed $_{(6MWT)}$) indicated a significant Time, Group and Treatment effect ($P < 0.05$; Table 5.5a). Additional analysis revealed that the EXP group improved their Gait speed (Gait speed $_{(6MWT)}$) by 10% ($P < 0.01$), while the CON maintained their Gait speed (Gait speed $_{(6MWT)}$) (1%) over the intervention. At post-test, the EXP and CON differed significantly by 13% ($P < 0.01$).

Like ST conditions, the DT Time effect results were significant for iTUG Total duration as well as Gait speed (Gait speed $_{(iTUG)}$; $P < 0.05$). Table 5.6b shows only the EXP group's DT Gait speed improving statistically significantly by 6% over time, and a weak tendency in the CON group to also improve with 5%. In contrast, like a mirror image, the CON group's time to complete the iTUG was statistically significantly improved by 7%, while only a weak tendency was seen in EXP group to change with 6% over time. Finally, there was also a significant Time effect for Cadence (Table 5.5a). A closer look at the individual time points show the CON group's DT cadence increasing with 5%, but this was only a stronger tendency ($P = 0.06$).

Neither Fixed effects nor post-hoc statistically significant differences, or changes were found, for DTC results (Table 5.5a and 5.6c).

Table 5.6a Single-task (ST) gait variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19)

Variables	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values	Effect sizes (*d*)	(% difference / △)
Gait speed (m.s^{-1}) 6MWT	1.49 ± 0.25 (0.92 – 2.0)	1.64± 0.21 (1.25 –1.99)	1.42 ± 0.14 (1.20 – 1.68)	1.44 ± 0.14 (1.21 –1.66)	**P^1 < 0.0001*** P^2 = 0.52 P^3 = 0.28 **P^4 = 0.002***	**d^1 =0.67^M** d^2 =0.15^S d^3 =0.35^S **d^4 =1.13^{VL}**	(10%) (1%) (5%) (13%)
Total duration (s)	15.95 ± 2.14 (12.18 - 21.28)	14.89 ± 1.53 (11.83 - 7.70)	16.65 ± 2.33 (12.9 - 23.08)	15.66 ± 2.51 (12.9 - 23.0)	**P^1 = 0.02*** **P^2 = 0.04*** P^3 = 0.30 P^4 = 0.26	**d^1 = 0.58^M** **d^2 = 0.42^M** d^3 = 0.32^S d^4 = 0.39^S	(7%) (6%) (4%) (5%)
Gait speed (m.s^{-1}) iTUG	0.89 ± 0.12 (0.66 - 1.15)	0.95 ± 0.10 (0.79 -1.18)	0.86 ± 0.11 (0.66 - 1.09)	0.91 ± 0.12 (0.61 - 1.09)	**P^1 = 0.01*** **P^2 = 0.02*** P^3 = 0.30 P^4 = 0.29	**d^1 = 0.56^M** **d^2 = 0.45^M** d^3 = 0.27^S d^4 = 0.20^S	(7%) (6%) (3%) (9%)
Stride length (% stature)	84.08 ± 3.98 (74.44 - 89.17)	85.08 ± 5.40 (74.66 - 91.53)	83.68 ± 5.67 (73.64 - 93.45)	84.28 ± 4.12 (76.81 - 92.81)	P^1 = 0.41 P^2 = 0.65 P^3 = 0.79 P^4 = 0.60	d^1 = 0.22^S d^2 = 0.12^N d^3 = 0.09^N d^4 = 0.17^S	(1%) (1%) (0%) (1%)
Stride velocity (%/s)	85.54 ± 9.43 (68.35 -102.17)	87.56 ± 8.60 (70.84 - 03.74)	83.47 ± 8.56 (69.57 - 98.91)	85.43 ± 6.72 (68.55 - 94.45)	P^1 = 0.15 P^2 = 0.19 P^3 = 0.44 P^4 = 0.43	d^1 = 0.23^S d^2 = 0.26^S d^3 = 0.24^S d^4 = 0.28^S	(2%) (2%) (2%) (2%)
Double support stance (%)	21.65 ± 5.56 (10.4 - 35.73)	20.66 ± 4.64 (10.47 - 35.73)	22.01 ± 4.30 (17.16 - 31.78)	21.74 ± 3.54 (16.58 - 30.50)	P^1 = 0.29 P^2 =0.78 P^3 = 0.80 P^4 = 0.46	d^1 = 0.20^S d^2 = 0.07^N d^3 = 0.07^N d^4 = 0.27^S	(5%) (1%) (2%) (5%)
Cadence (steps.min^{-1})	121.99 ± 12.38 (96.58 - 143.94)	123.32 ± 9.85 (96.58 - 143.94)	119.61 ± 7.99 (103.72 - 132.85)	121.56 ± 7.23 (101.52 - 133.25)	P^1 = 0.54 P^2 = 0.41 P^3 = 0.44 P^4 = 0.57	d^1 = 0.12^N d^2 = 0.26^S d^3 = 0.23^S d^4 = 0.21^S	(1%) (2%) (2%) (1%)

Notes: EXP: Experimental group; CON: Control group; s: seconds; cm; centimetre; min: minute; m: meter; %: Percentage; iTUG: instrumented Timed-Up and Go; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

Table 5.6b Dual-task (DT) gait variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).

Variables	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values	Effect sizes (*d*)	(% difference / △)
Total duration (s)	18.32 ± 2.62 (13.60 - 22.71)	17.28 ± 3.08 (12.54 - 23.74)	20.15 ± 4.41 (14.65 - 32.88)	18.74 ± 3.20 (13.86 - 24.53)	$P^1 = 0.08$ **$P^2 = 0.03$*** $P^3 = 0.09$ $P^4 = 0.17$	$d^1 = 0.37^M$ **$d^2 = 0.38^S$** $d^3 = 0.53^M$ $d^4 = 0.48^s$	(6%) (7%) (10%) (8%)
Gait speed ($m.s^{-1}$) iTUG	0.78 ± 0.12 (0.62 - 1.03)	0.84 ± 0.14 (0.60 - 1.12)	0.73 ± 0.13 (0.53 - 0.96)	0.77 ± 0.12 (0.58 - 1.01)	**$P^1 = 0.02$*** $P^2 = 0.07$ $P^3 = 0.18$ $P^4 = 0.11$	**$d^1 = 0.41^M$** $d^2 = 0.33^S$ $d^3 = 0.41^M$ $d^4 = 0.55^M$	(6%) (5%) (6%) (8%)
Stride length (% stature)	81.56 ± 4.74 (73.04 - 92.50)	82.12 ± 5.78 (72.57 - 89.90)	78.95 ± 7.18 (64.49 - 91.11)	80.66 ± 4.20 (72.60 - 88.76)	$P^1 = 0.68$ $P^2 = 0.24$ $P^3 = 0.14$ $P^4 = 0.41$	$d^1 = 0.11^N$ $d^2 = 0.30^S$ $d^3 = 0.45^M$ $d^4 = 0.29^S$	(1%) (2%) (3%) (2%)
Stride velocity (%/s)	76.70 ± 12.46 (48.86 - 100.36)	79.04 ± 11.71 (59.85 - 97.04)	69.63 ± 14.39 (26.72 - 85.65)	74.20 ± 10.05 (53.73 - 87.55)	$P^1 = 0.35$ $P^2 = 0.10$ $P^3 = 0.07$ $P^4 = 0.21$	$d^1 = 0.20^S$ $d^2 = 0.38^S$ $d^3 = 0.54^M$ $d^4 = 0.45^M$	(3%) (7%) (9%) (6%)
Double support stance (%)	23.35 ± 4.49 (13.68 - 30.52)	22.34 ± 5.36 (13.53 - 36.90)	25.14 ± 6.72 (19.45 - 45.82)	23.98 ± 4.22 (18.50 - 31.46)	$P^1 = 0.40$ $P^2 = 0.37$ $P^3 = 0.28$ $P^4 = 0.33$	$d^1 = 0.21^S$ $d^2 = 0.21^S$ $d^3 = 0.33$ $d^4 = 0.35^S$	(4%) (5%) (8%) (7%)
Cadence ($steps.min^{-1}$)	112.82 ± 17.26 (84.01 - 154.33)	115.07 ± 14.52 (92.15 - 146.64)	105.16 ± 13.58 (79.43 - 128.39)	110.36 ± 13.18 (81.62 - 128.95)	$P^1 = 0.38$ $P^2 = 0.06$ $P^3 = 0.11$ $P^4 = 0.32$	$d^1 = 0.14^N$ $d^2 = 0.40^M$ $d^3 = 0.50^M$ $d^4 = 0.35^S$	(2%) (5%) (7%) (4%)

Notes: EXP: Experimental group; CON: Control group; s: seconds; cm; centimetre; min: minute; m: meter; %: Percentage; iTUG: instrumented Timed-Up and Go; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

Table 5.6c Absolute Dual-task Cost (DTC) gait variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).

	EXP (n = 22)		CON (n = 19)		P-values; Effect sizes (*d*); (% difference / △)		
Variables (%)	**Pre**	**Post**	**Pre**	**Post**			
Total duration	16.63 ± 9.87 (0.30 - 30.36)	17.81 ± 14.90 (3.61- 39.32)	23.54 ± 29.49 (1.58 - 62.36)	20.67±19.03 (0.00 - 54.72)	$P^1 = 0.79$ $P^2 = 0.55$ $P^3 = 0.26$ $P^4 = 0.64$	$d^1 = 0.10^N$ $d^2 = 0.12^N$ $d^3 = 0.33^S$ $d^4 = 0.17^S$	(7%) (6%) (42%) (16%)
Gait speed iTUG	13.44 ± 7.19 (0.16 - 27.28)	13.69 ± 9.98 (1.25-33.07)	14.81 ± 12.64 (0.68-41.65)	15.02 ± 10.95 (1.17-39.82)	$P^1 = 0.93$ $P^2 = 0.84$ $P^3 = 0.54$ $P^4 = 0.42$	$d^1 = 0.03^N$ $d^2 = 0.02^N$ $d^3 = 0.14^N$ $d^4 = 0.13^N$	(2%) (1%) (10%) (10%)
Stride length	3.74 ± 2.13 (0.07 - 8.45)	3.95 ± 3.49 (0.58 - 15.56)	5.79 ± 6.03 (0.51 - 24.61)	4.37 ± 3.73 (0.26 - 16.00)	$P^1 = 0.83$ $P^2 = 0.19$ $P^3 = 0.11$ $P^4 = 0.74$	$d^1 = 0.07^N$ $d^2 = 0.29^S$ $d^3 = 0.48^M$ $d^4 = 0.12^N$	(6%) (25%) (55%) (11%)
Stride velocity	12.59 ± 6.88 (2.81 - 28.51)	11.41 ± 7.66 (1.41 - 23.92)	16.22 ± 17.39 (1.10 - 71.79)	13.01 ± 10.44 (0.95 - 38.82)	$P^1 = 0.67$ $P^2 = 0.29$ $P^3 = 0.30$ $P^4 = 0.65$	$d^1 = 017^S$ $d^2 = 0.23^S$ $d^3 = 0.29^S$ $d^4 = 0.18^S$	(9%) (20%) (29%) (14%)
Double support stance	15.00 ± 14.48 (0.41 - 72.21)	12.41 ± 12.38 (0.12 - 56.36)	19.42 ± 30.20 (3.73 - 120.82)	11.90 ± 10.48 (0.38 - 37.15)	$P^1 = 0.62$ $P^2 = 0.18$ $P^3 = 0.44$ $P^4 = 0.93$	$d^1 = 0.20^S$ $d^2 = 0.34^S$ $d^3 = 0.20^S$ $d^4 = 0.05^N$	(17%) (39%) (29%) (4%)
Cadence	10.24 ± 6.63 (0.97 - 24.98)	9.43 ± 7.12 (0.03 - 22.64)	12.36 ± 11.28 (0.10 - 34.47)	12.70 ± 10.83 (0.29 - 33.61)	$P^1 = 0.71$ $P^2 = 0.88$ $P^3 = 0.46$ $P^4 = 0.26$	$d^1 =0.12^N$ $d^2 = 0.03^N$ $d^3 = 0.24^S$ $d^4 = 0.37^S$	(8%) (3%) (21%) (35%)

Notes: EXP: Experimental group; CON: Control group; %: Percentage; iTUG: instrumented Timed-Up and Go; [1]: EXP within group; [2]: CON within group; [3]: Pre-test between groups; [4]: Post-test between groups; *d*: Effect sizes; [N]: negligible; [S]: small; [M]: medium; [L]: large; [VL]: Very large; $P < 0.05$*; $P < 0.01$**; △: Change

b) Transitional Variables

Transitional movements' Fixed effects are summarised in Table 5.5b, however results are presented in Table 5.7a – c.

For transitional variables during ST and DT conditions, the EXP and CON groups only differed statistically significantly for the ST condition Turn-to-sit duration at pre-test (Table 5.7a). The EXP group's results remained almost unchanged whereas the CON group were 11% faster to turn and sit down during the iTUG ST test (P = 0.03). Other than this group difference, none of the other transitional variables differed at pre-test for either conditions (P > 0.05).

During ST conditions, a Time effect (P < 0.05; Table 5.5b) was found for Turn-to-sit. Post-hoc analysis indicated a 9% time reduction for the CON group only (P = 0.01) (Table 5.7a).

A Time effect was found for step frequency during the turn, as well as a Group effect for Turn-to-sit during the DT conditions' transitional variables (P < 0.05; Table 5.5b). Table 5.7b shows only tendencies (P = 0.06) for the CON group's DT turning duration and number of steps during the turn to increase by 10% over the study period. No other statistical significant differences or changes over time were observed during the DT transitional movements.

No Fixed effects or statistically significant post-hoc differences or changes were found for DTC results (Table 5.5b and 5.7c).

Table 5.7a **Single-task (ST) transitional variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).**

	EXP (n = 22)		CON (n = 19)		
Variables	**Pre**	**Post**	**Pre**	**Post**	**P-values; Effect sizes (*d*); (% difference / △)**
Turning duration (s)	2.67 ± 0.43 (1.95 - 3.70)	2.63 ± 0.47 (1.86 - 3.54)	2.77 ± 0.50 (1.99 - 3.81)	2.77 ± 0.50 (1.99 - 3.81)	$P^1 = 0.26$ $d^1 = 0.09^N$ (1%) $P^2 = 1.00$ $d^2 = 0.00^N$ (0%) $P^3 = 0.26$ $d^3 = 0.21^S$ (4%) $P^4 = 0.09$ $d^4 = 0.28^S$ (5%)
Peak turning velocity (°. s^{-1})	153.37 ± 34.52 (91.61 - 231.54)	154.75 ± 36.71 (106.20 - 264.19)	144.15 ± 26.19 (78.86 - 179.32)	144.74 ± 30.34 (85.88 - 197.03)	$P^1 = 0.83$ $d^1 = 0.04^N$ (1%) $P^2 = 0.93$ $d^2 = 0.02^N$ (0%) $P^3 = 0.37$ $d^3 = 0.31^S$ (6%) $P^4 = 0.33$ $d^4 = 0.30^S$ (6%)
Number of steps (*f*)	6.05 ± 0.79 (4.00 – 8.00)	6.14 ± 1.21 (4.00 – 9.00)	6.11 ± 0.74 (5.00 – 8.00)	6.37 ± 0.90 (5.00 – 8.00)	$P^1 = 0.68$ $d^1 = 0.09^N$ (2%) $P^2 = 0.27$ $d^2 = 0.33^S$ (4%) $P^3 = 0.84$ $d^3 = 0.08^N$ (1%) $P^4 = 0.43$ $d^4 = 0.22^S$ (4%)
Sit-to-stand duration (s)	2.25 ± 0.39 (1.75 - 2.83)	2.25 ± 0.43 (1.80 - 3.15)	2.20 ± 0.39 (1.85 - 2.88)	2.38 ± 0.53 (1.83 - 3.53)	$P^1 = 0.99$ $d^1 = 0.01^N$ (0%) $P^2 = 0.19$ $d^2 = 0.41^M$ (9%) $P^3 = 0.68$ $d^3 = 0.15^S$ (3%) $P^4 = 0.34$ $d^4 = 0.28^S$ (5%)
Turn- to- sit duration (s)	3.60 ± 0.41 (2.86 - 4.40)	3.57 ± 0.43 (2.78 - 4.36)	3.97 ± 0.78 (3.08 - 5.44)	3.60 ± 0.50 (2.71 - 4.71)	$P^1 = 0.82$ $d^1 = 0.07^N$ (1%) **$P^2 = 0.01$* $d^2 = 0.58^M$** (9%) **$P^3 = 0.03$* $d^3 = 0.64^M$** (11%) $P^4 = 0.83$ $d^4 = 0.08^N$ (1%)

Notes: EXP: Experimental group; CON: Control group; s: seconds; cm; centimetre; min: minute; m: meter; *f*: frequency; °.s^{-1}: degrees/s; %: Percentage; iTUG: instrumented Timed-Up and Go; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

Table 5.7b Dual-task (DT) transitional variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).

Variables	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values; Effect sizes (*d*); (% difference / △)
Turning duration (s)	2.86 ± 0.42 (1.92 - 3.36)	2.95 ± 0.54 (2.10 - 3.81)	3.08 ± 0.76 (2.00 - 5.27)	3.31 ± 0.87 (2.00 - 4.97)	$P^1 = 0.25$ $d^1 = 0.31^S$ (6%) $P^2 = 0.06$ $d^2 = 0.42^M$ (10%) $P^3 = 0.95$ $d^3 = 0.02^N$ (0%) $P^4 = 0.54$ $d^4 = 0.19^S$ (4%)
Peak turning velocity (°. s^{-1})	140.65 ± 34.59 (84.72 - 208.10)	138.60 ± 36.13 (96.58 - 222.14)	136.71 ± 27.39 (80.82-181.59)	132.09 ± 31.98 (80.25-188.65)	$P^1 = 0.70$ $d^1 = 0.06^N$ (1%) $P^2 = 0.43$ $d^2 = 0.16^S$ (3%) $P^3 = 0.70$ $d^3 = 0.13^N$ (3%) $P^4 = 0.53$ $d^4 = 0.19^S$ (5%)
Number of steps (*f*)	6.02 ± 1.16 (3.00 - 8.50)	6.34 ± 0.96 (5.00 - 8.50)	6.00 ± 1.27 (4.50 - 10.00)	6.58 ± 1.54 (4.00-9.50)	$P^1 = 0.25$ $d^1 = 0.31^S$ (5%) $P^2 = 0.06$ $d^2 = 0.42^M$ (10%) $P^3 = 0.95$ $d^3 = 0.02^N$ (0%) $P^4 = 0.54$ $d^4 = 0.20^S$ (4%)
Sit-to-stand duration (s)	2.17 ± 0.25 (1.81-2.64)	2.29 ± 0.37 (1.85 – 3.319)	2.20 ± 0.28 (1.81 – 2.89)	2.17 ± 0.29 (1.80 – 2.71)	$P^1 = 0.11$ $d^1 = 0.39^S$ (6%) $P^2 = 0.69$ $d^2 =0.11^N$ (1%) $P^3 = 0.71$ $d^3 = 0.12^N$ (1%) $P^4 = 0.23$ $d^4 = 0.37^S$ (5%)
Turn- to- sit duration (s)	3.65 ± 0.59 (2.32 – 4.76)	3.61 ± 0.57 (2.82 – 4.84)	4.03 ± 1.08 (2.93 – 7.91))	4.02 ± 0.81 (3.06 – 5.82)	$P^1 = 0.86$ $d^1 = 0.07^N$ (1%) $P^2 = 0.12$ $d^2 = 0.01^N$ (0%) $P^3 = 0.97$ $d^3 =0.46^M$ (10%) $P^4 = 0.10$ $d^4 =0.61^M$ (11%)

Notes: EXP: Experimental group; CON: Control group; s: seconds; cm; centimetre; min: minute; m: meter; *f*: frequency; °.s^{-1}: degrees/s; %: Percentage; iTUG: instrumented Timed-Up and Go; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

Table 5.7c Absolute Dual-task Cost (DTC) transitional variables reported as mean ($\bar{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).

	EXP (n = 22)		CON (n = 19)		
Variables (%)	**Pre**	**Post**	**Pre**	**Post**	**P-values; Effect sizes (*d*); (% difference / △)**
Turning duration	11.33 ± 7.90 (0.30 - 30.36)	15.79 ±10.07 (3.61 - 39.32)	18.34 ± 18.85 (1.58 - 62.36)	19.76 ± 18.07 (0.00 - 54.72)	$P^1 = 0.21$ $d^1 = 0.50^M$ (39%) $P^2 = 0.71$ $d^2 = 0.08^S$ (8%) $P^3 = 0.12$ $d^3 = 0.51^M$ (62%) $P^4 = 0.38$ $d^4 = 0.28^S$ (25%)
Peak turning velocity	12.50 ± 7.49 (1.69 - 26.93)	13.15 ± 7.42 (0.37 - 31.56)	13.68 ± 8.65 (2.19 - 36.23)	15.42 ± 7.86 (4.53 - 33.30)	$P^1 = 0.77$ $d^1 = 0.09^N$ (5%) $P^2 = 0.48$ $d^2 = 0.22^S$ (13%) $P^3 = 0.63$ $d^3 = 0.15^S$ (9%) $P^4 = 0.36$ $d^4 = 0.31^S$ (17%)
Number of steps	15.25 ± 13.57 (0.00 - 50.00)	13.74 ± 11.79 (0.00 - 60.00)	12.63 ± 8.67 (0.00 - 33.33)	15.19 ± 12.80 (7.15 - 58.33)	$P^1 = 0.67$ $d^1 = 0.12^N$ (10%) $P^2 = 0.50$ $d^2 = 0.24^S$ (20%) $P^3 = 0.49$ $d^3 = 0.23^S$ (17%) $P^4 = 0.70$ $d^4 = 0.12^N$ (11%)
Sit-to-stand duration	15.99 ± 9.91 (2.02 - 35.13)	14.50 ± 10.14 (2.63 - 44.00)	18.70 ± 12.46 (0.65 - 46.20)	15.21 ± 13.37 (0.00 - 40.16)	$P^1 = 0.67$ $d^1 = 0.15^S$ (9%) $P^2 = 0.35$ $d^2 = 0.28^M$ (19%) $P^3 = 0.46$ $d^3 = 0.25^S$ (17%) $P^4 = 0.84$ $d^4 = 0.06^N$ (5%)
Turn- to- sit duration	15.56 ± 13.66 (0.63 - 52.26)	14.46 ± 15.00 (0.67 - 53.33)	14.36 ± 18.02 (0.39 - 80.03)	19.16 ± 17.56 (0.08 - 65.34)	$P^1 = 0.81$ $d^1 = 0.08^N$ (7%) $P^2 = 0.33$ $d^2 = 0.28^S$ (33%) $P^3 = 0.81$ $d^3 = 0.08^N$ (8%) $P^4 = 0.35$ $d^4 = 0.30^S$ (33%)

Notes: EXP: Experimental group; CON: Control group; s: seconds; cm; centimetre; min: minute; m: meter; *f*: frequency; $°.s^{-1}$: degrees/s; %: Percentage; iTUG: instrumented Timed-Up and Go; ^{1}: EXP within group; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05*; P < 0.01**; △: Change

5.4.2 Secondary outcome variables

Table 5.2 summarises the Main (i.e. Time as well as Group) and Treatment (Group x Time) effects for the secondary outcome variables as calculated by a multifactorial ANOVA.

Table 5.8 Main and Treatment effects for secondary outcome variables

Variables	Main effects		
	Time effect (Δ)	Group effect	Treatment effect
Global Cognition (MoCA)	**P < 0.001***	P = 0.96	P = 0.08
Depressive Mood (PHQ-9)	**P = 0.01***	P = 0.79	P = 0.43
Quality of Life (SF-36)	**P = 0.02***	P = 0.12	**P = 0.04***
Physical Functioning (PF-10)	P = 0.06	**P = 0.05***	**P = 0.006***

Note: Δ: Change over time between groups; MoCA: Montreal Cognitive Assessment; PHQ-9: Patient Health Questionnaire (Depressive Mood); SF-36: Short-Form Health Survey (Quality of Life); PF-10: Physical Functioning subscale (self-perceived Functional Mobility); P-values: P < 0.05*

5.4.2.1 Global Cognition: Montreal Cognitive Assessment (MoCA)

Figure 5.7 illustrates Global Cognition including scores of all seven sub-domains of the Montreal Cognitive Assessment (MoCA).

Post-hoc analysis showed Global Cognition, i.e. total MoCA score adjusted for education (Figure 5.7a), increased by 8% in the EXP group over time (P = 0.0001; $d = 0.91^{L}$), while the CON changed by 3% (P = 0.14; $d = 0.33^{S}$). No pre-test (P = 0.41; $d = 0.24^{S}$) or post-test (P = 0.37; $d = 0.34^{S}$) differences were visible between the EXP and CON group.

The multifactorial ANOVA revealed no significant Fixed effects for the seven domains, except for a Time effect in the visual spatial (Executive Function) (P = 0.02) and Abstraction domains (P = 0.008).

Figure 5.7b illustrates the visual spatial (Executive Function) domain. Post-hoc data comparison revealed a 13% improvement in visual spatial ability for the EXP only (P = 0.049; $d = 0.65^{M}$). There was a non-significant 4% (P = 0.57; $d = 0.15^{S}$) and 5% (P = 0.41; $d = 0.36^{S}$) difference at pre- and post-test, respectively.

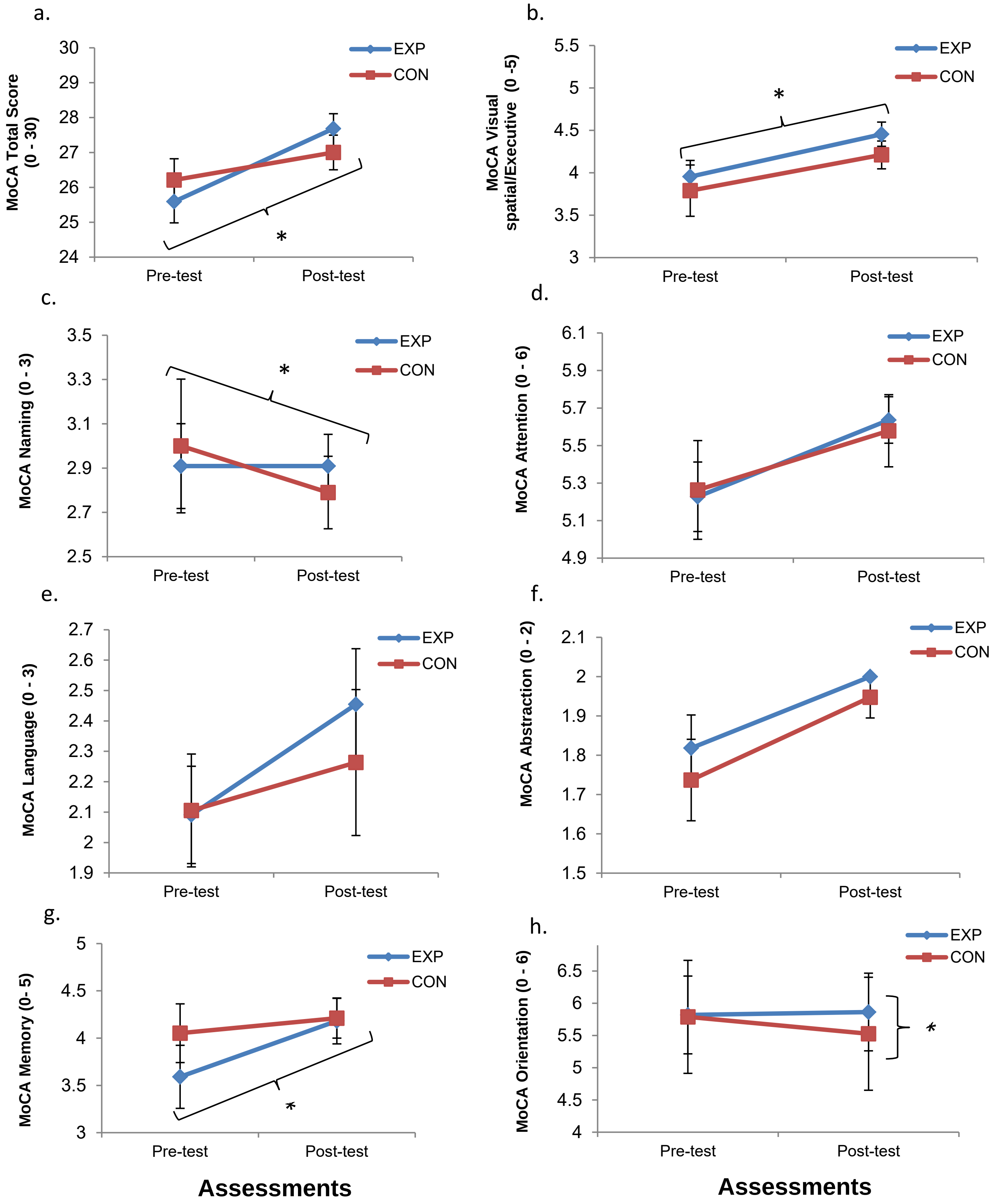


Figure 5.7 Total MoCA score (a) and the 7 cognitive domains (b – h), between EXP and CON over the 8-week intervention ($\bar{x}$ ± SEM; P < 0.05*).

The domain for Naming showed a 7% decrease in performance by the CON group over time (P = 0.03; *d* = 0.73[M]) and illustrated in Figure 5.7c. There was a non-significant 3% and 4% difference between groups at pre- and post-test, respectively (P > 0.05; $d < 0.44^{M}$).

Figure 5. 7d shows a similar non-significant increase in both groups (EXP: P = 0.13; $d = 0.57^{M}$; 8%; CON: P = 0.27; $d = 0.32^{S}$; 6%). There was no difference between groups at pre-test or post-test (P > 0.05; $d < 0.08^{N}$).

Similarly, in the cognitive domain of Language there was no difference between groups at pre-test (P = 0.96, $d = 0.02^{N}$) and 8% difference at post-test (P = 0.49; $d = 0.21^{S}$). The EXP increased by 17% (P = 0.06; $d = 0.46^{M}$) compared to a 6.6% change in CON (P = 0.43.; $d = 0.02^{N}$).

Abstraction for the CON group improved by 12% (P = 0.048; $d = 0.60^{M}$), compared to the 10% change in EXP group performance (P = 0.07; $d = 0.67^{M}$), although, none was considered significant. There was a non-significant 4% and 3% difference between groups at pre- and post-test, respectively (P > 0.05; $d < 0.36^{S}$)

Post-hoc data analysis, as illustrated in Figure 5.7g showed 16% significant improvement in Memory for the EXP only (P = 0.04; $d = 0.44^{M}$). There was a non-significant 13% and 1% difference between groups at pre- and post-test, respectively (P > 0.05; $d < 0.33^{S}$).

In the MoCA's Orientation domain performance deteriorated by 5% for the CON group (P = 0.051; $d = 0.47^{M}$). Groups did not differ at pre-test (P = 0.85, $d = 0.07$), although a 6% significant difference was found at post-test (P = 0.03; $d = 0.64^{M}$).

5.4.2.2 Depressive Mood: Patient Health Questionnaire (PHQ-9)

Figure 5.8 portrays the change in Depressive Mood over time and Table 5.8 indicates Fixed effects. The EXP group significantly improved by 36% over time (P = 0.01; $d = 0.53^{M}$) compared to 21% improvement of the CON group's depressive status, which was not significant (P = 0.17; $d = 0.33^{S}$). There were no pre-test differences between the two groups (P = 0.88; $d = 0.05^{N}$; 3%), and the 20% difference at post-intervention was not significant (P = 0.54; $d = 0.18^{S}$).

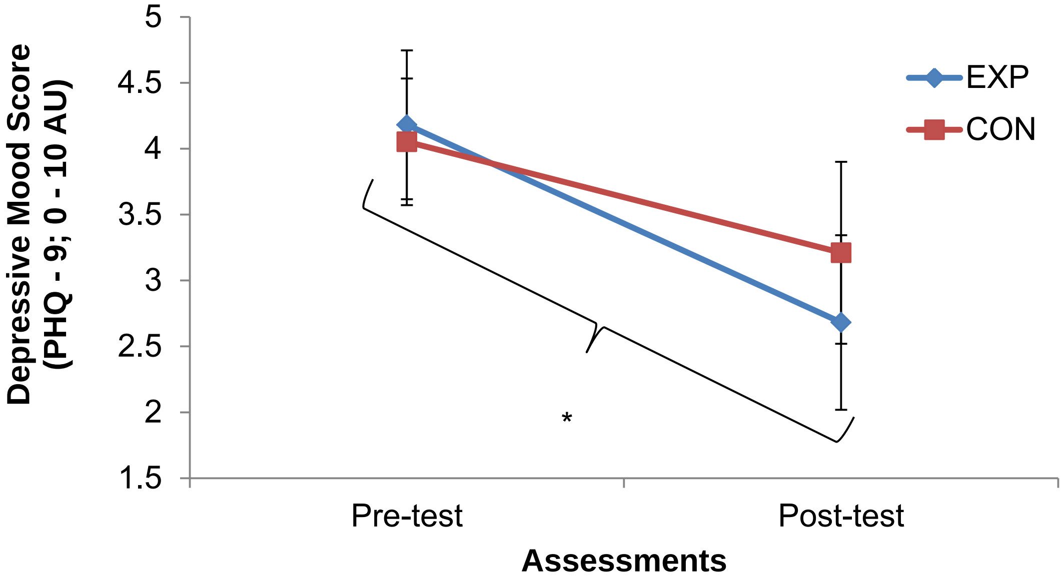


Figure 5.8 Depressive Moods (PHQ-9) between EXP and CON over the 8-week intervention ($\bar{x}$ ± SEM; P < 0.05 *).

5.4.2.3 Quality of Life: 36-Item Short Form Health Survey (SF-36)

Total SF-36 scores revealed both a significant Time and Treatment effect as reflected in Table 5.8. With regards to the sub-domains, no significant Fixed effects, except for a Group effect in the General health perceptions (P = 0.04) domain and a Time effect in the Vitality (energy/fatigue) (P < 0.001) and General mental health domains (P = 0.003). In addition, the Physical Functioning domain revealed a significant Treatment effect (P = 0.006).

Table 5.9 summarises the eight domains of the SF-36, including the PF-10 where higher scores indicate improvement.

Post-hoc analysis showed a 14% improvement in the EXP group's Total SF-36 (self-perceived QoL) scores (P = 0.0018; *d* = 0.63[M]). The EXP and CON group did not differ at pre-test (P = 0.69; *d* = 0.12[N]; 2%) but differed significantly at post-test (P = 0.02; *d* = 0.82[L]; 14%).

Table 5.9 The SF-36 (%) domains reported as mean ($\overline{x}$) ± standard deviation (range) between EXP (n = 22) and CON (n = 19).

Variables	EXP (n = 22) Pre	EXP (n = 22) Post	CON (n = 19) Pre	CON (n = 19) Post	P-values; Effect sizes (*d*); (% difference/△)		
PF-10	0.81 ± 0.15	0.84 ± 0.15	0.77 ± 0.0	0.63 ± 0.32	$P^1 = 0.50$	$d^1 = 0.19^S$	(3%)
	(0.55 – 1.0)	(0.35 – 1.0)	(0.25 – 1.0)	(0.00 – 1.0)	**$P^2 = 0.002$***	**$d^2 = 0.55^M$**	(19%)
					$P^3 = 0.58$	$d^3 = 0.21^S$	(5%)
					$P^4 = 0.003$*	**$d^4 = 0.89^L$**	(19%)
RLH	82.95 ± 29.26	90.91 ± 25.05	71.05 ± 40.19	75.00 ± 35.36	$P^1 = 0.30$	$d^1 = 0.30^S$	(10%)
	(25 – 100)	(0 – 100)	(0 – 100)	(0 – 100)	$P^2 = 0.67$	$d^2 = 0.11^S$	(6%)
					$P^3 = 0.25$	$d^3 = 0.35^S$	(14%)
					$P^4 = 0.13$	$d^4 = 0.54^M$	(18%)
BP	85.09 ± 15.67	84.63 ± 16.35	77.63 ± 26.69	73.68 ± 25.88	$P^1 = 0.90$	$d^1 = 0.03^N$	(1%)
	(55 – 100)	(45 – 100)	(23 – 100)	(13 – 100)	$P^2 = 0.33$	$d^2 = 0.15^S$	(5%)
					$P^3 = 0.27$	$d^3 = 0.36^S$	(9%)
					$P^4 = 0.11$	$d^4 = 0.53^M$	(13%)
SF	81.36 ± 20.96	92.68 ± 15.16	79.34 ± 19.14	79.11 ± 26.29	**$P^1 = 0.02$***	**$d^1 = 0.63^M$**	(14%)
	(38 – 100)	(38 – 100)	(50 – 100)	(0 – 100)	$P^2 = 0.90$	$d^2 = 0.03^N$	(1%)
					$P^3 = 0.80$	$d^3 = 0.08^N$	(2%)
					$P^4 = 0.04$*	**$d^4 = 0.66^M$**	(15%)
GMH	76.73 ± 12.93	82.00 ± 12.02	74.95 ± 16.05	81.47 ± 12.02	$P^1 = 0.05$	$d^1 = 0.43^M$	(7%)
	(52 – 92)	(56 – 100)	(48 – 100)	(52 – 100)	**$P^2 = 0.02$***	**$d^2 = 0.47^M$**	(9%)
					$P^3 = 0.67$	$d^3 = 0.13^N$	(2%)
					$P^4 = 0.90$	$d^4 = 0.04^N$	(1%)
RLEP	72.73 ± 43.21	89.41 ± 26.00	82.42 ± 32.22	86.00 ± 32.02	**$P^1 = 0.04$***	**$d^1 = 0.48^M$**	(23%)
	(0 – 100)	(0 – 100)	(0 – 100)	(0 – 100)	$P^2 = 0.67$	$d^2 = 0.11^N$	(4%)
					$P^3 = 0.37$	$d^3 = 0.26^S$	(13%)
					$P^4 = 0.75$	$d^4 = 0.12^N$	(4%)
VEF	57.05 ± 21.58	77.50 ± 15.56	59.47 ± 21.07	72.37 ± 13.78	**$P^1 < 0.001$***	**$d^1 = 1.11^{VL}$**	(36%)
	(20 –95)	(45 – 100)	(40 – 100)	(45 – 100)	**$P^2 = 0.009$***	**$d^2 = 0.74^M$**	(22%)
					$P^3 = 0.68$	$d^3 = 0.12^N$	(4%)
					$P^4 = 0.38$	$d^4 = 0.36^S$	(7%)
GHP	77.05 ± 11.51	83.41 ± 15.77	71.58 ± 18.86	71.32 ± 14.99	$P^1 = 0.05$	$d^1 = 0.47^M$	(8%)
	(55 – 90)	(35 – 100)	(40 – 100)	(45 – 100)	$P^2 = 0.94$	$d^2 = 0.02^N$	(0%)
					$P^3 = 0.26$	$d^3 = 0.37^S$	(7%)
					$P^4 = 0.02$*	**$d^4 = 0.80^L$**	(14%)

Note: PF-10: Physical Functioning subscale (self-perceived functional mobility); RLH: Role limitations because of physical health problems; BP: bodily pain; SF: Social functioning; GMH: General mental health (psychological distress and psychological wellbeing); RLEP: Role limitations because of emotional problems; VEF: Vitality (energy/fatigue); GHP: General health perceptions; ^{1}: EXP within group ; ^{2}: CON within group; ^{3}: Pre-test between groups; ^{4}: Post-test between groups; *d*: Effect sizes; ^{N}: negligible; ^{S}: small; ^{M}: medium; ^{L}: large; ^{VL}: Very large; P < 0.05* ; △: Change

5.5 SUMMARY

In summary, only a strong tendency for a Treatment effect (P = 0.05) was reported for the primary outcome variable of EF for the Walking Stroop Carpet's (WSC) incongruent colour walking condition (Condition 3). Functional mobility delivered a Treatment effect of significance during the Functional Capacity test (6MWT).

There were significant Treatment effects observed for the following secondary outcome variables: Health-related Quality of Life (HRQoL: SF-36), Physical Functioning (PF-10), BMI, body mass and Physical activity status (RAPA).

Although one between-groups difference was reported at pre-test for age (descriptive statistics), three primary outcome variables for EF and one for Mobility were found. EXP and CON significantly differed at pre-test for the pen-and-paper TMT B test (Cognitive flexibility) and calculated TMT derived scores (TMT Interference difference; TMT Interference Ratio). Upon completion of all single-task Mobility gait parameters and transitional movements (with the iTUG), it was found groups differed significantly at pre-test during postural transition of Turn-to-sit (TTS) only.

Post-hoc analysis delivered several significant post-test differences between groups for both primary and secondary variables. With regards to Inhibitory control (IC) as primary outcome variable, a post-test difference of significance was visible upon completion of the WSC's (Condition 3: incongruent colour) and (Condition 4: incongruent word) for spatiotemporal gait variable of Total duration (s). Post-hoc comparisons on Stride velocity (m/s) and Interference difference indicated EXP group differed significantly from CON group at post-test for Condition 4 as well as during the average obtained between the incongruent conditions. Functional Capacity (6MWT) and Gait speed - as measured with the (6MWT) - were the only two post-test differences between groups visible for Mobility. Differences found for secondary variables included the following in consecutive order: Orientation domain (MoCA); Total scores for self-perceived HRQoL (SF-36); self-perceived Physical functioning (PF-10); self-perceived Social functioning (SF); self-perceived General Mental Health (GMH); General health perception (GHP); self-perceived Activity status (RAPA).

Significant within-group changes over time in EXP were seen from pre- to post-test for for EXP groups' BMI, body mass and WSC Total duration: Congruent walking condition Interference (I.Time_N) for as well as for WSC Stride velocity: Interference (I.Time_N) and Facilitation calculation (F.Time_N) for EXP groups' Mobility significantly improved over time as indicated by assessments of Functional Capacity (6MWT), Gait speed as measured during the 6MWT, as well as ST Total duration, as measured during the 7m iTUG. Additionally, improvement of significance were reported for Global Cognition scores (MoCA), the visual spatial (Executive Function) domain (MoCA), Memory (MoCA), Depressive Mood (PHQ-9), Health-related Quality of Life (SF-36) and it's following domains: Social functioning (SF), self-perceived role limitations due to emotional health problems (RLEP), Vitality, energy and fatigue (VEF) and General health perception (GHP).

Several changes in primary outcome variables took place over the 8-week period for participants in the CON group and are briefly highlighted. Cognitive flexibility (TMT B) improved, including TMT Interference difference (ID) and Interference ratio (IR). Inhibitory control, as measured with the WSC showed significant improvement in Total duration for the CON group in the congruent Condition 2, the incongruent Condition 4, as well as Facilitation calculation (F.Time_N) pertaining to average incongruent Condition 3 and 4 for Stride velocity. Mobility, as measured with the iTUG, also improved for the CON group. Single-task as well as DT Total duration improved over time, however the acceleration in time during the DT postural transitional movement of TTS are considered as a deterioration due to possible lack in postural control. Within-group changes over time in CON group were seen in secondary outcome variables as well. The CON group deteriorated significantly from pre-to post-test in the Naming domain as well as Orientation domain of the MoCA. Overall self-perceived levels of Physical Functioning (reflecting Functional Mobility) (PF-10), deteriorated whereas VEF (as measured with the SF-36) improved significantly. Additionally, self-reported levels of activity status (RAPA) also showed improvement for both groups.

Normal probability plots were inspected and data was found to be normally distributed. However, the following chapter aims to clarify expected and unexpected findings. All variables tested were parametric and thus quantified.

CHAPTER 6
DISCUSSION AND CONCLUSION

6.1 INTRODUCTION

The main aim of this study was to evaluate the influence of a high-intensity, 8 - week water-based exercise intervention (WBEI) on Executive Function (EF) and Mobility, in apparently healthy older adults. The secondary aim set out to determine changes in older adults' perceived Health-related Quality of Life (HRQoL) and if improvements occurred in activities of daily living (ADL). The non-exercising group (CON), also performed an 8 - week programme of time-matched-attention (TMA) activities. These sessions included relaxation and educational activities. It was hypothesized that an 8-week WBEI would lead to improvements in EF and Mobility in the healthy older adults, aged 50 - 64 years. Furthermore, it was expected that the influence of the WBEI would lead to greater enhancement in both EF and Mobility, in comparison to non-exercising older adults, who participated only in relaxation and educational activities.

To answer the research questions, Executive Function as primary objective was assessed in terms of attention and Working memory (WM), Cognitive flexibility (CF) and Inhibitory control (IC). Mobility as the other primary objective was determined as Functional Capacity, spatiotemporal and transitional gait parameters assessed in single-task (ST) and cognitive dual-task (DT) conditions. Dual-task cost (DTC) was determined as well. The intervention also assessed Global Cognition, Depressive Mood, self-perceived levels of HRQoL as well as Physical Function, as secondary objectives.

The main findings demonstrated the 8-week WBEI partially supported the hypothesis. Selective components of both EF and Mobility improved for the EXP group as reflected by the significant Treatment effects found after the WBEI. The Treatment effects obtained are briefly highlighted, before being discussed together with the significant changes over time for the outcome measures. Primary outcome measures will be addressed firstly, followed by the secondary outcome measures.

Treatment effects for both Interference Ratio and Interference Difference scores reflected the improved primary outcome of EF. The EXP group experienced significantly less interference of irrelevant, yet meaningful stimuli during completion of the WSC due to the influence of the WBEI to improve IC. Their increased Stride velocity translates to faster walking speed or stepping on the targets. This implies faster Processing speed and improved selective attention, to switch more easily and quicker between the tasks of the WSC.

The Treatment effect found for HRQoL, suggested the EXP group had a more positive perception of their overall Quality of Life after the intervention. In contrast to the CON group, the EXP group could maintain their level of Physical Function during execution of daily tasks when compared to the significant deterioration over time for the CON group. In addition, the WBEI contributed to a significant loss of body mass, resulting in lower BMI for the EXP group, whereas both measures remained relatively unchanged for the CON group.

The following primary outcome variables improved only in the EXP group: Functional Capacity (6MWT) and Gait speed.The EXP group significantly improved in the following secondary outcome variables: Global Cognition, Depressive Mood, overall HRQoL and body mass ($P < 0.05$).

Furthermore, findings suggested the WBEI in combination with a programme of regular relaxation and educational activities, which included creativity and group socialisation within the community, could be ideal for preserving and enhancing certain aspects of EFs, Mobility and HRQoL. These findings will be discussed in more detail in the following sections.

A discussion about participants' descriptive characteristics and differences between groups found at pre-test is followed by the primary outcome and secondary variables, in same consecutive order as in chapter five (Results). Limitations, suggestions and practical applications are followed by acknowledgements.

6.2 PARTICIPANTS

Descriptive characteristics of both groups did not differ significantly except for age and average weekly Rate of Perceived Exertion (RPE) scores. Difference in age at pre-test indicated the CON group was on average 4 years older than the EXP group. Taking into account that normal ageing results in accelerated brain volume decline of 1-2% per annum, after the age of 55 years (Erickson et al., 2013), it could be estimated that the average older age of the CON group might have resulted in lower brain volume (estimated 4-8% difference) compared to the EXP group. Bherer and colleagues (2013) attenuated that EFs of Processing speed, attention, planning and reasoning diminish with reduced brain volumes which affect dual-task activities (ADL). Reason for the difference in RPE scores was due to the nature the intervention.

Even though not statistically significant a tendency was observed that the CON were physically more active when compared to the EXP group according to their RAPA score (P = 0.07). Both groups had participants of quite high BMI levels at pre-test. Increases in visceral adipose tissue, especially around the abdominal area are associated with normal ageing (Chodzko-Zajko et al., 2009). The mean values of BMI for each group were obtained and used to determine classification. According to the classification of BMI, the EXP group would be classified as obese whereas the CON group would be classified as overweight. Obesity or being overweight during the mid-life stage (53 – 64 years) increases the risk of EF decline, impairments in Mobility and even mortality before reaching 65 years (Cooper et al., 2014). Cardiovascular and neurological decline, together with a propensity in musculoskeletal weakness, may be associated with participants (50 – 65 years) in the current intervention (Smith et al., 2012; Jin et al., 2015; Prince et al., 2015). Additionally scores obtained at pre-test for Global Cognition indicated the EXP group might have had none to probable mild cognitive impairment (MCI) whereas the CON group were classified as normal (Nasreddine et al., 2005).

6.3 PRIMARY OUTCOME VARIABLES

6.3.1 Executive Functions

a) Attention and Working memory

The ability to retain and recall auditory stimuli, followed by verbal expression of the information necessitates attention, as measured by the Digit Span Forward (DSFW) (Julayanont et al., 2012). Reverse reporting in the Digit Span Backward (DSBW), requires an active, conscious process to manipulate digits in reverse order before articulation. This process is more demanding, relying on central EF processing to execute successfully, with transient memory and WM, enabling of the digits (Julayanont et al., 2012; Pearson et al., 1999; Baddeley et al., 1986).

Neither Fixed effects nor any significant change over time for both the EXP and CON group were found. Groups also did not indicate any difference at either pre- or post- test. Therefore, the WBEI programme did not have a significant exercise training effect on the EXP group's WM and attention, as measured by the two components of the Digit Span test. This is accordance with the results found by Albinet et al. (2016) who conducted a WBEI to assess the effect of aerobic exercise on EF performance (adults aged 60 – 75 years). The programme spanned 21 weeks, inclusive of a Mid-test at ten weeks. The test used to assess attention and WM, was similar to the DSFW and DSBW test used in the current study. It differed only in letters of the English alphabet being substituted for digit symbols. This test is considered valid and sensitive in assessing WM and attention (Natu & Agarwal, 1995).

Nevertheless, Albinet et al. (2016) also did not find improvement in WM and attention at Mid-test, although significant improvement was reported WM after 21 weeks. According to Albinet et al. (2012) it took longer to reach significant improvement in EFs, for example WM and related attention, compared to cardiovascular fitness. Therefore, it can be deduced the total duration of the current study (8-weeks), might have been too short to facilitate changes in WM and attention.

This conclusion of Albinet et al. (2016) contrasts with the meta-analysis of Colcombe and Kramer (2003) who reported larger cognitive improvements for older adults, with short programmes (4 – 12 weeks) than intermediate programmes (4 – 6 months). It seems that selective cognitive components could improve in a shorter time and some EFs need at least 5 months (Albinet et al., 2016) to be altered.

Similarly, the attention domain as measured with the MoCA, also did not indicate significantly improved attention. Perhaps neurogenesis (renewal and activation of older neural circuits) may take longer aerobic training periods of at least 21 weeks. Therefore the current non-significant results obtained for either the EXP or CON group over time, on both Digit Span tests tests could indicate the influence of an 8-week WBEI on attention and WM has not been represented in results obtained from the Digit Span tests. Perhaps the results might have been different if the intervention period was longer.

Further WBEI studies addressing this phenomenon might be advantageous. At the time of conducting this study, no WBEI addressing EF and cognitive functionality was found using the Digit Span tests (symbol) to assess attention and WM. However, different test protocols used to assess attention and WM, delivered significant results (Fedor et al., 2015; Sato et al., 2015).

b) Cognitive flexibility

Cognitive flexibility (CF), WM and IC are interwoven components of EF. The Trail Making Test (TMT) A and B predominantly assess CF during the switching of tasks (set-shifting). Trail Making Test part A (TMT A) mainly requires visual-perceptual abilities for speedy and accurate completion. This visual scanning of information, complemented by selective visual attention, relies on visual Processing speed. The MoCA also includes a mini Trail Making Test in the visual spatial and EF domain. An improvement by the EXP group has been visible in this domain of the MoCA, as well as the TMT A.

The Trail Making Test part B (TMT B) primarily reflects WM, and then CF (Sánchez-Cubillo et al., 2009; Bowie & Harvey, 2006; Arbuthnott & Frank, 2000). Consequently, the TMT derived composite scores provide additional indexes that are more sensitive for CF specifically (Bowie

& Harvey 2006; Arbuthnott & Frank, 2000). These composite scores include the TMT difference score (TMT_D = TMT B – TMT A) and ratio score (TMT_R = TMT B/TMT A). Lower ratio scores pertaining to TMT B indicate improvement. The composite scores diminish visual-perceptual and Working memory requirements, therefore providing relatively better indicators of executive control abilities (Perianez, 2007; Arbuthnott & Frank, 2000).

The significant difference at post-test between the groups for TMT A (Refer to figure 5.8), indicated the EXP group completed the task more speedily at post-test compared to the slower performance and deterioration of the CON participants. However, the improvement in performance over time by the EXP group was not of statistical significance, and Fixed effects did not indicate any significance. Therefore this improved performance could therefore not be referenced solely to the effects of the WBEI. Yet, their improved scores in the TMT A are suggestive of faster visual Processing speed and attention. Fedor et al. (2015) also reported a significant ($P < 0.01$) improvement on TMT A due to a WBEI. This suggests a one week combined water-exercise programme may even improve visual-perceptual abilities and visual Processing speed. Futhermore, the enhanced visual spatial abilities of the EXP group (as found in the MoCA) corresponds to the findings of Sherlock (2014), whom reported significant visual spatial Working memory after a 10 – week moderate intensity WBEI with older and elderly adults. Faster visual scanning of stimuli could possibly be attributed to enhanced visual attention.

Previous WBEI research reported increased cardiorespiratory output and elevated cardiovascular fitness levels (Fedor et al., 2015; Bocalini et al., 2008; Broman et al., 2006; Takeshima et al., 2002) improves blood flow to both the hippocampal region, which is primarily associated with memory, and the pre-frontal cortex. Blood flow and blood pressure have not been measured during this study. It was speculated that a possible increase in bloodflow due to the increased cardiorespiratory input (which correlated with the EXP groups 6MWT results) might have influenced neurogenesis and structural alterations in the pre-frontal cortex (Bielak, 2010). These areas are vital in the modulation of EF (Diamond, 2015; Diamond, 2013; Miyake et al., 2000; Erickson et al., 2013; Sherlock et al., 2013).

The additional benefit of water-immersion and the continuous exposure to the multiple directional flow of water when immersed, relate to increased cortical activation and corticospinal activity (Sato et al., 2015, 2013, 2012). Results of these investigations reported enhanced performance in Global Cognition (similar to this current intervention), as well as sensorimotor integration, combined with somatosensory processing. Furthermore, visual spatial attention and -Processing speed have been linked to cerebral cortical activation (Sato et al., 2013; Sato et al., 2012). These findings suggest the current EXP group possibly had heightened cortical activition due to being immersed in water, as well as due to exposure to sensorisomatic stimulation of the entire body (Sato et al., 2015, 2013, 2012). Therefore, it is suggested that immersion in water to sternum height, together with the multiple directional flow of water and higher activation in the cortex during exercise, could contribute to the improved visual attention results and Processing speed of the EXP group. Both Sato et al. (2015) and Fedor et al. (2015) established that a WBEI could enhance visual attention.

A large difference between groups was observed at TMT B pre-test. This could possibly be ascribed to the significantly older age of the CON group. Atrophy in the thalamus is associated with ageing (Philp et al., 2014). The thalamus is responsible for Processing speed, WM, as well as CF. Therefore, it could be expected that the CON group would complete the TMT B at a slower speed with pre-test. However, they significantly improved their completion times over 8 weeks. The substantially significant faster completion of TMT B, were quite unexpected. These results may be ascribed to the significant differences observed between the two groups at pre-test as well. Further research comparing similar age groups would be of an advantage.

Their improvement in CF might imply the time-matched-activities (TMA) enhanced the CON group's cognitive skills (Wang et al., 2012). Futhermore, Perrochon et al. (2013) elucidated that with the increase in age, the older adult relies more on cognitive reserve, which are more established neural networks, being more resistant to disruption or neural damage (Park Reuter-Lorenz, 2009). Increased neural network pathways (according to the scaffolding theory) could have influenced their motor-control and visual-perceptual skills (Arbuthnott et al., 2000; Park-Reuter & Lorenz, 2009). Park and Reuter-Lorenz (2009) argued that compensatory mechanisms to maintain the brain are associated with advancing age. Damaged pathways and/or neural circuits in the brain could be circumvented, new ones are formed and existing circuits are strengthened. Therefore as age advances, bi-lateral activation of neural circuits within the frontal lobes increase, which could be associated with increased attention (Cabeza et al., 2004). This is advantageous to the older adult who cognitively benefits through engagement of both the left and right frontal hemispheres of the brain. Since these lobes primarily host EFs (Diamond & Ling, 2016; Diamond, 2015; Diamond; 2013), it may clarify the CON group's improvement, being older than the EXP group.

The EXP group exhibited a 16% increase in task-switching ability in completion of the TMT B. Although non-significant, a strong tendency in performance increase was shown ($P = 0.07$). Results suggested the WBEI was not beneficial to significantly improve CF for the EXP group as measured by the TMT B. However, this finding does not correspond with the WSC results of this group. Perrochon et al. (2013) suggested a possible lowered sensitivy to indicate cognitive abilities with pen-and-paper cognitive tests.

However, the derived composite scores for the CON group indicated their significantly improved ability to switch between tasks, whilst holding and retrieving information from WM. They were less affected by the conflicting stimuli of the letters. They could not only switch between tasks (TMT B) in shorter time, but also hold and retrieve information faster, compared to their pre-test performance. However, at the time of writing, only the study of Fedor et al. (2015) was found using TMT as a measuring tool and did not report positive changes on TMT B. Comparison of results with other studies could not be done. However, Nyberg et al. (2012) emphasized the contributory effect of cognitive interventions to reduce or even improve age-related changes in the brain to maintain itself and preserve EF. This might be the reason for the CON group's positive results and warrants further investigation.

c) Inhibitory control

Motor performance and cognitive ability include IC, WM as well as CF. Since the WSC is a complex, visual spatial dual-task test in which a motor response is required to execute spatial navigation in task completion, these three main EFs of IC, CF and WM (Diamond, 2013) are all inherent to the cognitive demands required to navigate the WSC (Perrochon et al., 2013). The

WSC by Perrochon et al. (2013) is based on the initial Stroop Colour–Word Interference task which is a test of mental inhibition of selection and elicits the Stroop interference effect. This effect is mainly associated with IC and is centered on the two complementary processes of interference and facilitation. The former reflects the intrusion in WM of conflicting or irrelevant, though meaningful information, which might cause interference in information processing to affect task completion negatively (Sharma and Babu, 2017; Diamond, 2013). The latter is when one cognitive performance enhances the other and therefore facilitates information processing to enable task completion (Jensen, 1968).

i) WSC – Total duration (TD) and Stride velocity (SV)

The WSC findings indicated significant Time effects for all conditions, including the composite score. Since alpha was set to ($P < 0.05$) only a high tendency for a Treatment effect ($P = 0.05$) was found for Condition 3, as well as a tendancy for a Treatment effect ($P = 0.06$) in the average score for the two incongruent conditions. Nevertheless, Post-hoc analysis revealed significant improvements in the spatio-temporal gait variables, as reflected in the faster response times of both Total duration (TD) and Stride velocity (SV) which will be discussed below.

Both groups were more efficient in information processing on the congruent Condition 2 and incongruent Condition 4 (word) in TD. Medium size effects were found in Condition 2 for both groups, with very large to medium size effects for the EXP and CON group respectively obtained in Condition 4. However, only the EXP group reflected faster Processing speed and more effective IC on the complex Condition 3 (colour), to suggest better selective attention as well as IC, resulting in their faster responses in navigating the WSC. The mostly large to very large size effects, together with the significant difference between the two groups after the intervention (medium effect sizes), indicate the EXP group could successfully and faster meet the cognitively challenging and spatial-temporal demands of the WSC on these conditions for Total duration.

Furthermore, in comparison to the CON group, the EXP group could recruit their executive resources during cognitive and gait interaction more efficiently for facilitation and IC, for both TD and SV. To successfully meet the cognitively challenging and spatial-temporal WSC demands for both TD and SV, participants in both groups had to ameliorate the interference effect of the colour/word tasks. The different components of this dynamic process as explained by various authors (Sharma and Babu, 2017; Diamond, 2013; Perrochon et al., 2013; Park and Reuter-Lorenz, 2009; Bull & Scerif, 2001) can be broadly highlighted as follow: improved Inhibitory control (IC) is linked with quicker task-switching (CF) responses to step on the appropriate targets; meanwhile, stepping instructions (on either colour or word) must be kept in the verbal Working memory (WM), while reading the written text on the consecutive targets; stepping instructions and processed information is constantly updated in verbal WM, while directing attention and navigating the correct stepping order takes place through updating of visual spatial WM of the shapes and colours. However, due to the EXP group's faster cognitive response and stepping reaction times they ultimately outperformed the CON group in both TD and SV after the WBEI.

Although the CON group covered slighty further distance per second on both the congruent and incongruent walking conditions for the SV gait variable, they could not muster significant improvement. This is in contrast to the EXP group, whose faster stepping reaction times were significant on both incongruent conditions with medium size effects over the 8-week period. However, their IC performance on Condition 3 only revealed a strong tendency for significance at post –test. Nevertheless, the more sensitive derived scores (interference ratio and interference difference score) with large size effects, reflected EF performance (IC). The EXP group was therefore able to better suppress irrelevant information (colour or word) on the incongruent trials, with less processing delay and therefore quicker responses. Perrochon et al. (2013) underscored the importance of reduced SV as a possible indication of motor-cognitive fragility in older adults. A slow down in gait would afford the older adult more time to focus on the environmental stimuli due to age-related diminishing Processing speed (Bherer et al., 2013; Park & Reuter-Lorenz, 2009; Colcombe & Kramer, 2003). This enables the older adult to gain maximum visual information (Perrochon et al., 2013; Di Fabio et al., 2005) as a protective, compensatory mechanism. The non-significant performance on TD and SV for the CON group might be ascribed to such compensation.

On a noteworthy point, both groups used facilition significantly for the SV gait variable to navigate the targets. During the two incongruent walking conditions for SV, both groups used the cognitive task of reading the word to enhance their performance. Reading text is considered more practised than colour naming (Jensen, 1968). Therefore the pre-potent or automatic stimulus will be favoured before the more effortfull, incongruent stimulus (Park and Reuter-Lorenz, 2009). Jensen (1968) argued the habit of word-reading is dominant over colour naming and the interference effect can be ascribed to response competition between the two habits of unequal strengths. However, whereas the cognitive load on both incongruent conditions did not exceed the EXP group's executive resources, it did exceed the CON group's executive resources, leading to failure in the latter group for significantly improving their stepping reaction times for the SV gait variable.

The EXP group's ability to faster navigate the WSC, their quicker recognition and more effective inhibition of the irrelevant information (processing information), while adapting their gait during the more complex incongruent conditions (Total duration: Condition 3; Stride velocity: Condition 3 and 4), propose the WBEI was successful in improving EF of IC. Aditionally it can be suggested they improved not only IC but also CF, WM and higher-order cognitive processes as emphasized by Perrochon et al. (2013). These included i.e. Processing speed, attention, as well as their visual spatial navigation abilities. Similar findings have been reported in the WBEI conducted by Albinet et al. (2016). Their WBEI also included combined exercise components, i.e. aerobic training, resistance training and flexibility in a study spanning 21 weeks. Significant improvements in EFs of IC, CF as well as WM were found. However, at 10 weeks (Mid-test) significant improvements were only obtained for IC. The authors further reported improvements in attention, CF and WM were revealed after a prolonged exercise programme (21 weeks). They underlined the fact that the nature of their combined exercise programme was responsible for improvements. Interestingly, their CON group who performed flexibility and stretching exercises also improved in WM and CF after 21 weeks, yet not in IC at all.

Other WBEIs have also been associated with improved Global Cognition (Sato et al., 2015), memory and attention (Fedor et al., 2015; Sato et al., 2015), Processing speed, stepping reaction times (Elbar et al., 2012; Sato et al., 2015), visual spatial Working memory (Sherlock et al., 2014) as well as Gait speed and lower leg muscle strength (Sato et al., 2015). In the non-exercising water-based study by Schaefer et al. (2015) it was found that auditory, cognitive errors were less when immersed in water at xiphoid level, even though participants were in a stationary position. Importantly, this author emphasized that less interference (improved IC) was found in the water environment in comparison to the same auditory tasks performed on land. Therefore, it is suggested the EXP group's overall improvement in TD and SV on the WSC corresponds to the various abovementioned WBEI results. Likewise, it is proposed that this current WBEI led to increased EFs and associated higher order cognitive skills.

The EXP groups' improved TD and SV in comparison to the CON group, translated to faster visual spatial navigation, more efficient visual-spatial WM and other EFs, as they maintained their course of action on the WSC, reflecting their ability to resist interference (Perrochon et al., 2013). Working memory plays a co-ordinating and directing role in various EFs and associated skills such as visual spatial ability (Sharma and Babu, 2017; Bull and Scerif, 2001). The hippocampus is the primary area associated with WM (Becker et al., 2016), whereas EFs are primarily hosted in the pre-frontal cortex (Bherer et al., 2013; Diamond, 2013). Both these areas are sensitive to the beneficial structural and functional alterations due to exercise (Albinet et al., 2016; Erickson et al., 2015; Voss et al., 2011; Park and Reuter-Lorenz, 2009).

With its unique properties and the multi-directional flow upon immersion, a water-based exercise environment affords an increase in sensorisomatic stimulation which enhances cerebral cortical- and motor-cortex activation (Sato et al., 2015; 2013; 2012) which might play a contributing role in EF associated motor tasks, especially visual spatial tasks. Furthermore, due to increased cardiovascular output, higher blood flow due to exercise (Albinet et al., 2016) can be expected, in particular to the hippocampal region (Sherlock et al., 2013) and the pre-frontal cortex associated with EFs (Bherer et al., 2013; Diamond, 2013). The latter statements might be responsible for the EXP group's significantly improved performances compared to the

CON group after the WBEI. However, blood flow was not measured and should be taken into consideration during future research.

Aerobic exercise, with accrued fitness levels, particularly executed in a water training environment, may lead to enhanced pre-frontal cortex activation. The latter is particularly linked to the recruitment of scaffolding neural circuits in natural ageing (Park & Reuter-Lorenz, 2009). This activiation results in enhanced EFs and therefore WM, selective attention and improvement in visual spatial navigational abilities (Perrochon et al., 2013; Albinet et al., 2012) as reflected in the EXP group's accomplished performances.

Lastly, a brief overview is necessary of possible explanatory reasons for the CON group's selective WSC improvements. Decreased Processing speed, possibly associated with natural ageing (Bherer et al., 2013) is reflected in their lack of IC in selective components of both TD and SV. However, Park and Reuter-Lorenz (2009) stated that verbal ability is more protected from age-related decline and could explain the CON group's better performance on Condition 2 and Condition 4 (word) for TD. Furthermore, these authors underlined that increased age is associated with a larger network of compensatory scaffolding neural circuits. Therefore, being older it can be expected that these compensatory mechanisms could possibly have contributed to their performance. However, although no significant difference between groups at pre-test was found, it should be noted that individual variability with regards to cognitive reserve and brain maintenace (Nyberg et al., 2012; Park and Reuter-Lorenz, 2009) could be at play. Even though the CON group did no physical exercise during the intervention, their time-matched-attention (TMA) activities were cognitivly enriching and according to Wang et al. (2012) and Zeiden et al. (2010), mindfulness-, relaxation- and leisure activities, as well as socialization, may enhance selective EFs,

6.3.2 Mobility

a) Functional Capacity

A significant Time -, Group - as well as a Treatment effect was found, with no difference between groups at pre-test, but a significant difference at post-test. Gait speed during the 6MWT significantly improved in favour for the EXP group only, showing a Time-, Group – and Treatment effect of significance. Functional Capacity during the 6MWT gave an indication of the extent to which participants managed to maintain their intensity levels, providing a snapshot of their current cardiorespiratory efficiency, as well as overall muscle endurance. Although participants may walk at their own preferred Gait speed, they were encouraged to walk as fast as possible, to indicate their Functional Capacity and endurance. The current intervention demonstrated the efficacy of the 8-week WBEI to improve the EXP group's fitness levels and gait performance (i.e. Gait speed) under a walking condition. Lower limb strength has been linked to increased Gait speed (GS) as well as Processing speed (Sato et al., 2015).

Walking speed is key when measuring autonomy and functional status (Kearney, 2013) of the older adult. It correlates with Global Cognition scores (Demnitz et al., 2016). This statement rings true in the current study, as only the EXP group simultaneously improved their Global Cognition scores and exhibited faster Gait speed, as measured with the 6MWT. Several authors found that slower Gait speeds correlate with a dysfunctional EF system or underlying pathologies (Demnitz et al., 2016; Sanders et al., 2016; Perrochon et al., 2013). Gait speed is even used as a predictor for mortality (Feigin et al., 2016; Demnitz et al., 2015; Martinez et al., 2015; Clouston et al., 2013; Hardy et al., 2007).

Furthermore, diminishing habitual Gait speed have been associated with ineffective Processing speeds (Feigin et al., 2016; Demnitz et al., 2015; Martinez et al., 2015; Clouston et al., 2013; Hardy et al., 2007). This implies the EXP group improved Processing speed, as suggested with the improved 6MWT due to the WBEI, therefore reducing fall risk during habitual walking (Sanders et al., 2016).This result correlates with the finding of the WSC as well. Faster stepping and reaction times of the EXP group, as measured in the spatio-temporal gait variable SV on the WSC, could be indicative of improved Proscessing speed

Several WBEIs included additional testing measures other than the 6MWT to assess aerobic capacity, and also found increased cardiorespiratory capacities (Albinet et al., 2016; Bocalini et al., 2008; Broman et al., 2006; Takeshima et al., 2002), or walking ability as measured with the iTUG (Sato et al., 2015; Martinez et al., 2015). Only one study was found to investigate changes in Gait speed after a WBEI. Positive results were reported for a 10-metre walk test. A recent WBEI conducted by Sherlock, (2014) reported slight improvement in the EXP group, but a greater improvement (in distance covered) for the CON group, whom also took part in 10-weeks comprising of educational sessions. Emphasis was placed on the need for more water-based exercise interventions (WBEI's), in correspondence with the view of the current study. The limited number of WBEI's, addressing adults aged 50 to 64 years especially, impede data comparison with various resources.

b) Single-task Mobility

Similar to the improvement in Gait speed during the 6MWT by the EXP group, Gait speed (Gait speed $_{(iTUG)}$) and Total duration as measured with the 7m iTUG also improved for the EXP group over time. These results imply participants in the EXP group were able to maintain dynamic gait interaction and improved Processing speed (Sanders et al., 2017, 2016; Welmer et al., 2014; Donoghue, et al., 2012; Finkel et al., 2007). However, an interesting result found was the enhanced performance by the CON group. They also completed the single-task iTUG significantly faster, and their significant improvement in Gait speed implies enhanced EF of Processing speed over a shorter distance. This might be due to cognitive reserve (Perrochon et al., 2013; Nyberg et al., 2012). However, their relaxation and educational activities throughout the 8-weeks, could have contributed to their enhanced performance, as highlighted by Wang et al. (2012). The cognitive complexity and integration from multisensory input is associated with intellectual stimulation, social engagement and leisure activities, even without any physical exercise involved (Wang et al., 2012). It could result in improved cognitive performance and neuroplasticity may have contributed to their improved Gait speed. Another possible reason for the improved Total duration and Gait speed results of the CON group, are those found by Zeidan et al. (2010). The latter reported mindfulness and relaxation activities could improve overall EF, including Processing speed. Further research clarifying these results should be conducted to investigate if mindfulness or creativity and regular social interaction could beneficially contribute to enhance EFs without engaging in exercise. It has been suggested by authors that the latter could alter EF due to neuroplasticity in EF brain regions (Warren et al., 2016; Hyland et al., 2015; Alders, 2012).

Another intriguing result was the significant increase in time when CON participants returned to their original seating positions at post-test. Only a Time effect was reported for the Turn-to-sit (TTS) assessment under the single-task walking condition. At pre-test, the two groups did differ significantly and after the 8-week intervention (TTS) assessment, revealed faster times. This suggests the CON group possibly had less postural control during this turning variable compared to the EXP group. It might be explained by their lack of physical exercise during the intervention. The CON group did not have the benefit of a WBEI which improves lower limb muscular strength (Sato et al., 2015) or postural control (Elbar et al., 2012; Bocalini et al., 2008). The CON group significantly increased their Gait speed during the iTUG, ST walking condition at post-test. Perghaps this could have increased momentum from standing to sitting and therefore influenced results. The ideal however, when sitting down from a standing position is to always maintain postural control in order to prevent falling and the risk of injury. Therefore, this increasing in speed from standing to sitting down was not necessarily a positive result. The iTUG is a valid and reliable test and have been used across the world in a vast amount of literature.

It is possible the EXP group could have better maintained trunk stability due to the younger age bracket, as loss in Physical Functioning naturally decrease with age (Welmer et al., 2017; Bento et al., 2015; Cooper et al., 2014). Maintaining postural control and trunk stability during dynamic activities (i.e. rising or descending down to a chair) is imperative to prevent falls and injuries (Covill et al., 2016; Kearney et al., 2013; Plummer et al., 2012). Unfortunately, only one WBEI addressing gait variability was found at the time of writing. Hale et al. (2012) conducted a 12-week WBEI, similar to the nature of the current intervention. The WBEI programme included moderate aerobic intensity, resistance, balance and flexibility components whereas the CON group participated in non-exercising educational activities inclusive of creative activities and regular social interaction. This author also did not found results as measured with the iTUG and considered it unexpected as well. Similar to the TMT B and TMT_D results, the significant baseline differences could also have influenced the current results. However, future research studies should investigate iTUG, TTS results amongst similar age groups.

Additionally, an 8-week land-based high-intensity aerobic programme, inclusive of resistance and balance training, investigated gait performance (Stride velocity, Stride time, Stride length, Stride time variability, Stride length variability) with the iTUG (Wang et al., 2015). Similar to the findings of Hale et al. (2012) and this study, no significant improvement was reported for spatiotemporal gait parameters. Perhaps the intervention period of the current study was insufficient or additional mechanisms might be at play and require further research.

c) Dual-task Mobility

Similar to the improved Total duration under the single-task condition, CON participants completed these walking conditions with divided attention significantly faster. The EXP group did not show a significant change. However, calculated Gait speed under DT condition improved significantly for the EXP only. This implies the WBEI was successful in EF development. Improved Gait speed, specifically under dual-task conditions, aligns with enhanced EF performance as described earlier. Considering the nature of ADL accompanied with walking, this improved Gait speed suggests participants in the EXP group would be able to maintain Gait speed in the presence of interference more efficiently compared to the CON group.

It seems neither the WBEI nor the TMA programme altered the other spatiotemporal gait parameters, turning variables, postural transitions or calculated Dual-task Cost%. This is in accordance with a high-intensity land-based, combined exercise programme of Wang et al. (2015) who suggested an 8-week intervention period is insufficient, as they tested participants at both 8 weeks and 12 weeks. Positive changes in all gait parameters were found at the latter. However, no WBEI assessing dual-task gait could be found and the WBEI of Hale et al. (2012) only assessed single-task walking with the iTUG.

Perhaps a more challenging dual-task activity would have produced different results. This view is supported by Perrochon et al. (2013) and was the motive behind the development of the Walking Stroop Carpet.

In conclusion, in contrast to results as measured with the iTUG, it might be postulated that the WSC discriminated more sensitively for EF performance assessment when evaluating walking ability. The results obtained with the adapted WSC used in the current study corresponds to the suggestion of Perrochon et al. (2013), who stated the WSC seems to be more sensitive to EF performance assessment when evaluating walking ability or screening for MCI.

6.4 SECONDARY OUTCOME VARIABLES

6.4.1 Global Cognition

Global Cognition, as assessed by the Montreal Cognitive Assessment (MoCA), can be separated into seven subdomains i.e. Visual spatial, Naming, Attention, Language, Abstraction ability, Memory and Orientation (Julayanont & Nasreddine, 2017). In the current study there was no Treatment effect, or significant differences between groups at either pre- or post-test for this variable. However, over the 8-week period Global Cognition improved significantly with 8% for the EXP group, compared to the 3%, non-significant improvement of the CON group. Similarly, the Visual spatial and Memory scores of the EXP improved significantly, with no Treatment effect as well.

It is possible that the improvement in Global Cognition, Visual spatial and Memory scores of the EXP might have been to either the integrated cognitive and motor co-ordination (Lam et al., 2012) required in WBEI programme, or increased cerebral blood flow to the hippocampus and pre-frontal cortex due to cardiac output (Albinet et al., 2016; Cole et al., 2011; Bielak, 2010). Aerobic exercise and its cardiovascular benefits are linked to neuroplasticity and improvement in cognition as well as EF (Diamond, 2015; Voelcker-Rehage et al., 2013; Hillman et al., 2008). However, blood flow or blood pressure was not measured, and results cannot be ascribed solely to the nature of the current WBEI. Nevertheless, linking the current results to other WBEI, whom also found improved Global Cognition results due their WBEI, the results of the

EXP group in the current study might be explained to the neural benefits and improved cognition due to the nature of the exercise programme: a combination of aerobic and resistance components (Albinet et al., 2016; Bherer et al., 2013; Park & Reuter-Lorenz, 2009) at high intensity (Hsu et al., 2016; Fedor et al., 2015) with activities consisting of bi-manual co-ordination and sequential learning (Diamond and Ling, 2016; Verstynen et al., 2012; Niemann et al., 2014; Erickson et al., 2015, 2014).

At the time of writing two water-based exercise programme, which combined aerobic and resistance training, found improvements in Global Cognition. The study conducted by Fedor et al. (2015) assessed adults aged 50 – 80 years, overlapping with the age group of this study. However, Sato et al. (2015) assessed elderly participants (≥ 69 years) underscoring the continuous, adaptive capacity of the ageing brain (Park & Reuter-Lorenz, 2009). The 10-week water-based aerobic exercise programme of moderate intensity, inclusive of progressive resistance training, by Sherlock (2014), did not find significant improvement for Global Cognition, but for spatial working memory. It should be noted that the CON group in Sherlock (2014) also partook in weekly educational, relaxational exercises and interactive social engament activities.

The combination of aerobic and resistance training components are crucial for cognitive function (Erickson et al., 2016; Diamond, 2015; Diamond, 2013; Man et al., 2010). The latter may possibly be considered the recommended standard for neuroplasticity and EF enhancement (Sherlock et al., 2013). The water-based programme used in this intervention was based on the abovementioned principles. Therefore, Global Cognition could have improved due to the nature of the programme, however there was no Treatment effect.

Results of sub domains, including the improvement of the CON group's Abstraction ability and their deterioration in the Naming and Orientation domains are discussed below.

6.4.1.1 Visual spatial and EF

Similar to the results of Global cognition, Visual spatial ability showed only a significant Time effect, with a 13% significant improvement over time for the EXP group. This domain was tested by a modified Trail Making Test, copying of a three-dimensional cube and a clock-drawing section (Julayanont et al., 2012). Visual spatial ability allows an individual to interpret complex forms, shapes or angles (Julayanont et al., 2012).

Again, since there was no Treatment effect, it was speculated that the current water-based programme could have contributed to significantly enhancing Visual spatial ability. Participants were able to move safely move around in the water, constantly taking limb position into account and co-ordinating them accordingly (Niemann et al., 2014; Verstynen et al., 2012; Erickson et al., 2015, 2014) thus maintaining postural balance while executing the movement required.

Furthermore, the beneficial effect of a water-based aerobic training programme and its correlation with heightened activation of the pre-frontal cortex, is linked with efficient cognitive and EF functioning (Albinet et al., 2016). Thus, the results are in accordance with the scaffolding mechanisms activated in the pre-frontal cortex, to compensate for age-related alterations in the ventral visual cortex (Park & Reuter-Lorenz, 2009). These changes may contribute to diminishing visual Processing speed, but further comparative WBEI research studies is needed to shed light on the matter.

6.4.1.2 Naming

No Fixed effects were observed. However, the significant deterioration over the 8-week period for the CON group in this domain was unexpected. Differences at pre- and post-test were insignificant. This suggest that the CON group could either not process the visual features or shape of these animals, or experienced impairment in semantic memory. Semantic memory is associated with retrieval of information from earlier experiences, recalling abstract information with regards to names of places, people or objects (de Jager et al., 2010). It could be argued that individual mood or behavioural changes (i.e. lack of sleep or emotions on the testing day) might have influenced performance. However, this significant deterioration reflected the entire group’s performance and is contradicting to the self-perceived results of the CON group’s SF-36 QoL questionnaire. The CON group significantly improved over time in their General mental health domain as well as their Vitality (energy/fatigue) domain. The MoCA is a valid and reliable test and have been used widely

However, a reasonable explanation for this change within only 8 weeks could not be declared, adding that the specific study design could not control for possible external reasons that was not measured in the study. Therefore further research might be of an advantage.

6.4.1.3 Language

Both groups improved their Language ability over time, though it was not significant and therefore no Treatment effect has been revealed. Nevertheless, the 17% improvement of the EXP revealed a high tendency at Post-test in this domain (P = 0.06) in favour of the EXP group, compared to the 6.6% change of the CON group.

The language domain is associated with left cerebral hemisphere function, allowing individuals to understand and/or communicated efficiently (Clark et al., 2010). This subdomain consists out of two subdivisions. The first, for instance, require repetition of complex sentences. Good levels of attention and concentration, including Working Memory (EFs) is required, in order to remember these words and sentences (Julayanont et al., 2012). The second subdivision assesses letter fluency which not only requires that the person inhibit irrelevant words (Inhibitory control), but are also dependent on WM (Julayanont et al., 2012). The language domain could be influenced by education levels (Meyers et al., 2000) whereas letter fluency is highly associated with EF and could be influenced by depression (Crawford, 2005). However, descriptive results indicated neither education nor Depressive Mood could have influenced results.

6.4.1.4 Abstraction

The CON group's abstraction ability (i.e. conceptual thinking; pairing of words as done in the MoCA) improved significantly within 8 weeks, resulting in a significant Time effect but no differences between groups at pre-or post-test. This unexpected result might be ascribed to age-related increase of brain activity within the pre-frontal lobes, as supported by the scaffolding theory of ageing and cognition by Park and Reuter-Lorenz (2009). Furthermore, the combination of relaxation exercises with visualisation and mindfulness techniques, might be contributing factors to the CON group's performance and supported by Tang and colleagues (2012). The authors investigated mindfulness-based interventions (that entailed an increase in awareness of one's thoughts, emotions as well as actions) and stated that these activities are associated with increased pre-frontal cortex activity as well as changes in heart rate variability. Executive Function efficiency and WM capacity, required to perform cognitive tasks, have been noted to improve by brief (4 days) mindfulness exercises (Zeidan et al., 2010). The significant improvement of the CON group's abstraction ability is contradicting to the significant deterioration of their Naming ability in the MoCA. The question remained whether mindfulness exercise could enhance both semantic and Working memory (WM). According to de Jager et al. (2010) there are four separate memory systems as explained in Chapter two, page 13. Working memory is specifically associated with words, numbers and sounds whereas Semantic memory is associated mostly with abstract concepts or Naming of objects. Perhaps these memory systems also work in a compensatory manner (similar to the EF domains) where stronger domains compensate for the weaker ones.

6.4.1.5 Memory

Similar to Global Cognition, Fixed effects remained unsignificant. However there was a significant improvement of 16% for the EXP group only. The difference between the two groups at both pre- and post-test was insignificant. The type of stimuli used in memory testing classifies it as either verbal or non-verbal memory. The immediate recall of five words, followed by a five minutes delay (Julayanont et al., 2012) qualifies this subdomain as verbal memory test. Working memory entails recalling words, numbers or sounds, with storage lasting between 30-60 minutes (de Jager et al., 2010).

It should be noted that the EXP group have achieved lower scores than the CON group at pre-test, therefore it seems like the possibility of improving is much higher compared to the CON group. However, the CON group's performances did not differ significantly from those of the EXP group at pre-test, and the CON group's performance remained relatively stable over the 8-week period.

A regular aerobic exercise programme and its positive influence on memory have been confirmed by previous research (Fedor et al., 2015; Sato et al., 2015; Sherlock, 2014). Other researchers also found improvement in fitness might run parallel to improvement of memory (Komulainen, 2010; Angevaren et al., 2008) which could explain the improvement in of EXP group only as participants in the CON group were sedentary during sessions. Therefore, it can safely be concluded the current WBEI programme might have yielded positive results in delayed memory recall in accordance with previous water-based studies (Fedor et al., 2015; Sato et al., 2015). In contrast with the current 8-week exercise programme, Fedor et al. (2015) only conducted a one-week study whereas Sato et al. (2015) executed a 10-week programme and also found improvent in Memory.

6.4.1.6 Orientation

The significant deterioration in this domain by the ‘older’ CON group was quite unexpected, as it occurred relatively fast over a short period of time (only 8 weeks). No significant Fixed effects were visible, but the CON group differed significantly from EXP group at post-test. Nevertheless, ageing have been associated by structural changes, atrophy of neurons within the frontal lobes as well as the caudate (Turgeon et al., 2016) and could influence one’s internal clock and perception of time (Särkämö et al., 2014). Therefore, a contributing explanation to declined performance was the significant age difference between groups at Pre-test. The EXP group was on average four years younger than the CON group. Since the cortico-striatal circuits (which supports sense of time), are are also affected by normal ageing (Merchant et al., 2013) Turgeon et al. (2016) further stated, that increased temporal orientation variability could also be affected and perhaps a possible preclinical marker of dementia (Julayanont et al., 2012)

6.4.2 Depressive Mood

Only a Time effect was reported, and at pre-test, both the EXP and CON groups’ scores indicated a mood status of none to mild depression (Carey et al., 2014), not differing significantly from one another. Both groups improved their mood over time, causing a 21 %, significant difference at post-test between the groups. This indicated that other factors apart from the WBEI may have influenced the current results. The EXP group significantly experienced enhancement (36%) in their self-perceived levels of mood whereas the CON group improved with 21% (although not significant). The improvement in the EXP groups' Depressive Mood status, after the water-based exercise programme, could be linked to the elevated secretion levels of the neurotransmitter serotonin (Lamar et al., 2013), due to aerobic training, which facilitates improved mental health and lowers depression (Gripshover & Markman, 2013; Salmon, 2001).

Ageing itself is associated with vulnerability and susceptibility to psychological disorders such as depression (Feigin et al., 2016; Lamar et al., 2013) it has been noted as an associated risk factor for cognitive impairment (Rock et al., 2014). In severe depressive cases, a broad spectrum of impairments on neuropsychological measures of EF have been reported (Snyder et al., 2013) therefore eligibility criteria for the current intervention excluded individuals with a score higher than 9.

Unfortunately limited water-based interventions, addressing Depressive Mood in adults aged 50 – 64 years were found at the time of writing. Therefore further research would be of an advantage to compare changes in Depressive Mood not only during mid adulthood, but also amonght various age groups. Nevertheless, the 16 to 22 week water-based exercise study on adults (55 – 75 years) with osteoarthritis (OA), as conducted by Belza et al. (2002), also reported improved Depressive Mood due to their exercise programme. This is in accordance with similar results obtained by the water-based exercise intervention of Taheri and Irandoust (2014), Abinet et al. (2016) and the current study. Futher water-based research, exploring exercise interventions on apparently healthy adults of between 50 to 64 years are required.

6.4.3 Health-related Quality of Life (HRQoL)

The SF-36 was used to answer the secondary aim. Discussion of subscales PF-10, GMH, VEF and GHP follows. The EXP groups' significant improvement (over 8 weeks) in total SF-36 scores, Time effect, Treatment effect and difference between groups at Post-test reflected their improved self- perceived HRQoL. The additional significant improvements obtained over time in the subscales SF (Social functioning), GMH (General mental health), RLEP (Role limitations because of emotional problems), VEF (Vitality (energy/fatigue), and GHP (General health perceptions), with significant differences between groups, suggests the WBEI programme may be useful for improving HRQoL in older adult. The results were indicative of an improvement in the secondary outcome variable.

Furthermore, it has been suggested that HRQoL might be predicted by Inhibitory control (IC) and Cognitive flexibility (CF) (Forte et al., 2015).The significantly improved IC results (Refer to Table 5.4 and section 5.4.1.1, c) as obtained by the EXP seems to correlate with the statement made by Forte and colleagues (2015). These authors investigated which EFs interactively contributed to mental health as well as HRQoL in healthy older adults aged (65 – 75 years). They concluded that the efficiency of IC predicted HRQL of the older adult, as it relies on the individual's capacity to maintain effective action, irrespective of interference by irrelevant stimuli during Activities of Daily Living (ADL's) or walking (Diamond and Ling, 2016; Jensen, 1968). Most ADLs, for example walking, require complex and dual-tasks (DT) to be performed. Therefore, the ability to perform physical DT activities (i.e ADL's and walking) not only relies on IC and CF, but also predict HRQoL (Forte et al., 2015). The enhanced self-perception of the EXP groups' HRQoL in response to the WBEI, may also be attributed to improved performance in certain aspects of EF and Mobility, as explain later in this chapter.

Self-perceived Functional Mobility (PF-10) was found to deteriorate significantly over the 8-weeks in the CON group. This seems to be contradictory to their significantly improved scores on the VEF (Vitality/energy) and GMH (psychological distress and psychological wellbeing) subscales. Participants in the non-exercise programme, indicated a subjective view of themselves as energetic, with positive psychological wellbeing at post-test. According to Visser et al. (2015) subjective vitality levels might be a marker for general physical and psychological health in older adults (64 – 91 years). The relaxation exercises of the CON group could have influenced VEF and GMH scores, as mindfulness has been associated with improved sleeping rhythms -and quality (Visser et al., 2014). Therefore, their participation could translate to improved quality of sleep, feeling rested and less fatigued. Improved scores obtained in both the CON group's VEF and GHP might also stem from the pleasurable and therefore rewarding aspects of their TMA activities (Perry, 2008) in a social setting (Davidson, 2012), simultaneously enhancing mood (Alders, 2012; Perry, 2008; Hass-Cohen and Carr, 2008).

Resultant cardiovascular fitness, as reflected by the significant improvement in Functional Capacity and dicussed later in this chapter, may have augmented general well-being and QoL, especially in a WBEI environment (Albinet et al., 2016; Fedor et al., 2015). Albinet et al. (2016) reported that being physically active could improve specific psychological outcomes of wellbeing, such as QoL as well as Depressive Mood. In contrast, the water-based exercise intervention by Sherlock on older adults (60 – 90 years) did not find significant improvement in QoL and was unexpected and unexplained whereas Hale et al. (2012) also did not find significant improvement in QoL after a 12-week water-based exercise programme. However, these results were ascribed to the usage of self-reported questionnaires the possible inclusion of aerobically active participants (aged 55 – 65 years) which could have influenced results.

The enhanced sense of Vitality and more positive interaction in Social functioning (SF) for the EXP group were echoed in the GMH, RLEP and GHP results. This suggests the participants in the EXP group perhaps may have experienced less limitation due to emotional or health problems after participating in the exercise programme. Albinet et al. (2016) postulated according to results found in their WBEI (adults aged 60 – 75 years), that exercises leading to increased fitness levels improve EFs. This may cause an increase in psychological wellbeing and QoL which enhance confidence levels. Therefore, the EXP groups' improvement in both HRQoL and EFs (Global Cognition and the Walking Stroop Carpet) (refer to the Primary outcome variables), could have contributed to general functioning and fulfilment of roles, in which participants expressed themselves to be less limited, albeit their work-, social- or personal environment.

With regard to the results obtained in the PF-10 subscale and contrary to the significant deterioration of the CON group, the EXP group did not perceive themselves to decrease in their ability to execute physical activities (i.e. bending, kneeling, climbing stairs, walking, carrying groceries) and indicated a plateaued effect.

However, the positive results obtained for the EXP group in the 6MWT (as an objective measurement of Functional Capacity and Gait speed) indicated a more objective improvement in physical functioning (to be discussed later). Nevertheless, exercise has been noted to preserve and maintain Functional Mobility, thereby increasing levels of QoL in later life stages (Levasser et al., 2015; Mahishale et al., 2015). Similar reports of improved physical functioning have been obtained in other WBEI (Sato et al., 2015; Hale et al., 2012; Bocalini et al., 2008; Lord et al., 2006; QoL: Sherlock, 2014; Hale et al., 2012).

6.4.4 Body Mass Index & Body mass

The significant Time effect, Treatment effect and reduction in BMI as well as body mass of the EXP group over time, indicated the WBEI was successful for these outcome variables. None of the groups differed significantly at pre-or post-test for both BMI and body mass.

Being submersed in water and training within this viscous and buoyant nature, challenges the cardiorespiratory system (Sherlock 2014; Sherlock et al., 2013; Cole et al., 2011), as well as creates a safe environment, allowing for adherence to training principles which are crucial for weight loss. This significant drop in BMI and body mass over 8 weeks for the EXP group was similar to results found in other WBEI programmes (Albinet et al., 2016; Fedor et al. 2015, Sato et al. 2015; Broman et al., 2006; Tsourlou et al., 2006).

The 4% reduction in BMI as obtained by participants in the EXP group suggests the current WBEI programme may be useful to reduce weight in the older adult. Futhermore, it might suggest the EXP group are less at risk after the intervention for future EF decline, compared to the CON groups unchanged weight status. The CON group were still classified as being overweight after the current intervention, probably due to the nature of there non-exercise programme.

Nevertheless, Cooper et al. (2014) stated that being overweight, especially prior to 65 years, increase the risk of poorer EF performance in future but aslo risk a future filled with cardiovascular and/neurological diseases (Ratey et al., 2011; Bherer et al., 2013; Alhurani et al., 2016). Therefore it is crucial for the older adult (regardless of age) to engage in habitual combined exercise programmes that promote weightloss and improve functional Mobility (Chodzko-Zajko et al., 2009).

6.5 LIMITATIONS AND RECOMMENDATIONS

The serious shortage of WBEIs addressing EF as an entity and its influence on functional Mobility of the older adult (50 – 64 years) is of concern. Decrements in the neurocognitive domains of EF and Mobility are already evident in apparently healthy older adults (50 – 64 years). A physically active lifestyle which includes aerobic-, resistance- and flexibility exercises is therefore a necessity, especially for the older adult. Emphasis need to be placed on the water-based exercise environment, regarding the type, duration and intensity of the programme to facilitate optimal improvement in EF and Mobility, related to this age group.

Due to lack of testing assistants, logistic- and financial constraints, a large representative sample from the Western Cape was not possible. A small sample size was recruited. Although single-blinded randomization took place, generalizability of the intervention results to the bigger population of the Western Cape as a whole may be limited.

Possible changes in physical and mental activities, outside the intervention that could influence results, needs to be controlled. These measures need to be other than verbal and/or written confirmation. The current results of the CON group's RAPA status were unexpected, as this group attended a non-exercising programme. The interactive social engagement, together with the enriched nature of their relaxation programme, might have contributed to their boosted perception of vitality and energy. This may have led to their altered activity status during the 8-week period.

It is recommended that the role of mindfulness- and relaxation techniques, as well as the influence of interactive socialization sessions with, or without creative activities, be investigated. Considering the possible influence of these activities on EF, as well as HRQoL and Depressive Mood, it might be utilized as an alternative strategy with the older adult who already experiences cognitive and/or Mobility impairment, even in increased severity of impairment. Furthermore, it affords greater accessibility to those individuals who might not have access to a pool.

6.6 CONCLUSION

Although ageing is inevitable, it is not necessarily an illness. Structural brain shrinkage and deteriorating neural integrity, with associative decrements in EF and Mobility, present the greatest challenge in natural ageing to the older adult. However, the brain maintains and preserves itself through continuous renewal, reorganization and repair throughout the individual's life span. It is suggested that aerobic exercise of self-perceived high intensity can enhance neuroplasticity and neurogenesis with accrued fitness. A water medium, with its unique properties, may be considered a safe exercise environment for the older adult. It lends itself to being ideal when executing a combined exercise programme which includes cognitively and physically challenging components, even for the impaired older adult.

The findings from this water-based exercise intervention indicate it can contribute as preventative and ameliorating measure against age-related cognitive decline, to afford optimal improvement in aspects of both EF and Mobility of the older adult. The results indicate a neurocognitive and physically challenging exercise programme, is recommended for both EF and Mobility improvement. In addition, increased Health-related Quality of Life, decreased Depressive Mood and an improved ability to execute activities of daily living are associated benefits of a water-based exercise intervention. However, results of the time-matched activities group are suggestive of the important benefits a non-exercising and cognitively enriching programme in a social environment may provide to the older adult. The effect of these activities on the EF system, dual-task walking ability, visual spatial navigation ability and gait integrity, may encourage future research with regard to the balance needed between water-based exercise on one hand and relaxation and educational activities.

To the knowledge of the current researcher this is the first WBEI to address EF as an entity and its simultaneous relation to Mobility, using the dual-task motor-cognitive and visual spatial navigational measure of the Walking Stroop Carpet (WSC). The WSC seems to be a more sensitive test to measure EF of Inhibitory control, encompassing the related EFs of Working memory, Cognitive flexibility, as well as associated higher-order cognitive skills. The results could translate to visual navigation ability within the real environment. Identification and implementation of WBEIs and activity programmes that foster enhanced structural and functional brain integrity, might bring hope even for the older adult. Therefore, the sting of inevitability of age-related decline in EF and Mobility is removed.

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Appendices

Table of Contents

A. National Research Foundation (NRF) Bursary

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B. Ethics approval letter

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Approval Notice
New Application

08-Mar-2016
Grobler, Syndy S
Private Bag 19063
Matieland

Proposal #: SU-HSD-002062

Title: The Influence of an 8-Week Water Intervention on Executive Functioning and Mobility in Healthy Older Individuals.

Dear Miss Syndy Grobler,

Your **New Application** received on **25-Feb-2016**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **07-Mar-2016** and was approved.
Please note the following information about your approved research proposal:

Proposal Approval Period: **08-Mar-2016 -07-Mar-2017**

General comments:
Extensive provisions were made to ensure that healthy participants are recruited, such as pre-screening and physicians' approval. Recommendations of the DESC has been applied, especially the lowering of the age parameters of prospective participants. Informed consent forms are in place and proof of insurance provided.The REC wishes the researcher all the best with her research project.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**SU-HSD-002062**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Included Documents:
Expedited request_ S Grobler 2016.pdf
REC: Humanities New Application

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

C. Recruitment flyer

D. Recruitment Newspaper advertisement

ARE YOU
50 to 64 years old?

RECRUITING
RESEARCH VOLUNTEERS

Volunteers must be independent in
Activities of Daily Living
(e.g. dressing, bathing, shopping)

Recruiting until the 25th of April 2016

The aim of the study is to determine if
water exercises have an influence on
certain cognitive functions.
Study includes free aquarobics!!

INTERESTED VOLUNTEERS TO CONTACT
SYNDY GROBLER

Email: syndy@papillonhealth.co.za
syndyvandermerwe@gmail.com

Facebook:
https://www.facebook.com/syndy.merwe

Cell: (084) 548 - 7915

E. Informed consent form (English) *Afrikaans available on request

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CONSENT TO PARTICIPATE IN RESEARCH

THE INFLUENCE OF AN 8-WEEK WATER INTERVENTION ON EXECUTIVE FUNCTIONING AND MOBILITY IN HEALTHY OLDER INDIVIDUALS.

You are asked to participate in a research study conducted by Syndy Grobler (BA (Hons) Sport Science; 19893663) and Dr. Karen Welman (PhD in Sport Science; 13091115) from the Department of Sport Science at Stellenbosch University. The results obtained in this study will contribute towards a thesis, in order to meet the requirements of a Master's Degree in Sport Science, and will be published in a scientific journal. You were selected as a possible participant in this study because you meet the inclusion criteria of the study as a healthy older individual and have been cleared by your primary physician to participate in this study.

1 PURPOSE OF THE STUDY

The purpose of the study is to determine the influence of an 8-week water exercise programme on executive functioning* and mobility in healthy older individuals. Executive functioning is an umbrella term for mental skills that support activities of daily living like meal preparation, basic grocery shopping, dressing, bathing, financial planning, decision making or even paying bills

2 PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

After completing this informed consent form, questionnaires will have to be completed prior to participation. This is to establish if you meet the study's inclusion and exclusion criteria. This will entail general questions with regards to your health and quality of life, cognitive/mental abilities and depressive mood will be asked. Should you fall into the inclusion criteria, as determined by the researcher, you will be contacted to schedule your first testing visit. The first and last testing visit are exactly the same, and none of the tests are invasive or will hurt you. It is estimate that each testing visit will take approximately 60 to 90 minutes. After collecting information about your height, weight, Body Mass Index and resting heart rate; you will be asked to complete three computer executive functioning tests, two different 7m walking tests while doing one task and also more than one task i.e. walking Stroop task and 'Time-up and-Go' test, respectively. These test assesses your ability to walk and move about (i.e. mobility) with and without distractions. You will also complete questionnaires on how you perceive your own mobility. Please note that all tests will be explained carefully upon participation. This document provides only a short description of the tests that will be conducted. All tests and completion of questionnaires will take place during the week before the start of the study.

The first 8 weeks will be your own control period, in which we will present information and activities sessions to stimulate your mind without any exercise. Hereafter you will be reassessed again the week prior to the start of the 8 weeks water intervention, as well as after the 8 week water intervention.

During the 45 to 60 minute exercise sessions we will ask you to rate your perceived exertion after proper instruction which should help you to train in the correct heart rate zones. For the water intervention we will like you to join the sessions three times a week. The water exercises will take place in two heated indoor pool at the indoor pools in Vishoek. The depth of the pool is convenient in the way that you can stand comfortably at any time if required, but deep enough to cover up to the mid chest area of an average height person.

3 POTENTIAL RISKS AND DISCOMFORTS

The research is of low risk, and the researchers will do everything within their powers to prevent any injury, discomfort, and inconvenience. Pool areas are completely adapted to ensure a safe training environment. There are railings on each sides of the pool with safe and accessible, easy entrance and exit areas.

Additionally, your training intensity will be carefully monitored with a heart monitor to ensure that you do not over train. The only discomfort participants might experience is a feeling of fatigue initially after training sessions or some muscle stiffness due to the training. This is a normal side-effect of exercise and should subside within 24 to 48 hours as the body adapt physically and physiologically towards the training. The research assistants involved are registered Biokineticists and the main researcher is a qualified aqua instructor with a Level 3 First Aid qualification.

None of the tests are invasive, however if you do feel tired during any of the tests you may rest until you feel ready to resume the testing or if you want to withdraw you may do so. During the mobility testing chairs will be available and mats if you lose your balance. In the event that you injure yourself whilst participating in the research, the researcher has obtained Liability and Personal Indemnity Insurance through the University of Stellenbosch (Mr W van Kerwel; [redacted]). All research assistants and Biokineticists adhere to the latter indemnity requirements.

4 POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

There are no direct benefits in participating in the study. Your participation will contribute to the pool of knowledge. However you may experience indirect benefits such as relaxation, and possible improvements in your fitness after the water intervention. At the end of the research project you will be invited to a presentation on the findings of the study.

5 PAYMENT FOR PARTICIPATION

You have volunteered to participate in this study, therefore there are no fees that will be paid out and your participation in this study is free of charge.

6 CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Only the researcher and the study supervisor will have access to your data. To ensure anonymity your name will be coded. Your personal details and information collected during the study will be kept safely on a password protected computer. By no means will any personal identifying information be made available to any member, organisation whom is not directly involved with data collection and analysis of the study. We are planning to publish the research however only average data will be reported and no connection will be made to you or your personal details. Similar during the study presentation to which you will be invited to you only average data will be reported.

7 PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. For instance if you have been untruthful about your health status, do not attend at least 80% of the water exercise sessions and missed more than two consecutive sessions, or if you engage in any new exercise activities (including rehabilitation exercises) or adjusted your current recreational exercise intensity since the first baseline testing.

8 IDENTIFICATION OF INVESTIGATORS

For any questions or concerns about the research, kindly contact the principle investigator Ms. Syndy Grobler at 084 548 7915 (syndy@papillonhealth.co.za), or the study supervisor Dr K.E. Welman at 021 808 4733 ([redacted]).

9 RIGHTS OF RESEARCH PARTICIPANT

You have the right at any time (whether with or without cause) to withdraw from the study without you any consequences. In addition, do you not waive any legal claims or rights as a result of your participation in this research study. Should any questions arise from the participant's side, regarding their rights, please contact Ms Malene Fouché [mfouche@sun.ac.za; 021 808 4622] at Stellenbosch University's Division of Research.

10 SIGNATURES: RESEARCH PARTICIPANT OR LEGAL REPRESENTATIVE

The information above was described to me____________________________ by Syndy Grobler in either English or Afrikaans, or both upon my requested language preference. I hereby confirm that I fully understand all the information in this document and if needed Syndy Grobler translated the information to my satisfaction. An opportunity was provided with ample time to ask questions. All answers upon these questions were answered to my satisfaction. I hereby consent voluntarily to participate in this study and am fully aware of the terms, conditions and procedure applicable to this study. I received a written copy of this form.

NAME:_______________________________**SIGNATURE:**__________________

11 SIGNATURE OF INVESTIGATOR (RESEARCHER)

I declare that I explained the information given in this document to_________________________________. He/she was encouraged and given ample time to ask me (Syndy Grobler) any questions. This conversation was conducted in [Afrikaans/English] and no translator was used.

NAME:_______________________________**SIGNATURE:**__________________

DATE::____________________________

F. Rate of Perceived Exertion (RPE) Scale

RPE	**Rate of Perceived Exertion Chart on a scale of 0 – 10** Monitoring your exertion (How tired do you currently feel?) “Aim for the star!”	
10	**Maximum Effort:**	Completely out of breath, unable to talk and intensity level is completely impossible to maintain.
9	**Very Hard/ Vigorous:**	Very difficult to maintain intensity. Cannot speak a single word. **TO BE AVOIDED !!**
8	**Hard:**	Experiencing a shortness of breath. Heavy breathing. **Can still speak one/two words - NOT a sentence**. Might feel intensity level is on the verge of becoming uncomfortable if you train any harder.
7	**Hard:**	Experiencing a shortness of breath, BUT **still able to speak a sentence.**
6	**Moderate:**	Easy breathing and will be able to maintain for a while. Still able to speak without any difficulty. Will be able to maintain intensity for a while.
5	**Moderate:**	Easy breathing and will be able to maintain for at least 60min. Able to engage in full conversations without any difficulty.
4	**Light:**	Just starting to break sweat. Very easy breathing and will be able to maintain for hours. Able to engage in full conversations without any difficulty.
3	**Light:**	Very comfortable, not sweating. Easy breathing. Able to engage in long conversations without any difficulty.
2	**Minimum:**	Barest exertion. Barely moving any limbs of the body. Involve activities with sitting - or lying down (i.e. driving in a car, watching television, sitting at a desk etc.).
0-1	**Resting:**	Not moving at all (i.e. indicates sleeping).

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G. Water-based exercise intervention: Training principles, protocol, music, safety and costs involved

Principles	Program design
Setting **Pool characteristics**	WBEI: Water-based only (two, local, heated indoor pools) easy access, and plenty parking space. Both pools were similar in depth (xiphoid level), average temperature ($\bar{x}$ 31 - 33 ºC) which were manipulated according to the weather. During very cold mornings and evenings (initial water temperature would be approximately 33ºC - participants complained water was too cold upon entry if it was set on 31ºC. **Note**: The temperature would remain slightly higher when needed only during warm up (7-minutes). The temperature would be decreased to the arranged 31ºC halfway through the warm up by the pool owner. Both pools had graded steps for entry, safety hand railing for comfortable entry, and one internal length-wise, and aluminium against one side. Safety, anti-slip rubber mats over all walking surfaces, sufficient enclosed dressing space with chairs and one toilet, were deemed a necessity for rental agreement.
Time-line (April – June 2016)	Pre-testing occurred within 14 days prior to the 8-week intervention. Post-testing occurred directly the day after the 24th session. Intervention occurred over an 8-week period (Winter season; temperatures could reach 15 ºC - 25 ºC) REF
Pool time-slots & **Rental cost per hour**	Most participants could only attend classes before (08h00) and after work (18h00) and considered peak-hour for pool owners. Pool availability was extremely limited. Several time-slots had to be generated to avoid losing participants (work and/or travelling allowance and traffic). Morning to noon slots (08h00 – 12h00): Monday, Wednesday, Friday : 08h00 – 09h00 (R180/60 min * 3 sessions = R 440) Wednesday, Friday : 11h00 – 12h00 (R200/60 min * 2 session = R 400) Afternoon and early evening slots (12h30 – 18h30) Fridays : 17h30 – 18h30 (R200/60 min * 1 session = R 200) Saturday : 14h00 – 15h00 ; 15h00 – 16h00 (R200/60 min * 2 session = R 400) Sunday : 14h00 – 15h00 ; 15h00 – 16h00 (R200/60 min * 2 session = R 400) Early to late evening slots (18h15 – 19h50) Monday and Wednesday : 18h15 – 19h50 (R180/60 min * 1 sessions = R 180) **TOTAL cost (1-weeks): (11 sessions p/wk = R2020)** **TOTAL cost (8-weeks): (R2020 * 8-weeks = R16 160)**

Attendance and class presentation	Participants always attended the same time-slots, unless if there was an emergency (n = 2). These worked-in sessions have been executed at a different day, but still within 2 hours of the initial, allocated time. Attendance records and self-perceived intensity (RPE 0-10 scale; Appendix M) have been recorded for each session. Training days alternated with one resting day. The principal researcher and class presenter is a qualified exercise specialist, have ample water-aerobic and group training experience (12 years); have; excellent knowledge regarding exercise modifications according to individual mobility limitations and fully qualified in LEVEL 3 first aid. Presentation by a single person ensured the exclusion of possible instructor-technique variability.
Blinding status; Pool group-sizes	Concealed, single-blinded, randomised control design. Participants included had were able to walking independently and still executed general ADL independently. Participants were divided in smaller groups of 3 to 10. Both pools allowed a movement-space of approximately 1-metre radius per person.
Equipment (monitors, radio and music), safety, incidence and injury reports	Usages of heart-rate monitors were not possible logistically or financially. Based on the possibility of electronic failure (i.e. Sherlock 2014) self-perceived intensity is deemed reliable and valid and exclude possible contamination of results to mechanical or electronical failures. A portable (battery-powered) radio (30cm x 15cm) was used, music playing through blue-tooth via a Samsung S7 smartphone. This ensured music or volume could be manipulated, while the presenter walked around, ensuring correct executions of technique, intensity adjustments (depending on the phase of the session). The complete absence of electric current near the pool area ensured instructor, participant and facility safety. Floors were very wet due to jumping, splashing, having fun and exiting the pools. The class presenter (principle researcher of the study) was fully qualified and certified with a LEVEL 3 First Aid (never required during the 8-week intervention) qualification. The presenter was always present 15min prior and posts each session - ensuring participant safety, addressing intervention-related questions. Music of the 60's, 70's, and 80's were mostly used to encourage exercise performance according to beats per minutes (beats/min) with additional modern items as well. Only one low blood-sugar incidence were observed and resolved during an early morning session (Week 1, session 2). The participant did not consume break-fast. The situation was quickly and sufficiently resolved by providing two super C chewing tablets and a handful of peanuts (participant not allergic to peanuts). Education regarding healthy eating habits pre-and post-training were communicated during week 1. Participants were encouraged to try and eat a small/light breakfast at least 60 min prior to exercise session.

	Thorough education (regarding self-perceived pain, mobility limitation, own physical capacity and handling of injuries) were given at each session (See below). Technique of execution were considered a priority. The principal researcher would walk around the pool, while cuing movements correcting exercise techniques and continuously monitored participants. The "safety speech" follow: Since session 1, prior to the warm-up phase, the presenter always asked the same questions and gave the same speech (3-5 min): *"Are there any injuries, bone or muscle-related feeling of discomfort that I should know about prior to this session?* *Remember, should you feel any sudden pain during training – please let me know immediately by putting up your hand and stopping that particular movement. Depending on the limb/muscle affected, you could continue with a slow jog (similar as we do in the first 2 minutes of the warm-up, or you may stop moving altogether). Nevertheless, I will approach you immediately while the rest of the class continue, and depending on the nature of the pain, I will quickly adapt your execution or give you an alternative exercise modification. Safety and remaining injury-free is first priority. If the pain or discomfort persist, stop exercising that particular muscle/ limb completely. You may continue with these additional exercises (not affecting the injured area) or you are welcome to exit the pool and wait until I can assess the situation after class, and refer you to the Biokineticists or Physiotherapist if needed.* *Please remember for the remaining time of this intervention; should you feel unsure or self-conscious, about any perceived soreness (regardless if it was due to the training), you may approach me personally. I am always present 15min before and after the allocated training hour. Alternatively, you are welcome to communicate telephonically (although I will request a personal assessment regarding movement limitation prior the next session. Have fun guys and let's get started!" (Warm-up music and cuing started).*
The Pilot study (prior to intervention)	A trial study (10 days) preceded the final exercise program and commenced prior to pre-testing. Family members (55 – 76 years), friends (49 – 53), certified Virgin-Active aqua-aerobics instructor (38 years) (not part of the study in any other way), a Biokineticists (36 years) and Physiotherapist (28 years) took part in the trial study. None of the pilot-study members were involved in the 8-week WBEI or had any contact with the WBEI participants until completion of post-testing. The main characteristic of each session was to achieve a self-perceived intensity level of 7 to 8 on the taught RPE scale. Music of the 60's, 70's, and 80's were mostly used to encourage exercise performance according to beats per minutes (beats/min). This progressive, high aerobic-specific intensity program, included training components as set out in the literature, aiming to potentially enhance Executive functions, Functional Mobility and quality of life (Adults between 50 – 64 years): Different speeds of resistance training (according to each individuals capacity), localised slow-speed muscle-resistance, balance activities, 3 games to ensure enjoyment, socialization, continuous verbal feedback, technique demonstration and encouragement throughout the session. Session duration : 45 minutes Session frequency: 3 x p/wk Session intensity: High intensity according to the self-perceived, RPE scale 0-10 (Refer to Addendum C)

Exercise principles, main characteristics, progression	Intensity was safely increased with approximately 5% every 7 – 14 days as muscle adaptations and physiological responses took place. Resistance have been manipulated by extending limbs and aiming to move slightly faster. However, muscular resistance could only be safely manipulated increasing the speed of movement up to a certain point. Thereafter, cardiovascular intensity have been increased by fast jogging on the spot or punching movements while jogging. These are short-lever movements and can safely be executed according individual capacity. Moving in the water provides a natural resistance due to the viscous nature associated with water. NO equipment were used. All sessions have been designed using a block formation (3 – 6 endurance exercise with/without interval and depended on the perceived exertion levels verbally communicated: not exceeding RPE of ± 7/8 out of 10 “overall tiredness”; reference to these on the next page. Most movements followed in a sequential format, encouraging the individual to remember the next movement/sequence to follow. However, the moves were considered quite basic and fast jerky changes or moving in multiple directions, within one block of sequence were avoided. One movement approximately lasted between 8-16 counts before a slight variation of that movement, or change of direction commenced. All participants’ intensity progression seemed to occur at a relatively equal pace. The benefits of cardiovascular fitness and adaptations associated with a combined exercise program started to take place within the first week. All participants could execute more advanced movements and/combination during the last 2 weeks, and stamina increased tremendously. More sets of jogging, jumping jacks and punching moves have been incorporated and for longer periods during week 8. The minimum aerobic interval period during week 1 ranged between 5–8 seconds; week 2: 10–12 seconds; week 3-4: 15 – 18 seconds, progressing to 20 seconds after at least every 16 counts only in week 7-8.
	Warm-up/ cool-down exercises (7 min) (16 counts each) Setting up posture Marching on the spot, arms bent 90º al the elbow Marching on the spot, hand palms pushing forward Marching on the spot, arms slightly bent but swing forward and back ward and alternating with reaching left and right Marching with knee lifts and knee extensions forwards and laterally Travel/stepping forward, backward, sideways Cross-country skiing (opposite arm and leg reach forward; Lateral step with leg curl (Single, double, alternate), arms reach forward and pull back, squeezing shoulder blades together); Stretching (quadriceps, hamstrings, calves, shoulders, biceps, triceps)

	Endurance exercises with cardiovascular intervals (25min) Single leg side-kicks with opposite leg doing a slight jump; alternative single leg side-kicks with opposite leg doing a slight jump <u>Advanced:</u> Double leg side or forward kick (week 6 -8) Optional arm variation moves (punch, scoop, swaying, reach and pull) Single, double, alternate frontal and lateral high knee-lifts <u>Advanced:</u> Side or forward kick without touching the bottom of the pool (week 6 -8) Optional arm variation moves (punch, scoop, swaying, reach and pull) Twists with hands on the hips left to right with jump. <u>Advanced:</u> Keep arms bent at 90º do execute move faster or do full rotations (week 6 -8) **The following exercises could be used for endurance and interval exercises (do these as fast as you can)** Jogging on the spot, elbows bent 90º *(Note: used to bring the heart rate safely down if exertion exceeded RPE score 8; jogging @ warm -up speed or according to participants preferred speed)* Jogging with knees rising to naval height Punching forward,, side-wards, upwards, downwards, combination with fist Punching forward,, side-wards, upwards, downwards combination with fingers facing up (pushing) Jumps and reach out of the water Jumps with fast flicking motion of hands and fingers from the writs. (forward, upwards, combination) Half jumping jacks (arms above water) or if under the water with arms slightly bent Knee lifts and kick combinations (single-or double kicks or a combination – dependent on the fatigue level of the group) Treading water (no contact with the pool bottom) **Slow and controlled resistance: Core, back and leg strength (5 – 7min)** These exercises have always been executed at least 3-4 sets between 10 to 15 (last 5 min prior to stretching) at slow and controlled speeds. Chest fly exercises, reverse chest fly exercise were executed standing with a widen base of support, turning the palm towards the direction of movement (cupped hands). Leg raises to the front, side and backwards direction or combination. Abdominal exercises were standing crunches with opposite knee lifts, in week 2 alternating between each leg and faster speeds, progressing in week 3-4 to both knees lifting towards chest, and/or combined with single leg tucks, and eventually tucking in both knees, extending the legs first forwards, laterally and backwards – all done without touching pool's surface (Week 7-8)

H. Time-matched-attention (TMA) activities

A period of 15minutes were allocated prior to each 30min session, allowing sufficient time for greeting and settling down and was separate to the additional session. Therefore, total session duration was scheduled 45 minutes. The CON group had the option to participate in a complimentary WBEI (8 weeks) after Post- testing.

	Session 1 (30min)	**Session 2 (30min)**	**Session 3 (30min)**
Week 1	Orientation, Introduction, Discussion of activities, topics of wellness etc. within the programme.	Measuring Resting Heart Rate (RHR), Blood pressure. Teach how to take your own heart rate. Taking each other's RHR.	Orientation to relaxation and presentation about the importance of posture (guest speaker was a physiotherapist).
Week 2	Taking RHR again, Playing a game similar to musical chairs, remained seated. Taking RHR again and discuss within groups the influence of relaxation activities on heart rate and overall well-being.	General introduction of the guest speaker and speech. Relaxation and breathing therapy presented by a registered psychologist. (Participants will listen to relaxing music and lie on their backs, eyes closed) (20min).	Group divided in small teams. Short balancing games followed (10 – 20 seconds each): Balance in tandem stance (e.g. Heel of left foot touch toes of right foot). Forward, backwards and sideward walking on a line on the toes and heels – while having access to railing against the wall). Eating of cake; group discussion and views on: importance of creating enjoyment.
Week 3	Informative talk on nutrition by qualified nutritionist.	Adult colouring in activities, relaxing music, socialisation.	Measuring grip test and playing stick-figure paper game (Group divided in 3).
Week 4	Measuring RHR again – see if it changed in two weeks. Birthday celebration – snacks and refreshments – provided by members and presenter.	Informative Ted Talk video presentation on handling stress. Group discussion followed how to spot the warning signs (symptoms associated with stress)	Relaxing musing playing in the background. Playing with clay: participants taught to make small (5cm x 5cm) and easy clay animals (cat/dog/sheep/cow).- On Grade 3 level. Social engagement optional
Week 5	Guest speaker: Eye tracking introduction and presentation. This activity is a technique used to track an individual's eye movements if presented with stimuli on a computer (E.g. a picture of an angry face is shown. The eye tracker locates the initial point of focus).	Reminder about the Trauma Release Exercise (TRE) Bring rubber mats and water. Ted talk video about self-esteem, different personality types, different ways of handling stress responses. Individual uniqueness and variability w.r.t handling stress and conflict. Men versus woman: How are we alike yet so different? Participants really engaged and had fun during this session	Trauma Release Exercise (TRE) and the importance of introduction. Presented a power point presentation about TRE and did some fun multi-tasking activities. (E.g. talking while tapping fingers, then add a clap and movement of limbs). Practical was only 15min).
Week 6	PowerPoint presentation: The importance of solitude – but the danger associated with too much of it. How to find a balance.	Fun drawing activity with mirrors.	Presentation and activities based on wellness and well-being (Presented by a specialist) Guest speaker. Refreshments available and one on one engagement with guest speaker were optional.

Week 7	Casual relaxing walk on the boardwalk at the local beach. Session ended with eating ice-cream /optional drawing /magazine reading activity.	TRE Practical session presented by registered exercise specialist. Participants relaxed, lying on their mats and executed breathing and TRE exercises.	Watching a video clip on origami projects, viewing existing types of paper art across countries, searching for hidden faces in paintings, making simple paper frog (Grade 2 level) 5-10min.
Week 8	Presentation and practical regarding breathing techniques, information on stress and anxiety management (Summary on what was presented during the last week) Measuring RHR again and compared to findings in week one.	Relaxation and breathing therapy (Participants listened to relaxing music, lie on their backs, eyes closed).	Final session. Eating cake, snacks etc. Discussing their option to attend water training would only commence after Post-testing. General socialization.

Ia. Rapid Assessment of Physical Activity (RAPA)

How Physically Active Are You?

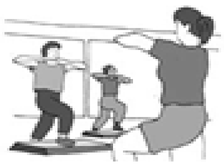
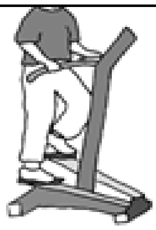
An assessment of level and intensity of physical activity

Rapid Assessment of Physical Activity

Physical Activities are activities where you move and increase your heart rate above its resting rate, whether you do them for pleasure, work, or transportation.

The following questions ask about the amount and intensity of physical activity you usually do. The intensity of the activity is related to the amount of energy you use to do these activities.

Examples of physical activity intensity levels:

Light activities - your heart beats slightly faster than normal - you can talk and sing	 Walking Leisurely  Stretching  Vacuuming or Light Yard Work
Moderate activities - your heart beats faster than normal - you can talk but not sing	 Fast Walking  Aerobics Class  Strength Training  Swimming Gently
Vigorous activities - your heart rate increases a lot - you can't talk or your talking is broken up by large breaths	 Stair Machine  Jogging or Running  Tennis, Racquetball, Pickle ball or Badminton

How physically active are you? *(Check one answer on each line)*

			Does this accurately describe you?	
RAPA 1	1	I rarely or never do any physical activities.	Yes ☐	No ☐
	2	I do some **light** or **moderate** physical activities, but not every week.	Yes ☐	No ☐
	3	I do some **light** physical activity every week.	Yes ☐	No ☐
	4	I do **moderate** physical activities every week, but less than 30 minutes a day or 5 days a week.	Yes ☐	No ☐
	5	I do **vigorous** physical activities every week, but less than 20 minutes a day or 3 days a week.	Yes ☐	No ☐
	6	I do 30 minutes or more a day of **moderate** physical activities, 5 or more days a week.	Yes ☐	No ☐
	7	I do 20 minutes or more a day of **vigorous** physical activities, 3 or more days a week.	Yes ☐	No ☐
RAPA 2 (3 = Both 1 & 2)	1	I do activities to increase muscle **strength**, such as lifting weights or calisthenics, once a week or more.	Yes ☐	No ☐
	2	I do activities to improve **flexibility**, such as stretching or yoga, once a week or more.	Yes ☐	No ☐

ID # ______________________________

Today's Date ______________________

Ib. Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) ______________________________ WITNESS ______________________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

CSEP | SCPE

J. Digit Span tests

Lists for Digit span Determination

After each of the following lists, in the space provided, enter a tick (√) if the list is correctly recalled and a cross (×) if it is not. At the bottom of the page, in the space provided, enter the subject's Digit Span as the maximum length of the lists of which the subject recalled 5/6 correctly. Present only 6 lists to the subject.

List	Result (√ or ×)	List	Result (√ or ×)	List	Result (√ or ×)
For Span = 2					
83		54		27	
28		37		91	
68		96		87	
For Span = 3					
829		687		871	
132		356		251	
152		637		915	
For Span = 4					
6241		1372		5316	
2359		7392		4815	
7132		6539		1872	
For Span = 5					
84132		85293		79514	
62143		91635		82691	
97438		16592		75468	
For Span = 6					
587261		492617		148239	
261384		247681		423896	
632147		429735		641357	
For Span = 7					
2941378		6297865		1897562	
1285394		8243167		3185624	
8693735		3945782		2473961	
For Span = 8					
65148279		28653197		85729136	
18472913		65792381		76591243	
42785921		74529638		76921358	
For Span = 9					
679174382		239874615		539748216	
746231958		867934612		513985267	
398724615		794831265		231986734	
For Span = 10					
4982176453		2853967624		2914984357	
5731298426		9781734826		6983285149	
8182397465		8491287637		6391727362	

Subject's Digit Span: Forward:

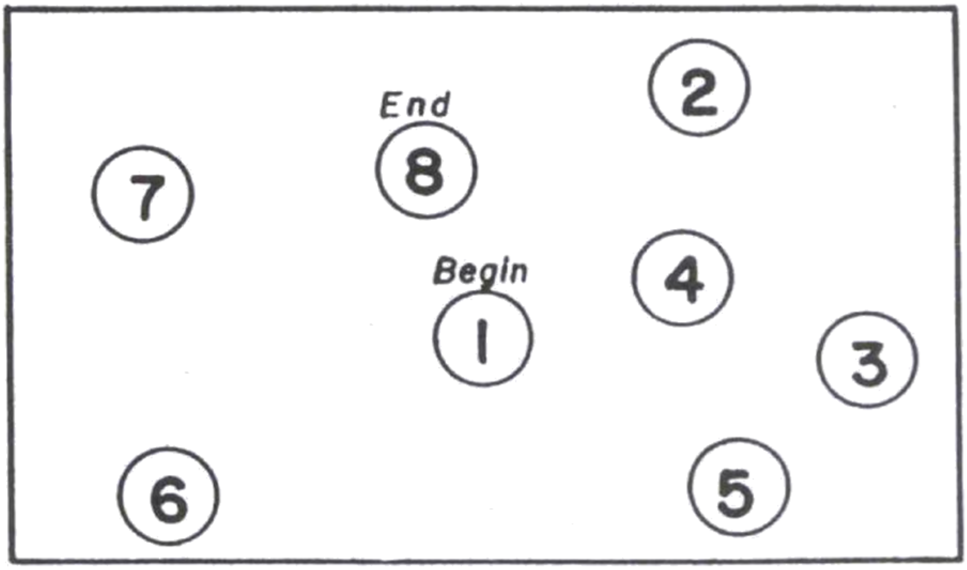
Subject's Digit Span Backward:

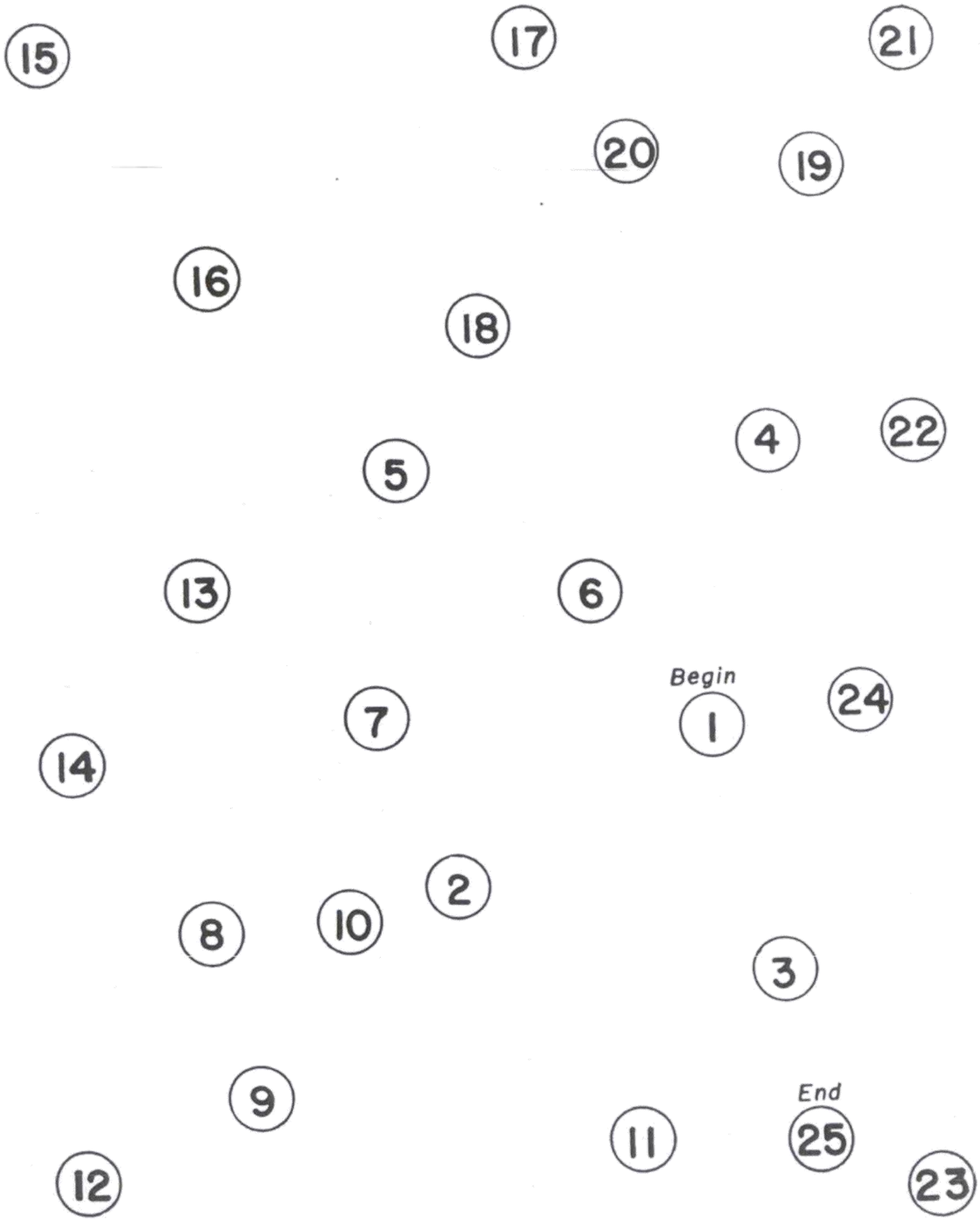
K. Trail Making Test A and B

TRAIL MAKING

Part A

SAMPLE

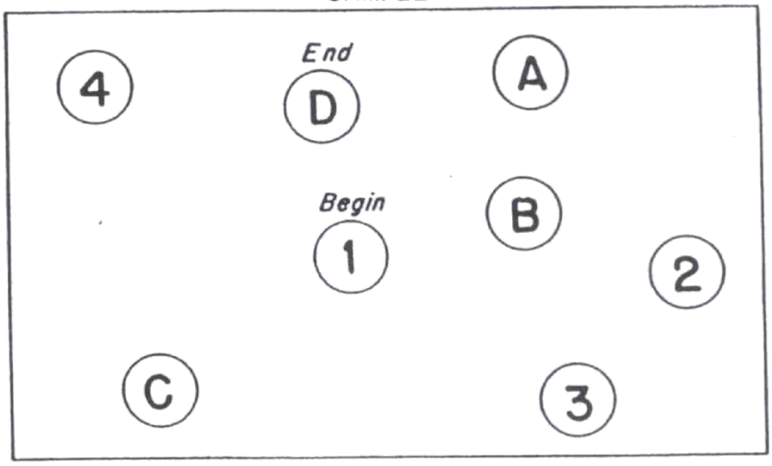


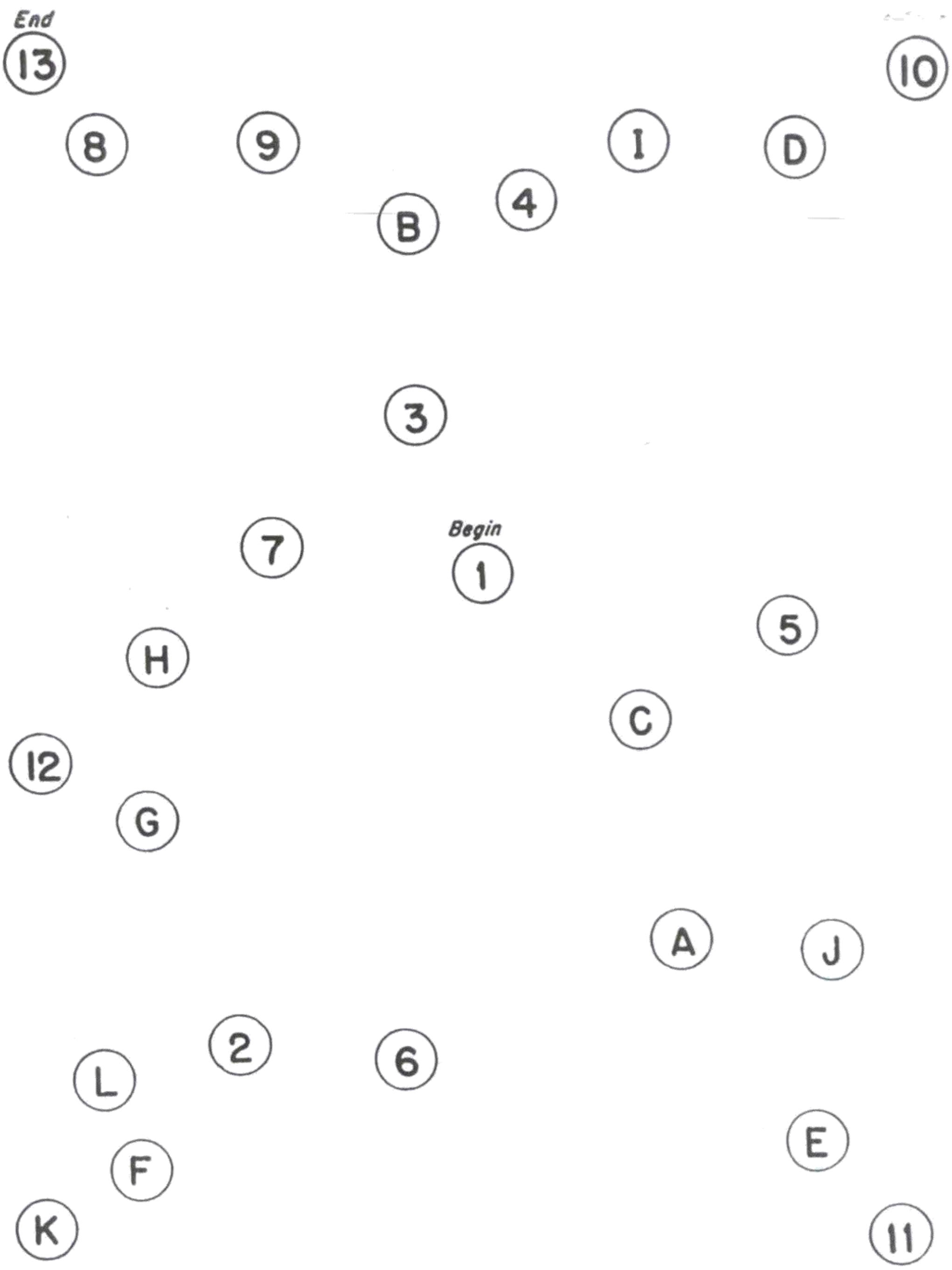

15
17
21
20
19
16
18
4
22
5
13
6
Begin
1
24
7
14
2
8
10
3
9
End
25
11
12
23

TRAIL MAKING

Part B

SAMPLE




End
13
10
8
9
I
D
B
4
3
Begin
1
7
5
H
C
12
G
A
J
2
6
L
E
F
K
11

L. Walking Stroop Carpet Protocol

Introduction

"Good day Mr…/Mrs…/Miss …

Thank you for your interest and participation in the research study.

The aim of this study is to determine the influence of executive functioning on mobility."

Sensors

"I require to fit sensors in your trunk and ankles

They will measure your speed of movement, as well as several gait variables.

May I please fit them?"

Video

"A video recording is made during the test procedure to record your progress as you step in the different targets on the mat."

3 Carpets, 4 Walking conditions

"There are 3 carpets with different targets. I shall first explain the procedure before you will do a test trial in the first 4 rows."

Comparison

"At the end of the research study, your initial baseline test results are compared to your final results to determine changes, if any, took place. Therefore you cannot fail or be unsuccessful in you endeavour."

Aim: Speed & Accuracy

"Let's start with the carpets.

The aim with each carpet is to determine the speed and accuracy of execution as you step onto the specified targets.

Please stand with your toes behind the line.

Don't look down onto the carpet unless instructed to begin walking."

Rows: 4 Targets, 4 Colours

"Each row consists of 4 targets, each one spelling a colour.

The four colours are yellow, red, blue and green."

Practice familiarise

"A practise round is done with the first 4 rows to familiarise yourself."

Ball of Both feet (Here the evaluator have to physically demonstrate the walking technique while explaining the instructions)

"You have to step onto the target, placing the ball of both your feet on the specified target. Do not walk on your "toes". Step comfortably, but ensure the ball of each foot makes contact with the target.. (Evaluater to indicate this area by touching the ball of his/her own foot)

Place both feet on your selected target, stepping together before proceeding to the next row. (Evaluater have to demonstrate on 4 rows on the word/ colour GREEN)."

Still at end

"You must stand completely still when you reach the end row. (Evaluator to go stand on the last row and demonstrate)

Keep both feet on your target, your whole body motionless until instructed to step off the mat."

Practice "green" (The participant have to practise untill comfortable with stepping action and technique) Do this for each walking condition

"As a practise round: Step on the word "green" regardless of the colour the word is written in.

Please stop. (This instruction is given upon reaching the fourth row's target).

Return to your initial position behind the line without looking at the mat until instructed."

Do you understand? Lets begin the test.

Participant position him/herself at the starting line, looking straight ahead, awaiting the instruction

"Please look ahead. Don't look down onto the carpet untill I say "BEGIN"

I will count down from 3 to 1. On my command "Begin" you will walk as quickly and accurately as possible.

Please ignore any incorrect steps and just proceed with rest of targets till the end row.

"Mr…., please choose a number between 1 to 16 and 1 to 4." (Evaluator use the randomisation sheet).

Neutral condition: (Black and white; Condition 1)

"step with the ball of your foot… on the word…"

In 3,2,1 BEGIN (Timer start)

Upon reaching the last row's target, evaluator clearly say STOP (Timer stop)

Congruent condition: (Colour; Condition 2)

"step with the ball of your foot… on the colour ink regardless what the word say …"

In 3,2,1 BEGIN (Timer start)

Upon reaching the last row's target, evaluator clearly say STOP (Timer stop)

Incongruent condition 1: (Colour; Condition 3)

"step with the ball of your foot… again on the colour ink, regardless what the word say…"

In 3,2,1 BEGIN (Timer start)

Upon reaching the last row's target, evaluator clearly say STOP (Timer stop)

Incongruent condition 2: (Word; Condition 4)

"step with the ball of your foot… on the word, regardless of the colour ink its printed (Ignore the colour ink, just focus on the word)…"

In 3,2,1 BEGIN (Timer start)

Upon reaching the last row's target, evaluator clearly say STOP (Timer stop)

M.Walking Stroop Carpet Randomisation Sheets

ENGLISH - 1 (Black & White)			
Condition 1 (Black & White)			
red	green	blue	yellow
green	yellow	blue	red
red	blue	green	yellow
blue	red	green	yellow
red	green	blue	yellow
blue	yellow	green	red
blue	yellow	red	green
yellow	green	red	blue
blue	green	yellow	red
red	yellow	blue	green
red	blue	yellow	green
yellow	red	blue	green
green	red	yellow	blue
blue	yellow	red	green
blue	red	yellow	green
green	yellow	red	blue

ENGLISH - 2 (Colour)			
Condition 2 (Colour)			
yellow	green	red	blue
blue	red	yellow	green
green	blue	red	yellow
yellow	green	blue	red
red	blue	yellow	green
yellow	green	red	blue
green	red	blue	yellow
blue	red	yellow	green
green	yellow	red	blue
blue	yellow	green	red
yellow	red	blue	green
green	blue	yellow	red
yellow	red	green	blue
blue	green	red	yellow
red	green	yellow	blue
yellow	blue	green	red

ENGLISH - 3 (Word)			
Condition 3 & 4 (Colour; Word)			
red	blue	yellow	green
green	red	yellow	blue
blue	red	yellow	green
red	green	blue	yellow
blue	yellow	red	green
green	yellow	blue	red
blue	red	green	yellow
blue	yellow	green	red
green	red	yellow	blue
yellow	green	red	blue
yellow	red	blue	green
blue	green	yellow	red
red	blue	green	yellow
red	yellow	blue	green
blue	yellow	red	green
red	green	blue	yellow

AFRIKAANS - 1 (Swart & Wit)			
Kondisie - 1 (Swart & Wit)			
rooi	groen	blou	geel
groen	geel	blou	rooi
rooi	blou	groen	geel
blou	rooi	groen	geel
rooi	groen	blou	geel
blou	geel	groen	rooi
blou	geel	rooi	groen
geel	groen	rooi	blou
blou	groen	geel	rooi
rooi	geel	blou	groen
rooi	blou	geel	groen
geel	rooi	blou	groen
groen	rooi	geel	blou
blou	geel	rooi	groen
blou	rooi	geel	groen
groen	geel	rooi	blou

AFRIKAANS - 2 (Kleur)			
Kondisie 2 - (Kleur)			
geel	groen	rooi	blou
blou	rooi	geel	groen
groen	blou	rooi	geel
geel	groen	blou	rooi
rooi	blou	geel	groen
geel	groen	rooi	blou
groen	rooi	blou	geel
blou	rooi	geel	groen
groen	geel	rooi	blou
blou	geel	groen	rooi
geel	rooi	blou	groen
groen	blou	geel	rooi
geel	rooi	groen	blou
blou	groen	rooi	geel
rooi	groen	geel	blou
geel	blou	groen	rooi

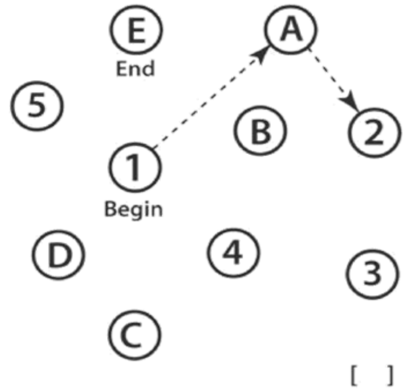
AFRIKAANS - 3 (Woord)			
Kondisie 3 & 4 (Kleur; Woord)			
rooi	blou	geel	groen
groen	rooi	geel	blou
blou	rooi	geel	groen
rooi	groen	blou	geel
blou	geel	rooi	groen
groen	geel	blou	rooi
blou	rooi	groen	geel
blou	geel	groen	rooi
groen	rooi	geel	blou
geel	groen	rooi	blou
geel	rooi	blou	groen
blou	groen	geel	rooi
rooi	blou	groen	geel
rooi	geel	blou	groen
blou	geel	rooi	groen
rooi	groen	blou	geel

N. Global Cognition: Montreal Cognitive Assessment (MoCA)

MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

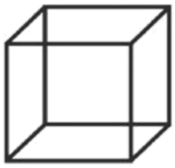
NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE — POINTS



[ ]

Copy cube

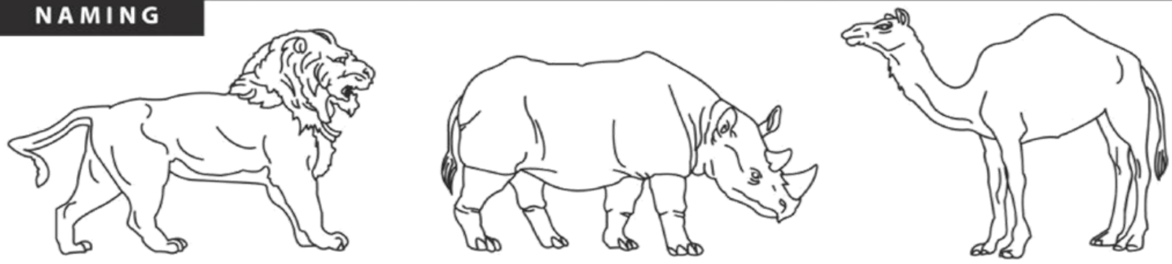


[ ]

Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands ___/5

NAMING



[ ] [ ] [ ] ___/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words) ___/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler ___/2

DELAYED RECALL	Has to recall words **WITH NO CUE**	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only	___/5
Optional	Category cue							
	Multiple choice cue							

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

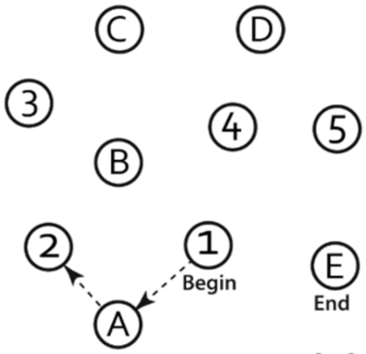
 www.mocatest.org Normal ≥26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________________

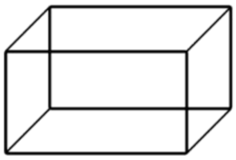
NAME :
Education : Date of birth :
Sex : DATE :

MONTREAL COGNITIVE ASSESSMENT (MOCA®)
Version 7.2 Alternative Version

VISUOSPATIAL / EXECUTIVE



Copy rectangle

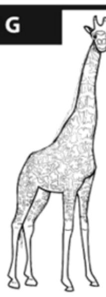


Draw CLOCK (Five past four)
(3 points)

[ ] [ ] [ ] Contour [ ] Numbers [ ] Hands

POINTS: ___/5

NAMING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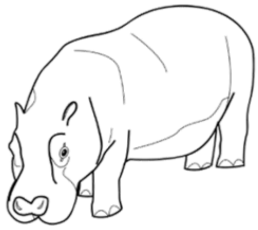
[ ]

___/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	TRUCK	BANANA	VIOLIN	DESK	GREEN
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 3 2 9 6 5
Subject has to repeat them in the backward order [ ] 8 5 2 ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 90 [ ] 83 [ ] 76 [ ] 69 [ ] 62 [ ] 55
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE

Repeat : A bird can fly into closed windows when it's dark and windy. [ ]
The caring grandmother sent groceries over a week ago. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter S [ ] _____ (N ≥ 11 words) ___/1

ABSTRACTION

Similarity between e.g. carrot - potato = vegetable. [ ] diamond - ruby [ ] cannon - rifle ___/2

DELAYED RECALL

	TRUCK	BANANA	VIOLIN	DESK	GREEN	
Has to recall words **WITH NO CUE**	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only
Optional Category cue						
Multiple choice cue						

___/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

Adapted by : Z. Nasreddine MD, N. Phillips PhD, H. Chertkow MD
 www.mocatest.org
Administered by: ______________________

Normal ≥ 26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

O. Depressive Moods: Patient Health Questionnaire (PHQ-9)

PATIENT HEALTH QUESTIONNAIRE-9 (PHQ-9)

Over the last 2 weeks, how often have you been bothered by any of the following problems? *(Use "✔" to indicate your answer)*	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

FOR OFFICE CODING 0 + ______ + ______ + ______

=Total Score: ______

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
...	...	...	...

Developed by Drs. Robert L. Spitzer, Janet B.W. Williams, Kurt Kroenke and colleagues, with an educational grant from Pfizer Inc. No permission required to reproduce, translate, display or distribute.

PASIËNTGESONDHEID-VRAELYS-9 (PHQ-9)

Hoe gereeld het die volgende probleme u gedurende die afgelope 2 weke gepla? *(Gebruik "✓" om jou antwoord aan te dui)*	**Glad nie**	**Etlike dae**	**Meer as helfte van die dae**	**Byna elke dag**
1. Min belang of plesier daarin om dinge te doen	0	1	2	3
2. Voel mismoedig, terneergedruk of wanhopig	0	1	2	3
3. Moeilik om aan die slaap te raak of te bly, of slaap te veel	0	1	2	3
4. Voel moeg of het min energie	0	1	2	3
5. Swak eetlus of eet te veel	0	1	2	3
6. Voel sleg oor uself — of dat u 'n mislukking is of uself of u gesin teleurgestel het	0	1	2	3
7. Moeilik om op dinge te konsentreer, soos om die koerant te lees of televisie te kyk	0	1	2	3
8. Beweeg of praat so stadig dat ander mense dit kon oplet. Of die teendeel — is so kriewelrig en rusteloos dat u baie meer as gewoonlik rondbeweeg	0	1	2	3
9. Gedagtes dat dit beter sou wees as u dood is of om uself op 'n manier seer te maak	0	1	2	3

FOR OFFICE CODING ___0___ + ______ + ______ + ______

=Total Score: ______

Indien u enige probleme op die vraelys afgemerk het, hoe moeilik het hierdie probleme dit vir u gemaak om u werk te verrig, dinge tuis te versorg of met ander mense klaar te kom?

Glad nie moeilik nie	**Ietwat moeilik**	**Baie moeilik**	**Uiters moeilik**
…	…	…	

P. Short Form Health Survey (SF36) with eight subscales

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups? (Please tick **one** box.)

- Not at all o
- Slightly o
- Moderately o
- Quite a bit o
- Extremely o

7. How much physical pain have you had during the past 4 weeks? (Please tick **one** box.)

- None o
- Very mild o
- Mild o
- Moderate o
- Severe o
- Very Severe o

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)? (Please tick **one** box.)

- Not at all o
- A little bit o
- Moderately o
- Quite a bit o
- Extremely o

9. These questions are about how you feel and how things have been with you during the past 4 weeks. Please give the one answer that is closest to the way you have been feeling for each item.

	(Please circle one number on each line.)	**All of the Time**	**Most of the Time**	**A Good Bit of the Time**	**Some of the Time**	**A Little of the Time**	**None of the Time**
9(a)	Did you feel full of life?	1	2	3	4	5	6
9(b)	Have you been a very nervous person?	1	2	3	4	5	6
9(c)	Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
9(d)	Have you felt calm and peaceful?	1	2	3	4	5	6
9(e)	Did you have a lot of energy?	1	2	3	4	5	6
9(f)	Have you felt downhearted and blue?	1	2	3	4	5	6
9(g)	Did you feel worn out?	1	2	3	4	5	6
9(h)	Have you been a happy person?	1	2	3	4	5	6
9(i)	Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives etc.) (Please tick **one** box.)

- All of the time o
- Most of the time o
- Some of the time o
- A little of the time o
- None of the time o

11. How TRUE or FALSE is each of the following statements for you?

	(Please circle one number on each line.)	**Definitely True**	**Mostly True**	**Don't Know**	**Mostly False**	**Definitely False**
11(a)	I seem to get sick a little easier than other people	1	2	3	4	5
11(b)	I am as healthy as anybody I know	1	2	3	4	5
11(c)	I expect my health to get worse	1	2	3	4	5
11(d)	My health is excellent	1	2	3	4	5

Thank You!

SF36 Health Survey

INSTRUCTIONS: This set of questions asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Answer every question by marking the answer as indicated. If you are unsure about how to answer a question please give the best answer you can.

1. In general, would you say your health is: (Please tick **one** box.)

- Excellent o
- Very Good o
- Good o
- Fair o
- Poor o

2. Compared to one year ago, how would you rate your health in general now? (Please tick **one** box.)

- Much better than one year ago o
- Somewhat better now than one year ago o
- About the same as one year ago o
- Somewhat worse now than one year ago o
- Much worse now than one year ago o

3. The following questions are about activities you might do during a typical day. Does your health Now limit you in these activities? If so, how much? **(Please circle one number on each line.)**

	Activities	Yes, Limited A Lot	Yes, Limited A Little	Not Limited At All
3(a)	**Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
3(b)	**Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
3(c)	Lifting or carrying groceries	1	2	3
3(d)	Climbing **several** flights of stairs	1	2	3
3(e)	Climbing **one** flight of stairs	1	2	3
3(f)	Bending, kneeling, or stooping	1	2	3
3(g)	Waling **more than a mile**	1	2	3
3(h)	Walking **several blocks**	1	2	3
3(i)	Walking **one block**	1	2	3
3(j)	Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health? **(Please circle one number on each line.)**

		Yes	No
4(a)	Cut down on the **amount of time** you spent on work or other activities	1	2
4(b)	Accomplished less than you would like	1	2
4(c)	Were **limited** in the **kind** of work or other activities	1	2
4(d)	Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (e.g. feeling depressed or anxious)? **(Please circle one number on each line.)**

		Yes	No
5(a)	Cut down on the **amount of time** you spent on work or other activities	1	2
5(b)	Accomplished less than you would like	1	2
5(c)	Didn't do work or other activities as **carefully** as usual	1	2

Short Form Health Survey (SF36) – Eight subscales (*cont.*)

i) **Physical Functioning (PF-10):** Assesses perceived limitation during execution of physical activities (i.e. bending, kneeling, climbing stairs, walking, carrying groceries) as well as estimating the severity of the limitation. Responses are rated on a 3-point scale (yes, limited a lot; yes, limited a little; no, not limited at all) (White et al., 2011) (10 questions).

ii) **Role limitations due to physical problems (RLPH):** Assesses to what extent does current physical health problems affect the individual's functioning, pertaining to either the work environment, social environment or even as a parent or spouse (4 questions).

iii) **Bodily Pain (BP):** Assesses pain severity and how it limits or affects the individual during execution of daily activities (2 questions).

iv) **Social Functioning (SF):** Assesses how the individual interact within their environment and includes the ability to successfully fulfil their roles at work, home or socially (Bosc, 2000) (2 questions).

v) **General mental health (GMH):** Assesses current psychological distress and psychological wellbeing (5 questions).

vi) **Vitality/ Energy/ Fatigue (VEF):** Assesses a subjective feeling of well-being which includes levels of energy and fatigue (4 questions).

vii) **Role limitations due to physical problems (RLEP)**: Similar to RLEP, except this subscale assesses limitations with regards to general functioning in a work-, social- and personal environment, specifically caused by emotional problems (3 questions).

viii) **General health perceptions (GHP):** Assesses current perceived physical health status compared to prior health status, ranging from the previous four weeks to a year ago (10 questions).

Q. Turnitin Originality Report

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