EFFECT OF COGNITIVE PLASTICITY TRAINING ON FALLING IN AGING

BY

MR. WARAWOOT CHUANGCHAI

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF MEDICAL ENGINEERING

FACULTY OF ENGINEERING

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ENTITLED

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was approved as partial fulfillment of the requirements for
the degree of Doctor of Philosophy

on August 1, 2018

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ABSTRACT

Aging leads to a decline in the executive function (EF). This in turn increases the risk of falls. Effects of cognitive plasticity training in contributing to the reduction of falls among elderly people was studied by first determining the reason for falls and then evaluating cognitive, motor, and sensory plasticity. Changes in heart rate variability (HRV) were also noted. The association among the cognitive plasticity, motor plasticity, and HRV was explored.

Participants were 8 males and 20 females, aged from 62 to 85. All were enrolled at the Watsanawet Social Welfare Development Centre for Older Persons, Phra Nakhon Si Ayutthaya, Thailand. The participants were given the Stroop neuropsychological test and juggling tasks as a combined EF training for 8 weeks. Data was measured before, during, and after the training. The participants were divided into groups prior to falls (n = 14) and not prior to falls (n = 14) following the final stage.

Results were that a slower cognitive processing, possibly accompanied with poor EF in the Stroop test as well as slow speed coordination in juggling tasks could affect falls. Plasticities of the cognitive, high gross motor skills, and position senses and foot sensation were able to achieve improvement. It may help minimize the risk of falling. Changes in HRV in sitting, supine, and standing positions exist, but are not obviously influential. Wrong decisions, along with nonlinear complexity in

HRV, may also result in falls, and vice versa. Weak gross motor skills affect the risk of falls, linked with reduced overall HRV, and vice versa. Slow reaction time in unpredictable circumstances was linked with slow eye-hand coordination movement as well as eye-foot coordination, which impacted falls. These findings suggest that moderately intense, short-term, combined EF training might help elderly people to reduce the risk of falls and improve overall well-being, in addition to an overall quality of life takes to the successful aging.

Keywords: Aging, Cognitive plasticity, Motor plasticity, Executive function training, Falls

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Mr. Warawoot Chuangchai

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LIST OF ABBREVIATIONS

Symbols/Abbreviations	Terms
%	Percent
6MWT	6 minute walk test
ADL	Activities of daily living
ANS	Autonomic nervous system
ApEn	Approximate entropy
BMI	Body mass index
BP	Blood pressure
bpm	Beats per minute
BRS	Baroreceptor sensitivity
cm	Centimeter
D2	Correlation dimension
DBP	Diastolic blood pressure
DET	Determinism
DFA α1	Detrended fluctuations analysis α1
DFA α2	Detrended fluctuations analysis α2
DFS	Design for sustainability
EF	Executive function
FFT	Fast Fourier transform
HF	High frequency
HR	Heart rate
HRV	Heart rate variability
kg	Kilogram
LF	Low frequency
Lmax	Max line length
Lmean	Mean line length
m	Meter
MET	Metabolic equivalent time

Symbols/Abbreviations	Terms
min	Minute
ml	Milliliter
mm	Millimeter
mmHg	Millimeter of mercury
MMSE	Mini mental state exam
ms	Millisecond
N/A	Not available
NN50	The number of successive intervals differing more than 50 ms
OH	Orthostatic hypotension
OT	Overtraining
pNN50	NN50 divided by the total number of RR intervals
PNS	Parasympathetic nervous system
PTT	Pulse transit time
REC	Recurrence rate
RMSSD	Square root of the mean squared differences between successive RR intervals
RR	Time between two R-peak of a traditional electrocardiogram heart-beat waveform
SampEn	Sample entropy
SBP	Systolic blood pressure
SD	Standard deviation
SD1	Standard deviation of the points perpendicular to the line of identity denoted
SD2	Standard deviation along the line of identity denoted

Symbols/Abbreviations	Terms
ShanEn	Shannon Entropy
SNS	Sympathetic nervous system
STD RR (SDNN)	Standard deviation of RR intervals
TINN	Triangular index
TPD	Two-point discrimination
VA	Visual acuity
VO_{2max}	Maximum oxygen consumption

CHAPTER 1
INTRODUCTION

1.1 Background

With sustained decline in mortality and fertility, Thailand has experienced expanding number of elderly adult population and the size would double in around 19-23 years with yearly growth rate of 3-3.6% (1, 2) as shown in Figure 1.1. Thailand at present, as statistics suggest, has already been an aging society and will eventually become a complete aged society in 20 years (3). The growing number of elderly people leads to concern of falls happening among this age group. After reaching 60 years of age, falls occurrence and the seriousness of fall-related problems consistently increase (4). Approximately 35-40% of population aged 65 and older who are community residents and generally healthy fall every year. The rates are higher after 75 years of age (5). Records and evidence of falls have suggested that falls are the biggest problem for elderly Thais.

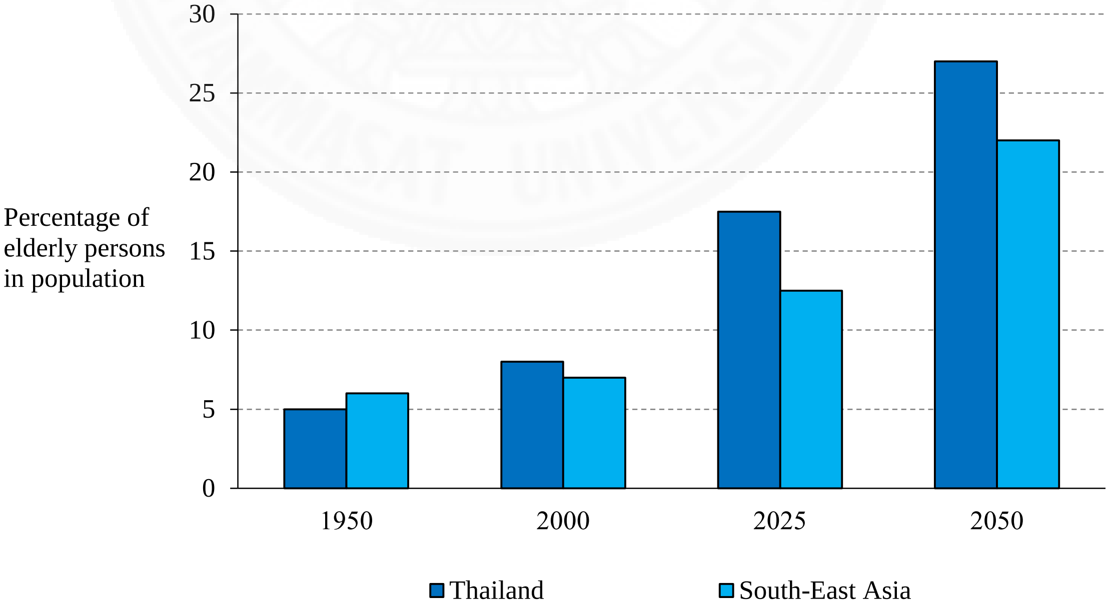


Figure 1.1 Thailand is aging faster than others in South-East Asia. Adapted from (2)

Orthostatic hypotension (OH) had played a key role in causing falls and fractures in elderly people, which could repeatedly occur with those who have fallen before (6, 7). OH, also called postural or standing hypotension, goes with a definition of blood pressure (BP) reduction caused by gravitation force, the symptoms of which are dizziness and loss of balance, occurring in elderly people changing position (8). Not only does OH in elderly people have a two-fold increased risk of falls (9, 10), but poor vision, particularly when accompanied with loss of both hearing and balance, also increases the risk of falls (11-13).

Loss of stability and foot sensation impairment in elderly people tend to make them fall, especially with those who sway in narrow base stance in a medial-lateral direction (14, 15). Better reacting elderly people might respond more quickly to prevent themselves from falls; that is, they react to postural or environmental perturbation (16-18), e.g. grabbing handrail in the bathroom when slipping, or having a capacity of finding enough space and direction for stepping out when losing balance. Investigators have included neuropsychological assessments in studies of balance control and in screening batteries for predicting falls. It has shown that the attention demands for balance control depend upon the complexity of the postural task, the nature of the secondary task, the age of a person and his balance abilities (19). Balance confidence and falls efficacy measures have been shown to be associated with objectively assessed measures of balance or falls (20). Poor performance in these tests probably indicating a general cognitive decline, the tests provide interesting insights into the causes of falls (18).

Most domestic environmental hazards for the elderly are found in the bathroom (21, 22). This suggests that the elderly who fell were more likely to go barefoot to the bathroom (23-25). Most of the recently launched investigations have emphasized on the independent effects of physiology of elderly people on falls, while only a few have approached design for sustainability (DFS), which is linked to relationships between the development of people's well-being, environment and a search for change and innovation. Especially, bathroom design that can contribute to reducing falls in the elderly is emphasized with the role of criteria in activities of daily living (ADL).

As mentioned above, the interaction between the physiology of the elderly people (e.g. dizziness, loss of balance, loss of proprioception, and poor vision with loss of hearing) (11-13, 26-29) and their exposure to environmental stressors (e.g. bathroom, flooring, and lighting) (30-35) seems evident that both of these respects are significantly important to the occurrence of falls. To experiment with falls under real-life conditions or situations for actual elderly people is thought unethical; thus, a non-invasive protocol must be an option to approach. Among the most popular non-invasive options the autonomic nervous system (ANS) activity biomarkers is HRV, where blood pressure homoeostasis is controlled. In order to reduce falls, the heart rate (HR) is rapidly increased and the blood vessels become contracted by ANS, which is to keep balance on homeostasis of BP (36).

In addition, executive function (EF) training is an approach that could benefit elderly people in restoration, maintenance or even enhancement of intelligence (37). Previous studies showed that the mechanisms of EF could evidently be modifiable by training and possibly with stimulation from exposure to novel experiences (38, 39). Stroop effect is a non-invasive test to measure selective attention by solving problems in the higher order of cognitive functions (18). A juggling task is a novel experience for motor skill learning of body movements and also for working memory training in dual task performance, which relies on eye–hand as well as eye–feet coordination (40). Concurrent training of Stroop test and juggling task in elderly people had not been studied before.

The present study therefore investigates the relationships among cognitive plasticity, motor plasticity, and HRV in elderly Thai people. By experimenting with EF training, which could improve cognitive-motor functionality, and allow a contribution to promote strategies in reducing fall risks and sustainably improving the quality of life to finally achieve successful aging. The present study is advantageous for the government to help reduce long-term increase in of medical care fees in the elderly Thai population. The present study is expected to be an innovative instrument for both interior architecture design, related to DFS, and innovative environmental design in order to reduce falls in elderly people. Also, it could be useful for universal design, accessible design, and barrier-free design in a greater extent, such as among designers, ergonomists and educators in related fields.

1.2 Research aims

1.2.1 To determine the fall-related factors in elderly people.

1.2.2 To examine and evaluate the cognitive, motor, and sensory plasticity along with HRV during training in elderly people.

1.2.3 To describe the associations among cognitive plasticity, motor plasticity, and HRV in elderly people.

1.3 Research questions

How does cognitive plasticity contribute to reducing falls in elderly people, and why does it have influence on the number of falls in elderly people?

1.4 Benefits of research

This research would:

1.4.1 Bring more possible opportunities to reduce the incidence and minimize chances of consequent injuries from falls in the ADL of elderly people.

1.4.2 Improve overall well-being of elderly people and possibly give inspiration to improve the quality of life.

1.4.3 Encourage DFS to be enhanced in cognitive plasticity in order to contribute to reducing falls in elderly Thai people.

1.4.4 Integrate fields of physiology and engineering into design as being an innovative instrument in the built environmental design.

1.4.5 Extend knowledge of medical engineering discipline and other related fields.

1.5 Research framework

The research framework is to build the understanding of structure of the present study in a systematic way. The following diagram (Figure 1.2) shows the overall concept and variables of the present study. The schedule of research (Table 1.1) shows organized stages and times of the present study.

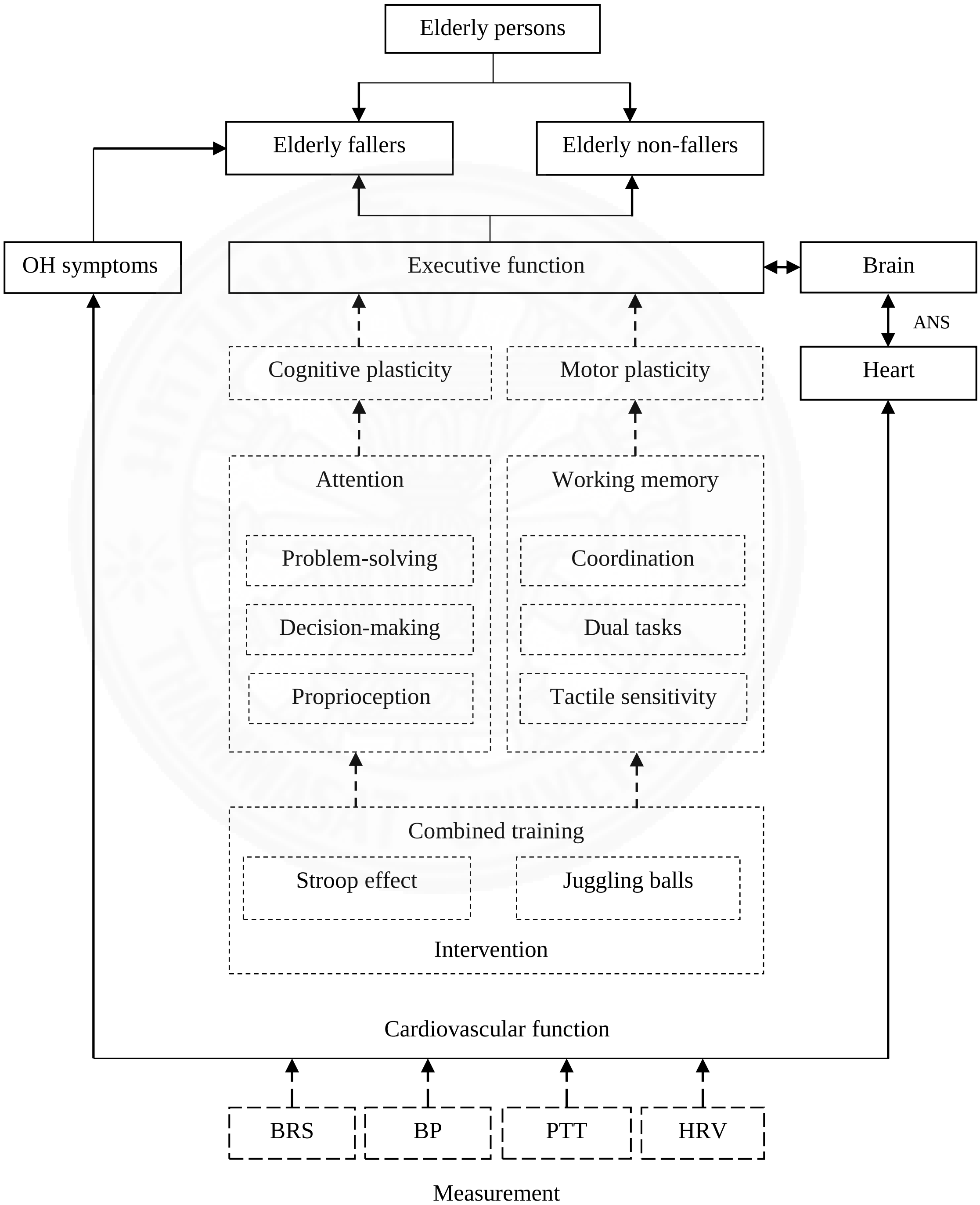


Figure 1.2 Research framework

Table 1.1 Research schedule of stages and times

No.	Times / Stages	2015		2016		2017		2018	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
A	Research design								
1	Research questions	■							
2	Research framework	■							
3	Research methodology	■							
B	Review of literature								
1	Falls in elderly people		■						
2	Cognitive and motor plasticity		■						
3	HRV in elderly people		■						
4	DFS for elderly people		■						
C	Materials and methods								
1	Population			■					
2	Tools			■					
3	Pilot study I			■					
4	Pilot study II			■					
5	Registration of patent				■				
D	Data collection								
1	Fieldwork				■				
2	Data management				■				
3	Statistical analysis					■			
4	Conclusion					■			
E	Documentation								
1	Introduction						■		
2	Review of literature						■		
3	Research methodology						■		
4	Results and discussion						■		
5	Conclusions and recommendations						■		
F	Submission								
1	Oral defense of dissertation						■		
2	Revision of dissertation							■	
3	Publication								■
4	Final submission of dissertation								■

1st = First semester, 2nd = Second semester

CHAPTER 2
REVIEW OF LITERATURE

2.1 Falls in the elderly population

2.1.1 Introduction to the situation of Thai elderly population

The term elderly adults could be defined as persons of age starting from 50 years (41). The most frequently used definition for an elderly person; nonetheless, is for people aged 60 years and over. The proportion of the senior Thai population aged 60 years and over was anticipated to increase from 8.7% in 2000 to 10.8% in 2010. This figure is predicted to develop to 15.2% and 30% in 2020 and 2050 respectively. The United Nations' latest estimate of the growth rate of such an age group for the Thai population is somewhat high with over 3% per year. It has been discussed that in around 19-23 years, the size of the population would double given the growth rate of 3-3.6% per year (3).

Thailand was the seventh most aged country among the eleven countries in South-East Asia in 1950. However, with elderly people filling out more than 10% of the population, the country now, after Singapore, has been the second most aged country in this region. This comparatively higher rate is a consequence of a decline in fertility and improvement in longevity. Thailand has encountered a situation of a speedily expanding population of elderly adults with a sustained decline in mortality and fertility in the last three decades of the 20th century. In around year 2020, the inhabitants of this category would overtake the population of children which would happen for the first time in the country's history (1, 2).

Likewise, life expectancy at age 80 years is predicted to increase, which means oldest old persons could live for more than 80 years. Then, the proportion of the oldest persons in the population is predicted to reach exponential growth, providing the circumstance where there is a rise in scale of Thai people living up to age 80 years and on average actually living longer than that. Presently, 590,000 people is the estimated number of the oldest old population, which in 2025 will grow to 1.3 million and go beyond 3.5 million by 2050. This indicates that there would be a demand of prolonged duration of social security and welfare expense, as well as increasing requirements for care of elderly people's ailment and incapability. The statistics suggest that Thailand has become an aging society already and will ultimately turn to a complete aged society in the next 20 years (1, 2, 42).

2.1.2 Characteristics of falls in the elderly population

Falls could be defined as "unintentionally coming to rest on the ground, floor or lower level which occurs from all causes that are unexpected" (43). Statistics have indicated falls circumstance differs considerably from a Poisson distribution, despite the fact that falls are often addressed as accidents (43). This signifies the link between causal procedures and falls; therefore, they are not simply occasional situations (26).

Age wise, after people reach 60 years of age, both falls occurrence and the seriousness of fall-related problems consistently increase. Figures suggest that approximately 35% to 40% of population aged 65 and older who are residents of a community, and healthy in general, fall every year. The rates are higher after 75 years of age (5). Both physical efficiency and level of disclosure to environmental dangers are associated with an individual's risk of falling. Therefore, both those living a sedentary lifestyle and those being physically active could be prone to falling in different circumstances (44). More than one-third of elderly people in the falls prediction of a 1-year prospective study experienced at least one fall each year (45). This occurred with 30-60% of them, where 10-20% required hospitalization (26).

The characteristics of falls seem to vary across genders and daily life activities. From research, it could be stated that women are more likely to fall inside their homes in the afternoon or the evening while men have a tendency towards falling outside their residence during leisure time activities (46, 47). This may be explained by the concept that women are likely to spend a greater proportion of time indoors on household duties (48). Many previous reports also suggest to the same direction that females have tendency to be injured more, which may link to the remark that it is challenging for them to get back up from the floor after falling (49). Also, the risk of falls, as reported in research, was higher amongst those elderly females who took four or more medicines and had poor body balance (50). A prospective cohort study of indoor fall injuries in community residence too found that elderly female adults who were concerned about falls and therefore attempted to restrain their activities ironically tended to suffer fall injuries (51).

In contrast, typical falls occurring outside the house when elderly people undertake recreational activities scarcely result in severe injuries or hospital admission. It has been suggested the fractures rate that is under the average figure could come from sufficient bone density and postural control of elderly adults in the study. These factors could help prevent injuries when falls happen. Additionally, the study also found that physically active elderly adults who lived alone in the neighbourhood experienced a great falls rate (44, 49).

It is possible that various causes could account for the falls. One of the potential risk factors is pain, which appears to be continually overlooked. Mobility inadequacy, impaired gait, and balance deficits are all related to falls and are well-established internal risk factors. This could be assumed as a common incident since it was experienced by up to 76% of the elderly population in the community. In particular, foot and chronic pain (hip and knee) are significant risk factors. The systematic review and meta-analysis suggested that people of older age who suffered from pain and also had fallen in the past 12 months were more likely to face a repeated fall in the future (52). Distinguishable risk factors such as weakness, unsteady gait, confusion and psychoactive medications are related to most falls (43). The challenge in daily life activities or in daily instrumental actions also could make the possibility twice as great (53). In terms of consequences, falls are perceived to be one of the leading causes of unintentional injuries and mortality which affect the quality of life in older age.

Falls situations that could present a precise etiology or reduce the differential diagnosis include immediately getting up from a lying or sitting position (OH), trip or slip (gait, balance, vision disturbance or environmental hazard), drop attack (vertebrobasilar insufficiency), looking up or looking sideways (arterial or carotid sinus compression) and loss of consciousness (syncope or seizure). A likely explanation of falls may come from symptoms that occur close to falling moment. They could be dizziness or giddiness (OH, vestibular problem, hypoglycaemia, or arrhythmia and drug-side effect). From research, elderly people with multiple sclerosis particularly experienced high numbers of falls that would be followed by injuries. Furthermore, medications and accompanying medical problems may also be key causes (26).

It seems that how the elderly cover their feet cannot be underemphasized when it comes to falls. The study showed that elderly people who fell inside the house tended to be shoeless or wear socks inside their homes (54). At the time of indoor falls, 51.9% of the 765 elderly participants in a prospective cohort study at MOBILIZE Boston were barefoot, wearing socks without shoes or wearing slippers. This leads to the advice for elderly persons to wear shoes inside their homes whenever possible in order to minimize the risk (23). Athletic and canvas shoes (sneakers) have been proposed to be the styles of footwear that could help bring a relatively low risk of falls in elderly adults' everyday activities (24).

Falls could further be linked to specific activities. A study from urban, rural and slum areas of Chandigarh, India in a cross sectional survey was carried out with 300 participants. Most falls (75%) were reported to take place when elderly people carried out their personal hygiene practices such as toileting and bathing. In such situations, the figure of consequent injuries was reported by 67% where lower extremities (37%) were the most usual spot of injuries. In addition, 8% were reported as fractures. Other than specific bathroom routine, falls have also been said to be related to a range of activities occurring during general movement, such as walking, turning and moving between positions (50). Over 3 months, 150 participants prospectively noted real and near fall situations on a daily journal. On a self-report survey, with regards to whether the fallers were in a hurried stage, most falls happened when elderly adults in the study perceived they either were not in a rush at all (45% of falls) or they were hurrying as usual (27.6% of falls). In response to the general "cause of falling", most falls, where a specific cause was identified, were linked to the loss of balance (19.4% of falls). Tripping, legs giving way, and being distracted contributed to approximately 10% each (25).

A consciousness about avoiding the environment that may require balancing skill (55) may tackle vertigo and poor postural stability (visual, proprioception, exteroception and vestibular). This is one of the major reasons of falls (56). Multiple fallers were reported to position themselves with a narrower stance width than non-fallers (53). Elderly people, in general, have difficulties in controlling sideways, center-of-mass, motion and have a higher risk of sideways falls during gait, which is caused by the larger center-of-mass/center-of-pressure inclination angles in the medial-lateral direction (57).

Apart from physical conditions, falls could be the by-product of psychological and social effects. Almost one-third of the actual falls of the elderly population from the study were associated with the feeling of "somewhat more" fatigue than usual at the time of their falls. Further, 13.3% of them experienced falls when fatigue was reported to be "much more" than usual (25).

A case-control study from hospital admissions in Brisbane, Australia was conducted with 387 participants residing in the community. It is suggested that psychosocial factors could crucially have an independent protective effect on hip-fracture risk. Such influential factors may refer to; the status of being presently married, residing in current dwelling for 5 years or more, owning private medical insurance, being resilient to stress, as well as having a greater level of life fulfillment and participation in social activities. Thus, injury prevention for the elderly population in relation to falls could be addressed by implementing healthy aging strategies that involve community-based approaches to improve elderly persons' psychosocial settings (58).

2.1.3 Personal factors (Intrinsic factors)

Sensory impairments in vision and hearing are usually found to happen with the elderly and frequently they are referred to as characteristics of the aging process. Some of these impairments are caused by intrinsic aging processes occurring in the sense organs and their neural and brain components. The eye's retina and the peripheral receptor cells of the ear's cochlea, permanently established at birth, with no turnover and regeneration in later life, also play a part in contributing to the functional decrements in vision and hearing (59).

2.1.3.1 Vision and hearing to body balance

Previous studies such as a prospective study of visual acuity, co-existing hearing impairment, and poor standing balance as predictors of falls (n = 428) with 1-year follow-up have shown that impaired vision could affect postural stability and increase the risk of falls in elderly people (13). Vision is key in maintaining balance by giving the nervous system constant new data about the location and flow of body segments in coordination with one another as well as with the environment (60). The study of visual function, peripheral sensation, strength, reaction time and sway with 156 participants found that moving visual fields could activate a strong sense of self-motion, and misguided visual cues could bring about considerable rises in sway (61). Independent predictors of growing sway in elderly people were the weak performances in tests of distant contrast sensitivity and stereopsis, a measure of depth perception (11). This indicates that the correct perception of visual stimuli and depth is key to producing a visual reference frame for body stabilization in connection with its surroundings. Vision produces a vital provider of balance; therefore, impaired vision is an important independent risk factor for falls and fractures. The major impairment associated with falls seems to be the reduced ability to detect low contrast hazards, to determine distances and to perceive spatial relationships. This is likely to be particularly important when elderly people walk up or down the stairway and when they are in the unfamiliar environment (11, 61).

From the National Center for Health Statistics: Trends in Vision and Hearing among Older Americans, approximately one-fourth of elderly aged 65 showed a symptom of deafness (62, 63) because of receptors change and extinction of hair cells in cochlear (64). Hearing and vestibular organs are anatomically closely localized. The eighth cranial nerve's function is to serve shared fluid-filled bony compartments and blood circulation and they have comparable mechanosensory receptor hair cells, which detect sound, head movements, and orientation in space. People make a remark on the surroundings or avoid hazardous environment potentially leading to falls by the help of hearing function which brings about acoustic information of the environment (12). Poor vision could increase the risk of falls especially when it is accompanied with absence of hearing or balance and this could get worse when impaired vision takes place together with lack of both hearing and balance ability (13).

Table 2.1 The normal changes in the elderly's eye. Adapted from (59, 65)

Structural changes
Cornea: Increased thickness; decreased curvature; some loss of transparency; pigment and lipid accumulation (arcus senilis); loss of epithelial cells; reduced epithelial regeneration.
Anterior chamber: Deceased volume and flow of aqueous humor.
Iris: Deceased dilator muscle cell number, pigment, and activity; mild increase in density of collagen fibers in stroma.
Lens: Increased size and anterior-posterior thickness; decreased curvature; increased pigment accumulation (yellowness) and opacity (optical density); decreased epithelial cell number; decreased new fiber formation and antioxidant levels; increased crossover in capsule collagens and lens crystallins; increased hardness in capsule and body and lens nucleus.
Vitreous body: Increased inclusion bodies; decreased water content; lesser support to globe and retina.
Ciliary body and muscles: Decreased number of smooth muscles (radical and circular); increased hyaline substance and fiber in ciliary process; decreased ciliary pigment epithelial cells.
Retina: Decreased thickness in periphery; defects in rod outer segments, and regeneration of discs and rhodopsin; loss of rods and associated nerve cells; some cone loss; reduced cone pigment density; expansion of Muller cells; increased cyst formation; formation of Drusen-filled lesion, and degeneration of macular region in diseased condition.
Pigment epithelium: Loss of melanin; increased lipofuscin granules.
Functional changes
Cornea and lens function: Decreased accommodation power (presbyopia); increased accommodation reflex latency; increased near point of vision; increased lenticular light scattering; decreased refraction decreased lens elasticity.
Retina function: Decreased critical flicker frequency; decreased light sensitivity (increased light thresholds before and after dark adaptation); reduce color vision initially in yellow to blue range and later in the green range.
General optical function: Increased papillary constriction (senile miosis); reduced visual acuity; presbyopia.
Major pathologies
Cornea: “Against the rule” astigmatism.
Lens: Cataract; hardening and loss of elasticity.
Retina: Senile macular degeneration; glaucoma; diabetes retinopathy.

Table 2.2 The normal changes in the elderly's ear. Adapted from (59, 65)

Structural changes	**Hair cell degeneration**
	Basal cochlea: frequent, especially in first quadrant; diffuse and patchy; main cause of sensory presbycusis.
	Nerve cell degeneration
	Observed in spiral ganglia often with vassal cochlear hair cell loss but not with apical cases (involved in neural presbycusis); is accompanied by loss of myelinated auditory nerve fibers.
Atrophic changes	Generally occur in nonneural components (vascular and connective tissue) of cochlea and lead to strial or conductive types of presbycusis.
	In stria vascularis; frequent in the middle and apical turns of cochlea.
	In spiral ligaments; accompanied with devascularization.
	In inner and outer spiral vessels.
	In Reissner's membrane; due to vacuolization in basilar membrane leading to mechanical damage.
Central Neural changes	Little neuronal loss in lower auditory centers; heavy loss in conical auditory centers; dendritic degeneration of cortical pyramidal neurons.
	Increased latency and decreased amplitude of auditory-evoked potential; effects more marked in elderly males than in females.
Functional changes	**Pure tone hearing**
	Loss of hearing in the high-frequency range (presbycusis); loss progressively worsens with age; effects more pronounced in males; noise exposure enhances loss.
	Speech perception
	Diminished ability to hear consonants; speech is heard but unintelligible.
	Sound localization
	Diminished ability to sound source, particularly at high frequencies.

2.1.3.2 Postural stability and gait to proprioception as sense of space

Postural stability could be described as the ability of an individual to control the body position, or more precisely its mass center, within certain bounds of space, referred to as stability limits. Stability limits are boundaries in which the body could preserve its position without adjusting the base of support

(43). Normal elderly persons have a tendency towards declining skill to control postural balance in standing in response to unpredicted disturbance and during voluntary stepping. Such fall in postural stability in elderly people could be addressed by the loss of muscle durability (14), visual acuity (11), peripheral sensation, vestibular function and central processing of afferent inputs (15). A 1-year prospective study of force plate variables to forecast the risk of multiple falls in elderly population residing in the community with 277 participants has reported the impaired performance on a range of balance tests in fallers compared to non-fallers (45). However, the ability of balance tests to predict falls is limited when used in isolation (43). A comparison of postural stability between fallers and non-fallers in the elderly study found that elderly population who experienced recurrent falls had increased sway in narrow base stance especially in the medial-lateral direction (15). The increase of loss of stability and the declining foot sensation in elderly people were also reported to be relevant to falls. When in standing posture, cutaneous mechanoreceptors at the soles of the feet provide postural balance. Thus, elderly people with less feet sensation could have greater instability and a higher risk of falls since they might not correctly notice when the gravity center reaches them. Forefoot anesthesia is likely to be vital in maintaining postural balance mainly when closing eyes. Thus, plantar insensitivity may have an impact on postural control where sensory loss occurred regularly with elderly people (14).

When standing upright, two-thirds of the body's mass is positioned two-thirds of the body height from the ground, solely balancing on two narrow legs with only feet directly touching the ground. Ignoring the basic mechanical engineering concepts, such a position needs an advanced postural balance system for the body to stay vertical. Nonetheless, continuously starting a forward fall and then playing back this force by proper positioning of the leading limb is required in order for the body to move forwards (55, 57). Most falls occur when elderly people are at the stage of walking. Selection of foot placement appears to be important in controlling of trunk movements. A direct relationship is difficult to establish as both narrow and wide foot placements have been associated with instability and falls. The movement patterns of the head and pelvis provide a more direct indicator of body stability during gait. It has been suggested that elderly people who could face the high risk of falls exhibit erratic and arrhythmic movement patterns which may interfere with stable vision, thereby increasing the risk of obstacle contact. Elderly people could be associated with suboptimal movement strategies when stepping over or avoiding obstacles, walking on steps and responding to trips and slips (26, 43).

Proprioception is the sense of one's position in space which is vital for efficient contact with the surroundings. The loss of proprioceptive acuity has been directly correlated with falls and would result in lack of functional freedom in elderly people (29). Proprioception in elderly persons could be improved by training which would aid in reducing the likelihood of slip-induced falls (66). It could also help in postural steadiness as well as static and dynamic stability that would provide advancement in gait and balance capacity to finally reduce fall threats (67).

2.1.4 Environmental hazards in elderly people's homes (Extrinsic factors)

Built environment has a direct link to daily life activities. Alteration related to age in later life could lead to the decline of elderly adults' general skills. The underlying assumption is that the less competent an individual, the greater the impact that the built environment has on him or her. By decreasing surrounding barriers, the built environment could enhance an individual's overall capability to function (68).

Most homes were reported to house possible hazards and a number of elderly persons' falls were from tripping or slipping inside their places. The review of environmental risk factors at home for elderly people's exposure to falls indicated that only home hazards may not entirely lead to falls. Instead, the physical abilities of elderly people and their contact with surrounded stressors could be even more key. It has been discussed that household environmental hazards may promote more dangers for the elderly people who have a fair balance, whereas those with weak ability to balance have less contact to the threats. Also, those with good movement ability are likely to have more skills to endure them (31). A cross-sectional survey of 425 participants in Australia found, the elderly who were never visited by the service providers at least twice had a tendency towards having more than five hazards at home compared to those visited weekly or more often (69). Additionally, it was found that elderly persons without a record of preceding falls had a 4-fold risk of falls in connection with the presence of six or seven home hazards compared to those without the home risks (33). However, the elderly people in the research with the history of preceding falls surprisingly had no increased risk of falls even though they had increasing numbers of home hazards and also had a greater risk to fall.

Many fall accidents come from the interaction between distinguishable surrounding danger and increased individual sensitivity to hazards from accumulated impacts of age and disease (26). From the study of environmental hazards with 570 intervention participants living in 452 homes, all homes had at least one fall-related hazard (34). The bathroom was identified as the most unsafe room in elderly people's home. Two or more hazards found in the bathroom frequently were related to floor surfaces, poor lighting, an absence of appropriate grab bars or handrails, steps, objects on the pathway, poor design of furniture, bad placement of furniture as well as the toilet design. Falls have been reported to occur mostly in bathrooms (21, 70). Also, for those who had experienced falls in the study, the most dangerous area for them was a bathroom (22).

The study of population-based prevalence rates of potential environmental hazards of 1,000 participants in New Haven, Connecticut suggested that prevalence of most hazards from built environment was high. Two or more hazards were found 59% in the bathroom and 23% to 42% in other rooms such as living room, kitchen, bedroom, and hallways (21). Environmental problems frequently found at the residence of elderly persons include lack of grab bars in the tub or shower and lack of protection against bathroom slipping (71). Built environment that is not suitable such as a built-in seat or chair in the bathroom that is too high in height could be seen as a crucial environmental hazard in a residential place. Some evidence indicated that the type of surface on which elderly people fall could affect the likelihood of suffering an injury (43). Therefore, the elderly people's homes are potentially dangerous since falls occurring inside the house could result from an interaction between stimulators of the surroundings and physical skills as well as risk-taking circumstance (31, 69). The interaction between physical function, the perception of risk and exposure to risk remains an area requiring further evaluation (43).

Although the participants have no record of preceding falls, they have an increased risk of falling because of home hazards (33). The development of the strategy to make home environment safer for the elderly is important not only for removing possibility of disability but also for preventing fall-related accidents (71). In the residences of elderly people, fall hazards are everywhere. The intervention could result in a small reduction in the mean number of hazards per house. Many study subjects have taken such action but they involved only removing a few hazard potentials. The impact of the intervention in achieving self-report action to reduce hazards was high (34).

Home hazards, in the built environmental factor, have been recognized as a contributing factor to falls in elderly people. Adjusting the home environment to prevent or reduce the number of falls is likely to be reasonable for everyone using the safer environment. A key factor for healthy aging is the built environment. Person-environment fit could have a considerable effect on quality of life, attachment to place, and sense of well-being and belonging (72). The results from the study of the relationship between home modifications and aging-in-place, using the ENABLE-AGE United Kingdom sample (376 participants) demonstrated that those who had home modifications carried out tended to live longer at their existing residence than those who did not and also proved that home modifications had positive impact on elderly people's living quality (68). The study of role of the environment to avoid fall both at home and in the community indicated that multifactorial interventions, including risk assessments, physical activity, and environmental modifications could help reduce fall incidents (73).

Housing could be perceived as the core of personal autonomy and social participation, especially for elders. The physical environment is an important determinant that might require long-term care services. It has been studied that home modifications could strengthen the personal and social meaning of home for the senior citizens and could help lessen their dependence on others in performing daily activities (68).

2.1.5 Summary

Fall problems happen commonly which could bring severe health issues as well as social and psychological impacts for elderly people. All parties including elderly adults and people, their families, and the healthcare professionals are most worried about possible injuries from falls. Therefore, one of the key public health objectives is to minimize fall risks in elderly people. Also, preventing fall is important because it could help sustain wellness of elderly people and prolonging their ability to live with less dependence on others at their own residences. Strategies to prevent falls once implemented effectively, rates of injuries from falls, emergency cases, hospital admissions as well as nursing home occupancy, would be decreased for those senior persons in the community. To lessen fall chance is to ensure that possible threats, house modifications and helping tools are enforced as they are all important contributors to prevent falls. Time should be invested for evaluating home settings as well as making needed alterations in order to significantly minimize threats for elderly people. Additionally, to incorporate ergonomics especially in the bathroom design to prevent or reduce fall risks, there should be collaboration of many parties including safety experts, design professionals, engineers as well as healthcare or homecare persons. Ultimately, this could promote sustainable quality of life in terms of safety and well-being of elderly people who wish to live independently in their own homes (74).

2.2 Cognitive and motor plasticity contribute reducing falls in the elderly people

2.2.1 Introduction

Increasing of population elderly people worldwide is a challenge for medical care nowadays. Several lines of evidence in the fall problem have reported how falls are still the biggest problem for elderly people. Poor EF, and cognitive and motor impairments are particularly major causes. Advancing age is closely associated with cognitive decline and motor learning skills deficit. Elderly people’s brain function declines, whereas this, in turn, color experiences and intelligence that remain. Recently, cognitive and motor plasticity is a new concept in elderly people now, for restoration, maintenance or even enhancement of intelligence. Selective attention in Stroop test and working memory in juggling are introduced as an EF training intervention for cognitive and motor plasticity respectively. In this review, the EF training summarized and linked essential data information with falls in elderly people. It will be the background data operating for promoting cognitive and motor plasticity and reduced falls in elderly people throughout a long life.

2.2.2 Executive function, attention, and working memory

EF is a comprehensive term that encircles the set of higher-order processes such as attention and working memory. EF is a series of allied cognitive abilities for reaching goal-directed behaviors. The EF impairment is linked to falls in various aspects. The elderly non-fallers are more likely to have greater baseline of EF than the elderly fallers. Elderly people with the poorest EF have the potential to experience a fall in the not too distant future which then leads to multiple falls. The EF decline reduces decision-making processes and motor balance in elderly people's gait. It affects a decrease in length and speed, and increase of variation of body sway. In coordinating multi-tasking, EF is an indicator in evaluating dual tasks. The incidence of falls is associated with the performance of dual tasks in elderly people. Activation and connectivity of the neural network for EF, such as frontal regions, plays an important role in predicting the future fall risks in the elderly (75).

Attention is an outstanding ability when needed to avoid distractions or interference situations. This ability assigns cognitive resources to process the information in one's focus. However, less information can be managed by the elderly when compared to the young. This is explained by the fact that attention decreases with advancing age. Reducing the concentration capacity enhances loss of mobility and gait disturbances. This suggests that the ability to concentrate may share similar neural origins with gait velocity. Normal gait pattern can be interrupted by sharing attention with a secondary task. Switching attention between tasks is a serious situation in elderly people who have stability impairment. It is even worse in an unfamiliar environment which is linked to a greater number of falls. Thus, lack of attention, along with advancing age, troubles gait and balance control, and is associated with an increased likelihood of single and recurrent falls (75).

Working memory is not only limited to cognitive functions but also to the practicing and learning of motor skills. With a repetition of daily practice, working memory can be possibly improved. Working memory requires an instruction or a sequence of movements' order, and past failures to store the related information in performing the skill (76). Training in working memory can improve the performance of motor skills during dual tasks, and can also generalize contribute to the success of various other tasks that where never trained.

Moreover, low performance in working memory reflects slow gait velocity. It suggests that gait's cortical control is linked to working memory degenerating as mild cognitive impairment in elderly people. Slowing gait speed and motor control deficit have often combined with cognitive and motor impairments in elderly people. In young persons, gait motor control is usually an automatic process whereas in elderly persons it requires a collaborative processing of cognitive control. Gait velocity slowing with advancing age has been related to the increasing rate in the risk of falls (77, 78).

Working memory is one of the age-related mechanisms that can illustrate the differences in intelligence. By acting on much information at the same time, a limited processing capacity needs to be shared by working memory and intelligence. Both demand controlled and effortful processing (79). A number of environmental stimuli can obstruct the elderly working memory from completing a task. A low rate of accuracy and slow reaction time reflect a high load on working memory. It is even more difficult when more items and conditions have to be maintained with a limit of time. This suggests that the dorsolateral prefrontal cortex is associated with capacity and processing speed reduction with an increasing age (80).

2.2.3 Stroop test and cognitive plasticity in the elderly people

The Stroop effect, or the color-word test, is one of the most widely used tests in cognitive studies. An original test, the examiner is required to name the ink color of color words as fast and accurately as possible. Items in the test can be congruent, with a match between ink color and color word (e.g. ‘‘red’’ written in red), or incongruent (‘‘red’’ written in green). Reaction time of an answer is typically slower for the incongruent than the congruent task. This phenomenon is known as the interference effect. It is generally considered to reflect the time needed to overcome the conflict between the automatic word-reading tendency and the more controlled color naming response (81).

Attention plays a crucial role in the Stroop effect (82), which requires attending to less automatically processed, task-relevant attributes of stimuli and the suppression of involuntary processing of task-irrelevant attributes (83). There is considerable current interest in relating age differences in the Stroop effect and on other measures of EF to neuroanatomical and neuroimaging findings suggesting that aging particularly affects functions served by prefrontal areas of the brain (84, 85). This suggests that the Stroop can be an indicator of attention in prefrontal areas of the elderly brains.

The Stroop test has also been used to examine purported age-related declines in inhibitory control. Since it produces interference from two competing streams of information, from which individuals must inhibit processing of one to select and respond to the other. The Stroop effect is greater for the elderly person which is believed to be due to a decline in the ability to inhibit processing of one of the competing inputs (84). Computerized training has been suggested to be beneficial for elderly people. Training with real-time strategy tests can attenuate declines across a range of cognitive abilities like EF and reasoning (75). Thus, the Stroop test as a technological device is suitable to guide training in the elderly people.

2.2.4 Juggling balls and motor plasticity in the elderly people

Juggling balls requires working memory as well as managing multiple tasks. Juggling tasks challenge performers to hold more information in working memory while manipulating that information. Juggling balls improves the ability to make rapid decisions and solve problems in complex environments. It slightly increases working memory capacity by increasing the ability to attend to a number of different things at once. The performance becomes more complex when increasing the number of balls as well as increasing the speed of the movement.

Aging is usually accompanied by a decline in motor performance. Results of rapid aiming arm movements show that the elderly people are considerably slower and less smooth in motor execution than children and young persons. The elderly people also showed more frequent feedback-related corrective sub-movements during motor implementation than younger persons. The elderly showed greater deficits in postural control on a moving platform than did the young. Motor performance remains generally stable throughout young adulthood and declines in late adulthood (83).

The majority of motor learning research focuses on a key aspect of skill acquisition, namely, the rate of skill learning. For elderly people, learning efficiency or proficiency is impaired. For instance, in motor skill acquisition, young persons used both on-line (improvement during practice) and off-line modes (improvement beyond practice). In contrast, elderly people were limited to on-line motor learning, thereby signaling poor memory consolidation or reduced learning efficiency as a result of cognitive aging. In acquiring bimanual coordination skills, the elderly people are slower learners in comparison with young learners (83).

Motor learning potential is the capability to achieve certain levels of performance with extended practice. Despite aging-related declines in motor performance and learning efficiency, the potential to learn motor skills is usually preserved in the elderly. Elderly people required a much longer time to reach a performance level similar to that achieved by young persons. In addition, in a 6-day juggling training regime, the elderly people reached a skill level comparable to that of most young persons. More importantly, juggling practice resulted in growth in gray matter within the left hippocampus and the nucleus accumbens, on both sides of the brain, for the young and elderly people. Whereas the learning proficiency was low, the elderly people were able to learn motor skills. Furthermore, the number of practice trials for acquiring a mirror tracing skill was predicted by the age and fitness of the elderly people. Overall, these studies suggest that, with extended motor practice, and at a slower pace, elderly people are able to learn new motor skills and to achieve a skill level similar to that of young persons (83).

2.2.5 Summary

This review suggests a combined training regime as a key factor in promoting and maintaining mechanisms of EF for elderly people. Attention and working memory in EF can be improved by the Stroop effect and juggling balls. It benefits cognitive and motor plasticity in elderly people. In the event of novel experiences, the new learning can change the brain of the elderly people. By exposure to novelty, the development of new learning contributes to better cognitive and motor functions. The Stroop effect and juggling balls are not a common activity in ADL. This supports new and productive experiences that have impact on elderly people. The EF training programs should be realistic and easy to accomplish. By improving attention and working memory in aging, they enhance the mechanisms that allow plastic change in cognitive and motor functions. In the near future, eventually, it may also increase the quality of life by contributing to the reduction of falls in aging people.

2.3 HRV in elderly people

2.3.1 Introduction

The impact of HRV is important in elderly people. Even if the understanding of it is still ongoing, HRV is a significant parameter in cardiovascular assessment. HRV reflects the activity of ANS that is the function of the cardiovascular system. It is a trending indicator of sympathetic and parasympathetic systems in various populations. The application of HRV is usually used as a physiological marker in physical activity and training. By monitoring and tracking an adaptation, it is useful for investigating the development of performances (86, 87). This session reviews the relevant articles in the use of HRV in elderly people, the measurement and interpretation, and PTT as well.

2.3.2 Autonomic innervations of the heart

The heart and circulatory system are primarily controlled by the higher brain center (central command) and by the cardiovascular control area located in the brain stem, through the activity of the ANS. The ANS comprises the sympathetic and parasympathetic nerves (vagal nerves) outflow to the heart and blood vessels, which are primarily regulated by the medulla (88). Particularly, the nucleus tractus solitarius in the medulla receives sensory input and stimulates cardiovascular responses for emotion and physical stress. From the medulla, the parasympathetic vagus nerve innervates the heart to the sympathetic nerve fibers. The right and left vagus nerves innervate the sinus atrial (SA) and atrioventricular nodes, respectively. The atria are also innervated by vagal efferent, whereas the ventricular myocardium is sparsely innervated by the vagal efferent. Sympathetic efferent nerves are present throughout the atria, particularly in the SA node and ventricles. Sympathetic stimulation increases the HR, and contractility and conduction velocity through the mediation of α and β adrenoreceptors. Parasympathetic stimulation has the opposite effects through the muscarinic receptor. Autonomic control of the cardiovascular system is also affected by baroreceptors, chemoreceptor, muscle afferents, local tissue metabolism, circulating hormones, and environmental behavior (89). Although sympathetic and parasympathetic systems are active at rest, the parasympathetic fibers release acetylcholine, which acts to retard the pacemaker's potential of the SA node and thus reduce the HR (86).

2.3.3 ANS regulation of HRV

HRV refers to the beat-to-beat alteration of the heart. The ECG of a healthy individual measured under resting conditions shows periodic variation consisting of a rhythmic phenomenon known as respiratory sinus arrhythmia (RSA). RSA fluctuates with the phase of respiration with cardio-acceleration during inspiration and cardio deceleration during expiration. Vagal efferent pathways trafficking to the sinus node occurred primarily in the phase with expiration, and absent or attenuated during inspiration. This data identify, RSA as predominantly mediated by respiratory gating of parasympathetic efferent activity to the heart; referring HRV as a marker of dynamic and cumulative loads. As a dynamic marker of loads, HRV appears to be sensitive and responsive to acute stress. Regular physical activity retards the aging process, increasing HRV, presumably by increasing vagal tone. Therefore, HRV is considered a marker of frequent activation (short dips in HRV in response to acute stress) and the inadequate response (long-term vagal withdrawal, resulting in the over-activity of the counter-regulatory system), leading to the sympathetic control of cardiac rhythm (86).

2.3.4 Measurement of HRV parameters and interpretations

HRV may be evaluated by a variety of complex methods. The most common method is standard ECG, considering the temporal variation between the sequences of consecutive heart beats. The lengths of successive R peaks (R-R) in the QRS complex can be described mathematically. R-R is not consistent between successive R peaks. Of note, during the onset of physical activity, R-R intervals become shorter and more uniform, resulting from increased sympathetic activity and parasympathetic withdrawal. Thus, despite the complexity of the type of mathematics involved in the calculation of HRV, a variety of algorithmic models that represent R-R intervals are widely available, and autonomic activation can be evaluated by analyzing HRV to estimate the sympathetic-vagal balance (90-92). In addition, the period between the QRS complex resulting from sinus node depolarizations is termed the normal-normal (N-N) interval. HRV is the measurement of the variability of N-N intervals (93).

The crucial element for the analysis of HRV is the time-domain parameters reflecting the standard deviation (SD) of all N-N intervals (SDNN) that reproduce the total variability and the root mean square of SDs between adjacent N-N intervals (RMSSD), which reflect parasympathetic activity (86) as shown in Table 2.3. HRV time domain indices quantify the amount of variability in the interbeat intervals between successive heartbeats. Frequently used measurements include the Mean RR, SDNN, Mean HR, STD HR, RMSSD, NM50, pNN50, RR triangular index, and TINN. All measures of HRV are affected by physical conditioning (94).

Table 2.3 HRV time domain indices

Index	**Mechanism**
SDNN	Sympathetic and parasympathetic
pNN50	Parasympathetic
RMSSD	Parasympathetic

Frequency-domain analysis describes high and low frequency rates of the variability changes, corresponding to the activity of different branches of ANS (86). By applying these frequency range differences in HRV analysis, the individual contribution of parasympathetic and sympathetic systems were identified. Parameters LF referring to modulation of the R-R interval changes between 0.04 and 0.15 Hz corresponds to the sympathetic and parasympathetic activity together. High frequency (HF) modulation (0.15-0.4 Hz) of R-R interval changes is primarily regulated through innervations of the heart by the parasympathetic (vagal) nerve. LF and HF parameters are provided as normalized (LFn and HFn) by calculating the fraction of LF or HF relative to the total, minus LF (86) as shown in Table 2.4.

Table 2.4 HRV frequency domain indices

HRV Band	**5 Minutes Recording**	**Processes**
LF	0.04-0.15 Hz	PNS, SNS, and baroreflex activity (when breathing at resonance frequency)
HF	0.15-0.40 Hz	Inhibition and activation of the vagus nerve by breathing (respiratory sinus arrhythmia)

Another parameter that may be considered is the Pointcaré plot, calculated as follows: an individual's R-R intervals plotted over time and SD used to interpret changes are evident in the plot. The standard descriptor 1 (SD1) is the fast beat-to-beat variability in the R-R intervals, while the standard descriptor 2 (SD2) describes the longer-term variability. SD1 reflects mainly the parasympathetic input to the heart, while SD2 reflects the sympathetic and parasympathetic contributions to the heart (90-92). However, as mentioned above, respiration greatly affects HRV, thereby increasing HRV when respiratory frequency decreases, rendering difficult the proper interpretation of HRV data. Thus, investigators have accepted various respiratory frequency ranges (e.g. 6-15 beats/min) and admitted self-organized respiratory pattern to be maintained during the recording period, in order to have interpretable results (86).

2.3.5 HRV on the effects of age on exercise physiology

HRV is becoming one of the most used training and recovery monitoring tools in training programs. The possibility of applying HRV on such a variety is based on the fact that cardiovascular autonomic regulation is an important determinant of training adaptations, before also being responsive to training effects. The beneficial effects of physical exercise on enhancing vagal tone have been identified (95). Using SD1 normalized (SD1n) for average R-R intervals on subjects from different age groups and conditioning showed that SD1n was significantly higher at rest. However, age-related differences in cardiac vagal activity were not significant after exercise (96). The age-matched subjects with good, average and poor VO_2 peaks showed no difference in SD1n at rest, but were significantly different in the low- to moderate-intensity levels. These findings suggest that poor physical fitness was associated with impairment in cardiac vagal function during physical exercise (86).

The use of HRV is a suitable solution, since it reflects the major regulatory processes after physical exercise. The use of HRV to detect which measures are altered versus physical exercise, type and intensity have been extended to demonstrate how monitoring physical fitness during exercise and post-exercise periods can be applied to a program of training more broadly in the future. HRV changes during a prolonged period, over 4 weeks of exercise has been shown to be a particularly good indicator of physiological adaptation in athletes able to assist in the planning of training programs. Previous findings showed that daily exercise intensity based on the HRV of the athlete, and lowering the intensity based on HRV, decreased maintained fitness levels comparatively to the control groups (97, 98), indicating the importance of HRV use in exercise physiology (86).

The usefulness of HRV measurements in prescribing exercise training in moderately active people has also been identified within the prescription of standard training or HRV-guided training, including 2 months of moderate training (70% max HR) or vigorous training (85% max HR). Additionally, the utility of HRV measurement in daily endurance exercise prescription during a 4-week training period showed similar beneficial outcomes in individuals who were prescribed lower-intensity exercise with decreased HRV. Additionally, in athletes, HRV monitoring is frequently applied to prevent and diagnose overtraining (OT) syndrome, which is associated with numerous syndromes such as ANS dysfunction and imbalance. The test to diagnose fluctuations in ANS and the OT state is based on the measurement of the orthostatic HR that occurs between sitting and standing. Athletes in an OT state may show a significant decrease in frequency domain (TP, LF and HF) and time domain (RMSSDD and SDNN) variables. Additional observations have yielded information revealing hyper-responsiveness in the frequency and time domain in OT athletes. Changes in HR do not occur in OT athletes with short-term training (e.g. 6 days) or long-term (6 months) OT. Other findings have shown predominance for LF (sympathetic) or HF (vagal) parameters. This shift from vagal to sympathetic predominance has been reported in female athletes assayed for HRV in the supine rest position after 6 to 9 week high-intensity training (86).

2.3.6 Pulse transit time

PTT is introduced as a non-invasive method and useful automatic monitoring tool, in elderly people. Between two arterial sites, the time delay for the pressure wave to circulate is PTT. The estimation of PTT is often calculated by times between R wave peak of QRS complex and a finger tip's pulse wave peak. The pressure wave normally travels more rapidly than blood. It may be visible as an acute dilation of the arterial wall. PTT is usually associated to BP in a negatively way. Between proximal and distal waveforms, the relative timing is used as an estimator to specify the arterial pulse. When heart increases contractility or decline in vasomotor tone of peripheral vessels, therefore, pulse wave velocity increases and PTT is short. This may be explained by sympathetic activation increasing blood pressure and vascular tone and stiffening the arterial wall, causing the PTT to shorten (99).

2.3.7 Summary

Physiological changes in elderly people as a reflection of physical activity and training could be investigated by a non-invasive method, through HRV (86). The SA node normally generates the heartbeat, which is modulated by autonomic efferent neurons and circulating hormones. There is a dynamic balance between sympathetic and parasympathetic nervous outflows in a healthy, resilient, and responsive nervous system. Multiple regulatory mechanisms that operate on different time-scales produce HRV. Vagally-mediated HRV appears to represent an index of self-regulatory control, such that individuals with greater resting HRV perform better on tests of EF (100). HRV parameters are relevant in the analysis of stress that the body experiences during training and to increase insight into physiological recovery after training (87). Referring to athletes, changes in the patterns of ANS reflected by altered HRV may serve as useful parameters for managing physical fatigue and establishing exercise intensity (86).

2.4 DFS for Thai elderly population

DFS refers to the design which links the relationship among the development of people's well-being, the environment, and the search for change and innovation. Obviously, DFS is not only helping the elderly persons overcome physiological factors and various obstacles in society with specific approaches, but also promoting their social accessibility by increasing equal opportunities to social participation. This article proposes the guidelines to developing DFS for elderly persons in Thai society, and based on the ministerial regulations on facilities in buildings for the disabled or deformed and the elderly of Thailand (2005) and ISO/IEC GUIDE 71: Guide for addressing accessibility in standards (2014) by the international organization for standardization (ISO) and the international electrotechnical commission (IEC). To develop the guidelines, the regulations were explored to identify all gaps between the Thai and international standards, focusing on DFS. The guidelines aim for Thai society to consider and pay more attention to sustainable design for elderly persons, and to be aware of their rights regarding facilities design, as they are part of society and are also entitled to live freely without excessive concern in everyday life. It also aims to increase the sense of self-respect in elderly persons as valuable members of society and not an obligation. Their experiences are priceless and respectable, capable of establishing prosperity for the nation. DFS also helps government reduce the long-term loads of elderly persons' medical fee, which immensely benefits the country. DFS not only gives quality of life to elderly persons but also to all in the society. In order for it to succeed, everyone needs to be aware and participate.

2.4.1 Introduction

DFS is a concept to meet the requirements of survival, safety and mental security, and guarantee the long-term and stable development of society, mind and intelligence of people. DFS takes the needs of people and the basic functions of products into consideration to fulfill requirements for the survival of further generations and to solve recycling issues of energy and materials. It undermines the economic development conception of chasing high speed, high production and high quantity. DFS is more like a natural ecosystem which will helps to build a sustainable life style and construct barrier-free facilities which are good for the development of cities (101). In addition, DFS refers to design which takes into consideration the relationship between the development of people's well-being, the environment, and the search for change and innovation. On one side, DFS is not only related to the design for elderly persons by helping them overcome physiological factors and various obstacles in the society with specific approaches, but also emphasizes their social accessibility by increasing equal opportunities to social and economic participation. The elderly encounter several difficulties for ADL due to the alteration of circumstance and requirements because of a gradual decline of physical and cognitive abilities. So it is very necessary to discuss guidelines to develop DFS for elderly persons in Thai society to maintain their life qualities.

Therefore, this article proposes guidelines to developing DFS for elderly persons in Thai society, based on the ministerial regulations on the facilities in buildings for the disabled or deformed and the elderly of Thailand (2005) and ISO/IEC GUIDE 71: Guide for addressing accessibility in standards (2014) by the international organization for standardization (ISO) and the international electrotechnical commission (IEC). To develop the guidelines, the regulations were explored to identify all the gaps between Thai and international standards, focusing on DFS for elderly persons.

2.4.2 An overview on Thai and international standards

The ministerial regulations on the facilities in buildings for the disabled or deformed and the elderly of Thailand (2005) consisting of 12 parts in 16 pages expressed as 1) Introduction, 2) Signage displays facilities, 3) Ramp and lift, 4) Steps, 5) Parking, 6) Building entrance, circulation and connection between the buildings, 7) Doors, 8) The water closet, 9) Touch surfaces, 10) Theater, auditorium and hospitality, 11) Clause, and 12) Remarks. Without change or development since 2005 the recently issued document which is most relevant to the elderly persons accessibility standard is the ministerial regulations on the characteristics or accessories, facilities or services, in buildings, places or public services accessible and applicable for the disabled (2012). However, the content is focused primarily have on persons with disabilities. It could be seen therefore, that Thai standards for elderly persons have never developed for over a decade (102, 103).

In contrast, ISO/IEC GUIDE 71: Guide for addressing accessibility in standards was issued in 2014 by the international organization for standardization (ISO) and the international electrotechnical commission (IEC), consisting of 14 parts in 50 pages which contain 1) Foreword, 2) Introduction, 3) Scope, 4) Terms and definitions, 5) Accessibility, 6) Accessibility in the standards development process, 7) How to apply the Guide, 8) Accessibility goals, 9) Human abilities and characteristics, 10) Strategies for addressing user accessibility needs and design considerations, 11) Annex A: Global trends supporting accessibility, 12) Annex B: The International Classification of Functioning, Disability and Health (ICF) as a resource for terminology, 13) Annex C: Questions to aid in achieving the accessibility goals, and 14) Bibliography.

This second edition cancels and replaces the first edition (ISO/IEC Guide 71:2001), which has been technically revised. The second edition of this Guide, retitled "Guide for addressing accessibility in standards," builds upon the edition published in 2001, titled "Guidelines for standards developers to address the needs of older persons and persons with disabilities". This edition takes account of developments in thinking and practice which have taken place since 2001 and takes a more inclusive approach. This edition also sets out to improve the usability and adoption of the Guide itself. This Guide, like its predecessor, is intended to be part of the overall framework that standards bodies could use in their efforts to support the development of systems that suit the needs of diverse users (104).

Within the next decade, Thailand will become an aging society, which means Thai standards could no longer be ignored. On the other hand, it is a good opportunity to take action to develop the standards focused on basic infrastructure, facilities and services.

2.4.3 Application of the concept of DFS for elderly persons in Thai society

The purpose of both Thai and international standards are guidelines to assist elderly persons, whether directly or indirectly, and also, to enable them to live more freely and conveniently in ADL with focuses on various types of systems. Thai standards are focused on excessive characteristics, dimensions and places (locations) of the physical environment. In contrast, the international standards focused on the systems, process and diversity of users by giving details of the individual characteristics, including physiological factors and cognitive abilities. It does not only support elderly persons being equal in society but also protects elderly persons from impairments by using their standards. Unsurprisingly, Thai standards should give more attention in their contents to the understanding, interpretation and development of the guidelines. However, international standards are not just ordinary content since they contain complex information. It also has several connections tied up within the topics. Thus, it is not easy to understand in a short period of time. By clarifying relationships, correlations between parts are very important making careful reading essential. In the same way, the Thai language in the standards could easily lead to misdirection as well. Because the Thai language is flexible by its nature, depending on interpretation. Even though there maybe similarity of meaning, in different circumstances or situations there could be misunderstanding.

In the next edition, The DFS facilities should be designed as a part of the urban space to form a unified and complete environment for the travel convenience of elderly persons. Thai standards should set out the basic principles for ensuring that the needs of elderly persons (and persons with disabilities as well) are incorporated into the standards development process, providing justification on human rights and economic grounds. One of the core points is “accessible or universal design”, which aims at ensuring that products, systems, services, environments and facilities could be used by persons from a population with the widest range of characteristics and abilities. Moreover, the guides should intend to supplement the Joint Policy Statement by providing a set of accessibility goals and describing human abilities and characteristics of elderly persons to assist standards developers in identifying accessibility needs of diverse users in diverse contexts of use. Based on their individual abilities and characteristics, people’s accessibility needs vary substantially and change throughout the course of their lives (e.g. as people advance from adulthood to pre-aging and on into aging). Impairments could be permanent, temporary or vary on a daily basis, and sometimes they are not fully recognized or acknowledged. In addition, although some limitations could be minor in nature, combinations of limitations could pose significant problems for individuals attempting to interact with systems. This is the case particularly where user accessibility needs and accessibility requirements were not recognized during development of those systems. Standards that include accessibility requirements could support development of systems that could be used by many users (104).

At the same time, the guidelines to developing the DFS for elderly persons in Thai society should not only coordinate with other facilities, but also reflect the cultural connection of Thai society, combined with the context of city, though the DFS. The guidance provided in these guides should cores broadly. The guides recognize the principle that the standards should uniquely respond to the Thai context and culture, but normally not in a way that design restricts. The guides therefore should suggest ways of determining user accessibility needs without providing specific solutions. As a result, the next guidelines edition developing DFS for elderly persons in Thai society could shape the physical appearance of the city and sustain its culture.

2.4.4 Summary

The aim of these guidelines is to enable Thai elderly persons to approach sustainable design which concerns Thai society, easily and pay more attention to them. It also aims to increase the sense of self-respect in elderly persons, as they are indeed valuable to society and not an obligation. Their experiences are priceless and respectable, capable of establishing the prosperity of the nation. DFS also helps government reduce the long-term loads of medical care fees if both the quality of life and general health can increase in Thai elderly persons. The guidelines are presented as information that can be useful to other persons, such as manufacturers, designers, service providers and educators. Moreover, for the greatest extent possible, such as universal design, accessible design, design for all, barrier-free design, inclusive design and transgenerational design.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Sample size calculation

The calculation of sample size to compare the difference in the ratio between the 2 population groups which are independent from each other.

$$n/\text{group} = \frac{2(Z_{\frac{\alpha}{2}} + Z_{\beta})^2\ pq}{(p_2 - p_1)^2}$$

n = Number of the sample size

$Z\alpha/2$ = Confidence level of the Z statistics at 95%

$Z\beta$ = Power of the test at 90%

p_1 = Ratio of the first population group

p_2 = Ratio of the second population group

n_1 = The number of first population group

n_2 = The number of second population group

p = $(n_1p_1 + n_2p_2) / (n_1 + n_2)$

q = 1-p

The Thai elderly population, (60 years and older) recently numbered 9,110,754 people, based on data from civil registration by the Department of Provincial Administration (2014). The report of Thailand's population health examination survey IV (2009) by the Thai national health examination surveys, Health Systems Research Institute (HSRI) reported that 18.5% (1,685,490 people) of the elderly people had at least one fall within 6 months. Without extrinsic factors 25.15% (423,901 people) of the elderly fallers were caused from loss of their balance and fainting. The report on the 2002 survey of the elderly in Thailand by the national statistical office, The Ministry of Information and Communication Technology, reported that 5.03% of the aging people had OH. Consequently of the Thai elderly population who had falls without extrinsic factors, by OH, was estimated as 21,322 people.

$$\frac{n}{2} = \frac{2(1.96 + 1.28)^2\ 0.791 \times 0.209}{(0.046 - 0.815)^2} = \frac{3.684}{0.591} = 3.47$$

p_1 = 0.815 (Ratio of the elderly non-fallers group)

p_2 = 0.046 (Ratio of the elderly fallers group)

n_1 = 7,425,264 (The number of elderly non-fallers group)

n_2 = 423,901 (The number of elderly fallers group)

p = (7,425,264 x 0.815 + 423,901 x 0.046) / (7,425,264 + 423,901) = 0.791

q = 0.209

According to the result of the sample size calculated above, the number of the sample size for the present study was 4 elderly persons in each group (8 elderly persons in total number). In case of any unpredictable situation, another 20% was added, to increase the total number of the sample size. This ensured that there would be enough elderly persons left in the final stage. Therefore, the total number of the final sample size was 10 elderly persons, or 5 elderly persons in each group.

3.2 Participants

The present study recruited and selected male and female participants from the Watsanawet Social Welfare Development Center for Elderly Persons, located in the Phra Nakhon Si Ayutthaya province of Thailand. This study comprised 28 participants (8 males and 20 females) aged 62-85 years old. The previous 12 months of medical records or official reports were used to divide the participants into 2 groups. One or more falls made the group of elderly fallers. A group of elderly non-fallers were those who had had no record of falls (Figure 3.1).

3.2.1 Inclusion criteria

The selection criteria included those aged 60 years or older, with the ability to walk for 6 minutes without any helping equipment or support (105), the score of THAI-MMSE at 24 or above (106), and, most importantly, the lack of prior experience in juggling.

3.2.2 Exclusion criteria

Unqualified applicants were, those who were not capable of comprehending the study purpose and not available at the training for more than one day. Those having a record of severe psychological, psychiatric problems, neurological disorders (45) as well as motor cognitive restriction such as Stroke and Parkinson's Disease (39) were also not eligible.

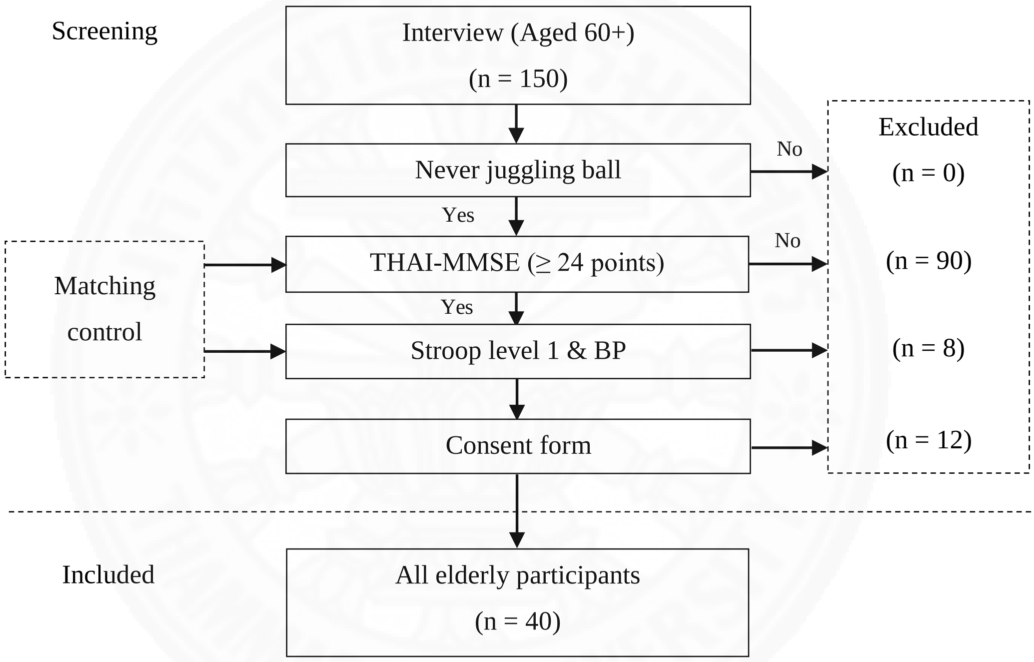


Figure 3.1 Flow diagram of the experimental research process

3.2.3 Screening processes

One hundred and fifty inquiries were solicited via a public voice address at the center. The short advert was about the purpose and an overview of the present study. After an initial interview screening, all the elderly people selected were people with no prior experience in juggling. They were all invited to participate in the THAI-MMSE screening assessment. Fifty individuals had an unqualified score on the THAI-MMSE. The remaining 60 individuals agreed to participate in the next screening test of the Stroop at level 1. Eight individuals were unable to complete the Stroop. The remaining 52 individuals, who had THAI-MMSE and Stroop values matching in the same range, were invited to an orientation meeting where all details of the present study where provided. Participants were also asked whether they felt curious about the present study. Twelve individuals were excluded at this stage because of an inability to understand the purposes of the study. Therefore, a total of 40 participants (8 males and 32 females) gave their written and informed consent to join the present study, which was approved by the local ethical committee, Faculty of Medicine, Thammasat University (MTU-EC-DS-6-069/59) in the final stage.

Once recruited, interviews on topics of overall health and background were conducted and collected to confirm eligibility status (Appendix X). Medical conditions were recorded, such as dizziness, low blood pressure, visual impairments, muscle weakness, osteoporosis, foot problems, and daily alcohol consumption. The use of drugs like benzodiazepines, psychotropics, class 1a antiarrhythmic medications, digoxin, diuretics, and sedatives and/or the use of more than four different medications (multiple medicine use) were noted (17, 45).

3.3 Measurement methods

The measurement of the present study was carried out with pretest, mid-test, and posttest data. Weight and height of the participants were measured for body mass index (BMI) calculation. For the six-minute walk test (6MWT) (107), HR at rest, systolic blood pressure (SBP) at rest, and diastolic blood pressure (DBP) at rest, and distance were measured to calculate velocity, $VO_{2\ max}$, and metabolic equivalent time (MET). The visual acuity (VA) test was examined with the Landolt ring chart (13) to determine eye ability, both when the participants were with, and without, their own glasses. The proprioceptive sense was measured in both dynamic, and static positions (29). The finger–nose test was used to evaluate the dynamic movement of coordination, and toe position sense was for testing in static joint position sense. The two-point discrimination test (TPD) was measured in metatarsal (108) and toe areas of foot to detect the tactile perception ability (15). The range of motion (ROM) was only used for screening test, not for the statistical analysis in the present study. The short-term HRV was examined with 3 positions in the sitting position, the supine position, and the standing position continuously.

3.3.1 The six-minute walk test

The participants were invited to sit back and relax at least for 5 minutes before starting the test. After 5 minutes, a digital automatic blood pressure monitor was used to measure SBP, DBP, and HR in participants at resting. Any participants whose BP was more than 100 bpm, SBP more than 180 mmHg, or DBP more than 100 mmHg have been excluded. In addition participants were not to be in a condition of tiredness, fatigue, or feeling unwell. The participants were asked to return to sit back and relax if their conditions were accepted.

The participants were asked to wear comfortable clothes and shoes to perform the test. For female, trousers or pants were preferred, a Thai sarong was allowed but no longer than 15 centimeters from the ankle. The participants were asked to take off all accessories, for example, hats, watches, rings, earrings, necklaces, bracelets, keys, wallets, or anything things that could slow the performances or could be the cause of accidents. Only glasses were allowed to be worn during the test.

The 6MWT was performed over 60 meters in the quiet corridor next to the center's infirmary. At all times the physician of the center was present. The participants walked on a flat, hard and straight floor with handrails on both sides. There was sticker tape clearly marked on both ends and every 3 meters on the floor (Figure 3.2). The participants received the instructions for the test with the sequence randomly assigned by drawn lots. Two participants were challenged to the test each time. The participants were asked to walk 6 minutes without personal or equipment assistance. The participants were instructed to walk as quickly as possible to cover the longest distance at their comfortable paces and were encouraged to walk as far as possible without running (107, 109).

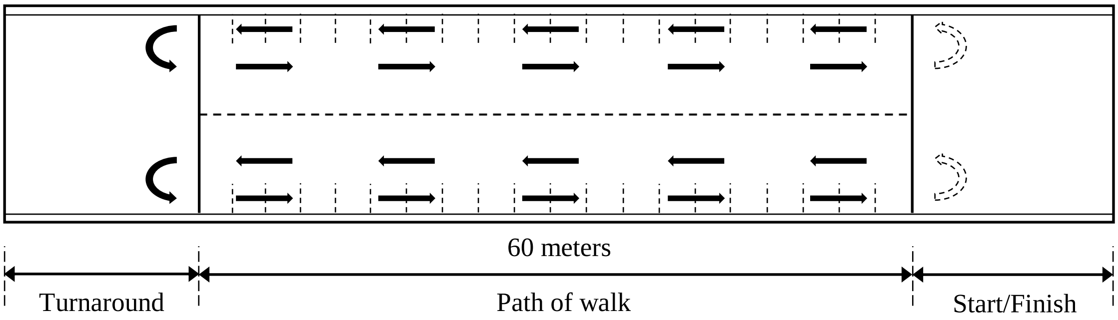


Figure 3.2 The setting of the 6MWT

During the test at every 1 minute intervals, the participants were informed that they were "doing well" or to "keep up the good work" and the time remaining. The participants were allowed to take a standing rest and/or hold a handrail if they chose to do so at any point, but were asked to resume walking if and when possible until the 6 minute period had elapsed. The distances covered in 6 minutes were documented at the end of the test.

3.3.2 Visual acuity test

The participants were invited to sit back and relax on a chair for a couple of minutes before starting the test. Those with symptoms of eye strain, eye fatigue, tired eyes, itchy eyes, burning eyes, or any abnormal symptoms of the eye were excluded. Participants were asked to wear any clothes that where comfortable and to sit upright on the chair for the 5 minutes test. The participants were asked to bring their current glasses to the test if they normally use them in ADL. The participants had received the instructions of the VA test, which where given in a well-lit environment in the quiet private laboratory of the center, without being disturbed. The laboratory has been illuminated with a good ambient light from artificial light and with a comfortable temperature.

The VA test in the present study used a digital screen instead of the original paper chart. The digital screen of the Landolt ring chart (Oculus 4512) was illuminated on a tablet device (Figure 3.3). The whole rings on each line of the chart did not permanently display. It could be changed randomly with a command by a touch on the screen. This helps the chart has a sharp and clear vision, and also reduced the human bias of predicting the test by remembering the chart to give correct answers.

The sequence of the participants taking the test was randomly assigned by drawn lots. Each participant performed the test one by one. The participants were invited to sit on the chair at 2 meters distance away from the screen. The tests were measured without, and then with, participants' own glasses. Both eyes were examined separately, starting with the most unclear eye first. At all times the participants were asked to keep both eyes open during the test and informed to wear the prepared spectacles covering their naked eye and their own glasses. The spectacles cover one eye at a time instead of using a palm of the hand to cover the eye.

The test started from the largest ring at the top of the chart. The participants were asked to describe each ring on each line that they see with their uncovered eye. The participants have to answer by pointing in the direction toward which the open end of the ring is facing. The participants were asked to guess if they were not sure of the answers. The test was turned back to the previous step in case that the answer was wrong or unsuccessful. The smallest line that they could accurately answer was recorded as the result. The decimal scale was used to record the results of the test (11, 13, 17).

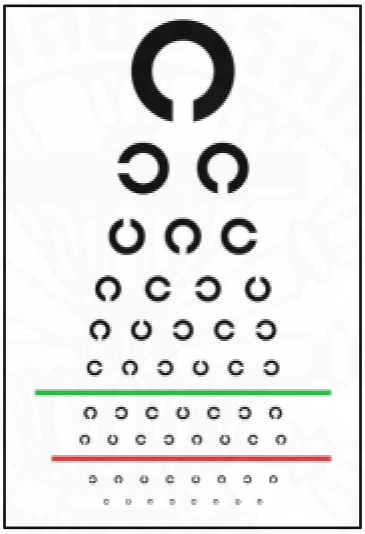


Figure 3.3 The screen of the Landolt ring chart in the VA test

3.3.3 Proprioception tests

3.3.3.1 Finger-nose test

The participants were invited to sit back and relax on the chair for a couple of minutes before starting the test. The participants who had weak upper limb muscles, painful upper limbs, or found it uncomfortable to move any part of the upper limbs were excluded. The participants were asked to wear any clothes that where comfortable for them to sit upright on the chair for the up to 5 minutes of the test. The participants were allowed to wear their glasses during the tests. The participants had received instructions for the test which where given in a well-lit environment, in the quiet private laboratory of the center, without being disturbed.

The laboratory had been illuminated with a good ambient light from an artificial light and with a comfortable temperature.

The sequence of the participants in the test was randomly assigned by drawn lots. Each participant performed the test one by one. The participants were invited to sit on a chair facing an examiner. The distance between the tester and the examiner depended on each case. The most comfortable length from a short practice before the test started was adjusted to apply to each participant.

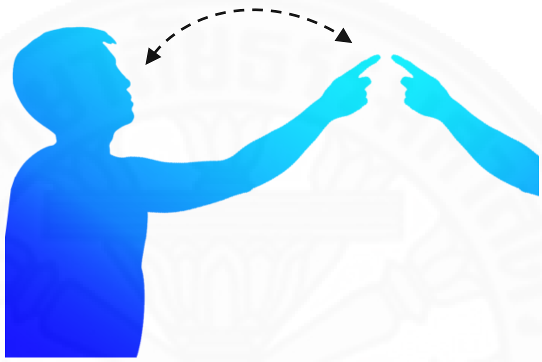


Figure 3.4 The examination process of the finger-nose test

For a short practice test of one minute, the participants were asked to touch the tip of their nose with the index finger and then extend their index finger to touch the examiner's outstretched static index finger. The participants were asked to go back and forth in the median plane between touching their nose and the examiner's finger. Once it was done correctly at a moderate rhythm, it was continued with increasing speed. Both hands were practiced separately, startling with the left hand first. The distance of the length between the tester and the examiner at this stage was applied to the test (Figure 3.4).

For the test stage, the participants were asked to perform the test as the practice but the position of the examiner's finger moved randomly (29). The participants were asked to perform as rapidly as they could for 5 times per test, of which 5 tests were performed on each hand. The best 3 of 5 tests were selected and summarized in the results of the present study. It was recorded from the lowest number of unsuccessful or failing to touch results, first, and then of the shortest of the total times taken during the test.

3.3.3.2 Toe position sense test

The participants were invited to lie down on an examination table in the supine position with bare feet. For a few minutes before starting the test, the participants were asked to relax, while both of their big toes have been gently skin cleaned with isopropyl alcohol 70%. The participants with a big toe which had any pain, blisters, injuries, restriction of the joint, or any abnormal symptoms were excluded. The participants were asked to wear comfortable shirts with long trousers or pants for the 5 minutes test. The participants had received the instructions for the test given in a well-lit environment in the quiet private laboratory of the center without being disturbed. The laboratory was illuminated with a low ambient light from an artificial light and with a comfortable temperature. The sequence of the participants taking the test was randomly assigned by drawn lots. Participant performed the test one by one.

Figure 3.5 The examination of the toe position sense test

The participant was asked to close the eyes at all times during the test. The big toe of the participant was lightly grasped in the coronal plane by the thumb and the index finger of the examiner at the proximal interphalangeal joint. The big toe was held away from the other toes to avoid the friction. Another thumb and index finger of the examiner lightly grasped at the distal phalanx of the same big toe. The distal phalanx has been slowly moved of 3 degrees in the positions of either dorsiflexion or plantar flexion (up or down) one time, and then held steady for 1-2 seconds (110). The participant was asked to identify the direction that the toe had been moved. Both correct and incorrect answers were documented as the result. The test was repeated for 5 times with the random moved positions. Both of the big toes were examined separately (Figure 3.5).

3.3.4 Two-point discrimination test

The participants were invited to lie down on the examination table in the supine position with bare feet. For a few minutes before starting the test the participants were asked to relax. The plantar surfaces (skin) of their feet in the areas of the big toe and the ball of the foot (underneath the heads of the metatarsal bones) have been gently cleaned with isopropyl alcohol 70%. Participants who had foot pain, foot injuries, or other foot problems were excluded. The participants were asked to wear comfortable shirts with long trousers or pants for 10 minutes test. The participants had received the instructions for the test, given in a well-lit environment in the quiet private laboratory of the center, without being disturbed. The laboratory had been illuminated with a low ambient light from an artificial light and with a comfortable temperature. The sequence of the participants taking the test was randomly assigned by drawn lots. Participants performed the test one by one.

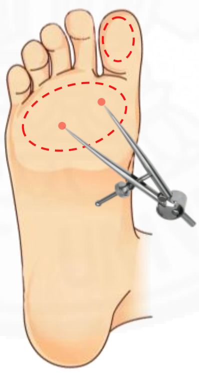


Figure 3.6 The examination of the TPD test

Each participant was asked to close the eyes at all times during the TPD test. The test was performed by a two-prong device which is a simple hand-operated device. It was performed by softly apply two tips of the device to the plantar surface of the big toe. The tips made a perpendicular contact (at 90 degrees) with the skin with a minimal amount of pressure that the skin just began to blanch. The contact time was approximately 1.5 seconds (111), without any shaking, but no longer than 3 seconds (112). The stimulus intensity was chosen to be that which the participant could perceive as constant touching without the perception of discomfort or pain. The participant was asked to say either “one” if the participant felt 1 point or “two” if 2 separate points were felt. The default distance of the tips started at 20 mm. If the answer was incorrect, the distance was increased in increments of 1 mm. In contrast, if the answer was correct, the distance was decreased in increments of 1 mm. If the participant said “I can’t discriminate one or two”, it was regarded as an incorrect answer. The test value for each participant was the shortest distance correctly answered at least 2 times (14, 15). The big toes and the metatarsal areas of the both feet were examined separately. The results were documented in millimeter units (Figure 3.6).

3.3.5 Range of motion test

The participants were invited to sit back and relax on the chair for a couple of minutes before starting the active ROM test. Participants who had any symptoms of pain, injury, restriction of any joints or muscles were excluded. The participants were asked to wear comfortable shirts with shorts that were suitable to move their joints in various range of motion for 30 minutes test. The participants were asked to take off all accessories, for example, watches, rings, earrings, necklaces, bracelets, keys, wallets, or anything that worked against the test and could be a cause of injury or accidents. Only glasses were allowed to be worn during the test.

The participants were instructed to perform all the tests with bare feet on the examination table, except the tests of the back and the shoulder, which were performed standing on the ground with bare feet as well. The participants had received instructions for the test, which were given in a well-lit environment in the quiet private laboratory of the center, without being disturbed. The laboratory had been illuminated with a good ambient light from an artificial light and with a comfortable temperature. The sequence of the participants taking the test was randomly assigned by drawn lots. Participant performed the test one by one.

The participant was asked to perform the test moving slowly, gently, and smoothly. Fast and jerky motions should be avoided. Each participant was asked to hold for 5 seconds at the end of all ranges and allowed to stop at any movement that caused them pain (113). The test used the “Range of Joint Motion

Evaluation Chart" from Washington State Department of Social and Health Services: DSHS 13-585A (REV. 03/2014) as a guide except that the thump of MP joint and IP joint sections were exclued (Appendix II).

3.3.5.1 Parts of the upper body

The upper body tests were as follows: The back was measured with extension of 25 degrees and flexion of 90 degrees, lateral flexion to the left of 25 degrees and to the right of 25 degrees. The neck was measured with extension of 60 degrees and flexion of 50 degrees, lateral bending to the left of 45 degrees and to the right of 45 degrees, rotation on the left of 80 degrees, the right of 80 degrees. The shoulder was measured abduction-adduction, on the left abduction of 150 degrees and adduction of 30 degrees, on the right abduction of 150 degrees and adduction of 30 degrees. The shoulder was measured flexion-extension, on the left extension of 50 degrees and flexion of 150 degrees, on the right extension of 50 degrees and flexion of 150 degrees. The elbow was measured on the left, extension of 0 degrees and flexion of 150 degrees, on the right, extension of 0 degrees and flexion of 150 degrees. The forearm was measured pronation-supination, on the left pronation of 80 degrees and supination of 80 degrees, on the right pronation of 80 degrees and supination of 80 degrees.

3.3.5.2 Parts of the lower body

The lower body tests were as follows: the hip was measured backward extension on the left of 30 degrees and the right of 30 degrees. The hip was measured flexion on the left knee, flexed at 100 degrees and the left knee, extended at 100 degrees, on the right knee flexed at 100 degrees and the right knee extended at 100 degrees. The hip was measured, adduction to the left of 20 degrees and to the right of 20 degrees. The hip was measured, abduction to the left of 40 degrees and to the right of 40 degrees. The knee was measured, flexion on the left of 150 degrees and the right of 150 degrees. The ankle was measured, on the left, inversion of 30 degrees to eversion of 20 degrees, on the right, inversion of 30 degrees to eversion of 20 degrees. The ankle was measured flexion-extension, on the left plantar of 40 degrees to dorsal of 20 degrees, on the right plantar of 40 degrees to dorsal of 20 degrees. The wrist was measured radial and ulnar, on the left radial of 20 degrees and ulnar of 30 degrees, on the right radial of 20 degrees and ulnar of 30 degrees. The wrist was measured, on the left extension of 60 degrees and flexion of 60 degrees, on the right extension of 60 degrees and flexion of 60 degrees.

The test was measured in degrees by a manual goniometer. The test was used to assess the physical movements of the participants as a screening test. Therefore, no results were used for the statistic in the present study. The participants who could reach the range of degrees determined in the test were eligible to take the further step. If not, the participants were excluded from the training of the EF.

3.3.6 Short-term HRV test

Participants were invited to sit back and relax, with bare feet, in the chair for 10 minutes before the test start. The participants who had any pathological cardiovascular conditions, neurological, psychiatric disorders, or other severe diseases, or had taken any caffeine or alcohol in the 12 hours prior to the test were excluded. The participants were asked to wear comfortable shirts and shorts which where negative conductors of electricity for 30 minutes test. Participants were asked to take off all accessories; for example, glasses, watches, rings, earrings, necklaces, bracelets, keys, wallets, or any wearable metals.

After resting for 5 minutes, both wrists and ankles, including the tip of the index finger on the right hand of the participants, were gently skin cleaned with isopropyl alcohol 70%. Then, the wearable ECG devices were firmly applied onto the participants, there were the wristband electrocardiogram sensors, lead II (bipolar limb leads), and the fingertip sensor (Figure 3.7). The participants had worn the ECG devices at all times during the test. The ECG recordings were used as the results of the HRV of the test.

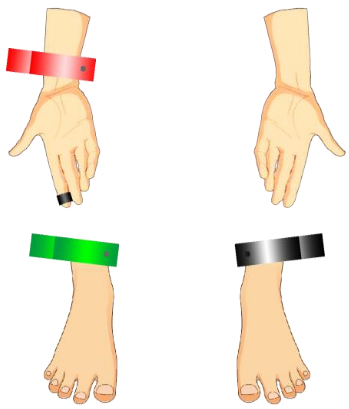


Figure 3.7 The ECG devices

The participants had received the instructions for the test which were given in a well-lit environment, in the quiet private laboratory of the center, without being disturbed. The laboratory had been illuminated with a low ambient light from an artificial light and the room had a comfortable temperature. The noise levels were minimized during the test. Participants performed the test one by one. The sequence of the participants to the pretest was randomly assigned by drawn lots. For the midtest and the posttest they followed in the order of the pretest.

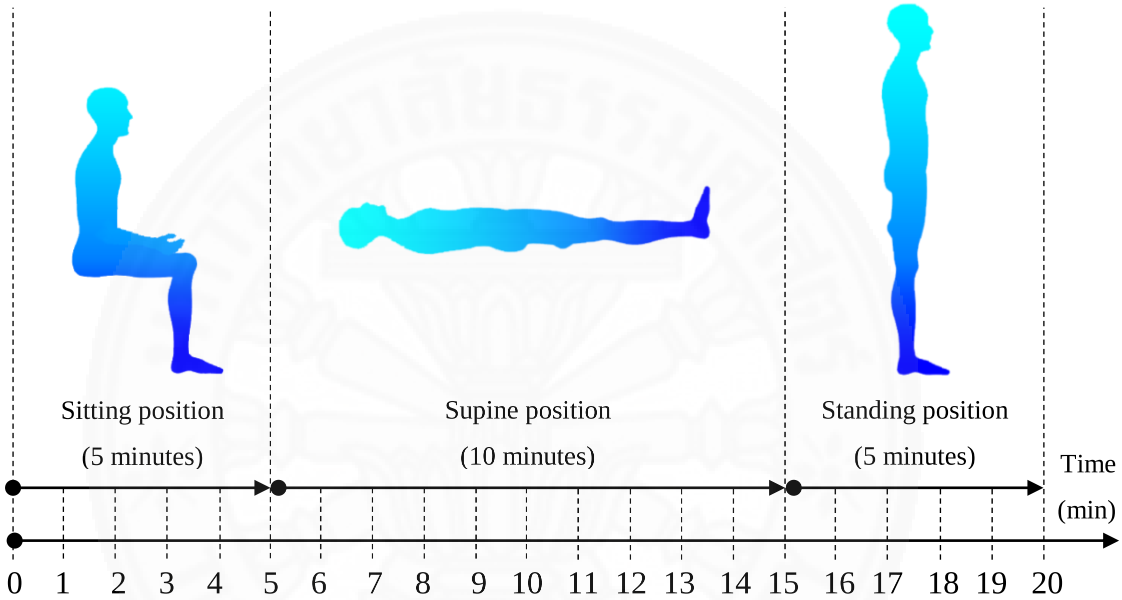


Figure 3.8 The 3 phases of the HRV test

The test was composed of 3 phases which where, in the sitting position, to the supine position and then the standing position continuously (Figure 3.8) as described below:

Phase 1 (the sitting position): the participants were informed to sit steady, try not to move, in a comfortable position for a baseline recording of the ECG for 5 minutes, from time 0 until time 5.

Phase 2 (the supine position): participants were invited to take a short few steps from the chair, to lie down on the examination table in the supine position. The participants were asked to stay in a comfortable position and try not to move their bodies during the test. The ECG was recorded during these for 10 minutes, from time 5 until time 15.

Phase 3 (the standing position): participants were asked to stand up actively, get down from the examination table without any help, and to stay in an upright position. The participants were all trained to stand up in a uniform manner: tilting the trunk and simultaneously twisting the body to the left, putting on the floor (first the left and then the right foot), resting for 5 seconds, and finally standing up. Once standing, the ECG was recorded continuously for 5 minutes, from time 15 until time 20 (8, 36, 114).

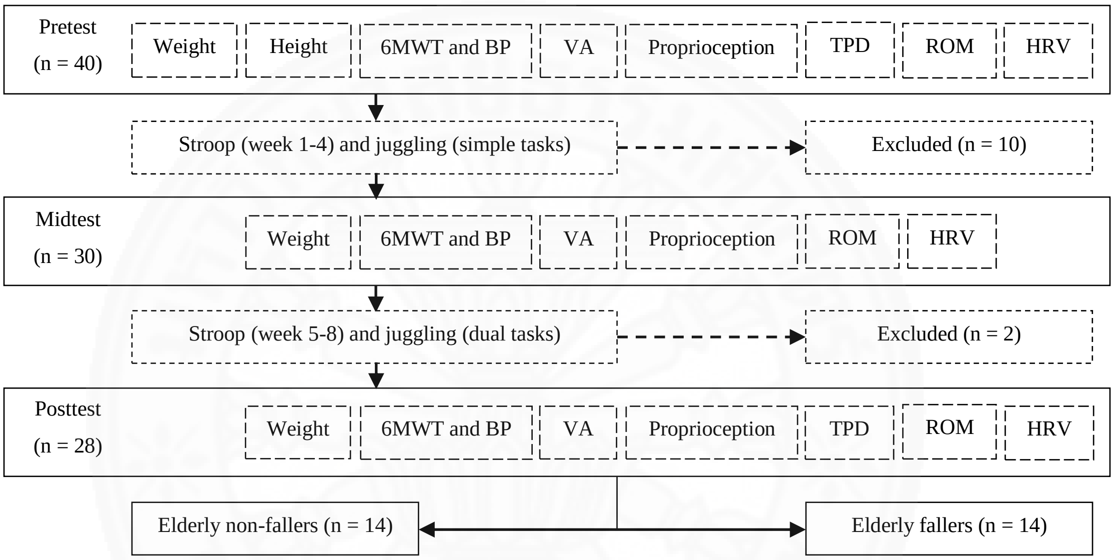


Figure 3.9 The diagram of the experimental research process

The present study populations at pretest were comprised of 40 participants. All were originally Thai with 8 males and 32 females. After the EF training of week 4, 10 females were excluded from the present study because of their absence from the EF training for more than one day. The midtest was started with 30 participants of 8 males and 22 females. During week 5-8 of the EF training, one female had scheduled the date of an eye operation within the following 2 weeks, and the second female had sustained a minor injury by falling in the bathroom. The physician at the center had agreed to exclude both of them from the present study. Thus, the posttest was carried out with a total number of 28 participants of 8 males and 20 females. After that, the results of the 28 participants were systematically collected into the elderly non-fallers group and the elderly fallers group according to the baseline data of the medical records, incident reports, and structured interviews.

The final number of participants then was 14, with 4 males and 10 females in each group (Figure 3.9).

3.4 EF training protocol

The program comprised training activities for 8 weeks which ran from Monday to Friday (40 days) through morning and afternoon sessions. Mondays to Thursdays were for practicing, and testing was on every Friday. The participants were asked to wear comfortable clothes and shoes to practice the training. The EF training took place in the main hall of Watsanawet Social Welfare Development Center for Older Persons. The juggling task involved training in the morning at the public hall, located in the main hall. It was an open space with good ambient natural light. The Stroop test was rehearsed in the afternoons at the quiet private room within the main hall. This room has a good ambient light from artificial light with comfortable temperature. Participants lived close to the location and the place was also convenient for the occupational health safety officers to access and observe the activities.

3.4.1 Stroop test

Stroop test is used for cognitive plasticity training. It has 8 levels. At level 1, the participants viewed "+ + + +" symbol and were required to identify the color of the symbol. For level 2, the participants viewed a word suggesting a name of a color with letters of the word also in the color. They were asked to identify the name of the color suggested by the word. The participants at level 3 needed to tell the actual color of the letters (115). For level 4, the participants were requested to identify the opposite of both the name of the color and the color of the letters. For level 5 to 8, the same conditions as of level 1 to 4 were repeated but the background also came in color (Figure 3.10).

The participants were asked to answer the questions by touching one of the red, yellow, green, or blue buttons on the tablet screen as rapidly and as correctly as possible. Methodically, the training took place 10 trials a day, (200 times). All results were recorded automatically on the application, covering total time spent with test, number of correct answers, time spent with each correct answer, number of incorrect answers, and time spent with each incorrect answer. The three best Stroop test results, which were ordered by the most number of correct answers first, and then the least total time spent on the test, from each week were summarized for the statistical analysis.

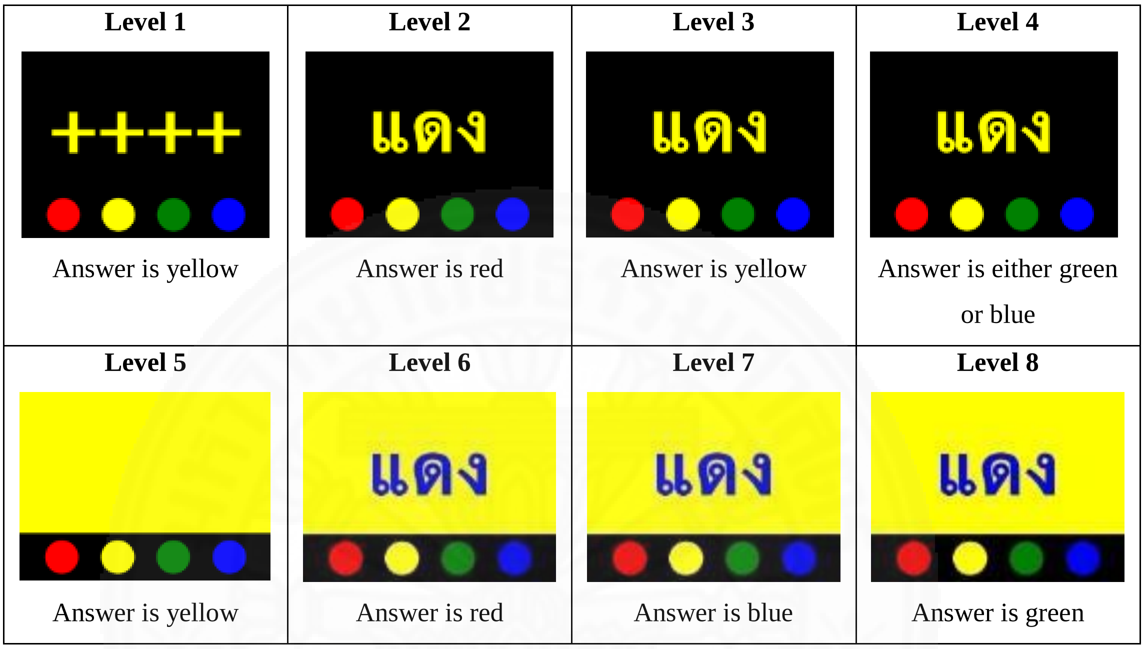


Figure 3.10 The samples of 8 levels of the Stroop test

3.4.2 Juggling task

A juggling activity was used for motor plasticity training. Participants were asked to systematically learn juggling with 3 standard tennis balls. Standard tennis balls of 654 millimeters diameter and 56 grams weight were used. The participants were asked to juggle for 1 hour a day and the session also included warm-up and cool down activities. They were encouraged to juggle with accuracy as long and as fast as they could. All juggling performances were recorded by high-speed cameras.

Eight sessions of practice started with 1 ball and the difficulty was increased to up to 3 balls. Juggling practice covered different sessions with 1 session of training weekly. From session 1 to session 4, simple tasks were covered. Dual tasks were on session 5 to session 8 with participants tramping on pebble wash tiles barefoot while doing juggling (Table 3.1).

The juggling task has 8 levels. At level 1, one ball was used. The participants had to throw 1 ball with their right hand and catch it with their left hand, and vice versa. For level 2, two balls were used and the participants held 1 ball in each hand. Then they had to throw 1 ball with their right hands and catch it with their left hands, and vice versa. Level 3 had 3 balls. The participants would hold 2 balls in their right hands and 1 ball in their left hands. Then, they had to throw 1 ball with the right hand and catch it with the left hand, and vice versa. Level 4 was also trained with 3 balls. The participants would hold 2 balls with their right hands and 1 ball in their left hands. Then they had to throw 1 ball with the right hand and catch it with the left. Before catching the ball with the left hand, the participants needed to throw 1 ball with their left hand and catch it with their right, and vice versa (116). Level 5 to level 8 repeated the same conditions as level 1 to 4 respectively except that the participants kept tramping on pebble wash tiles, barefoot, at the time of juggling (Figure 3.11).

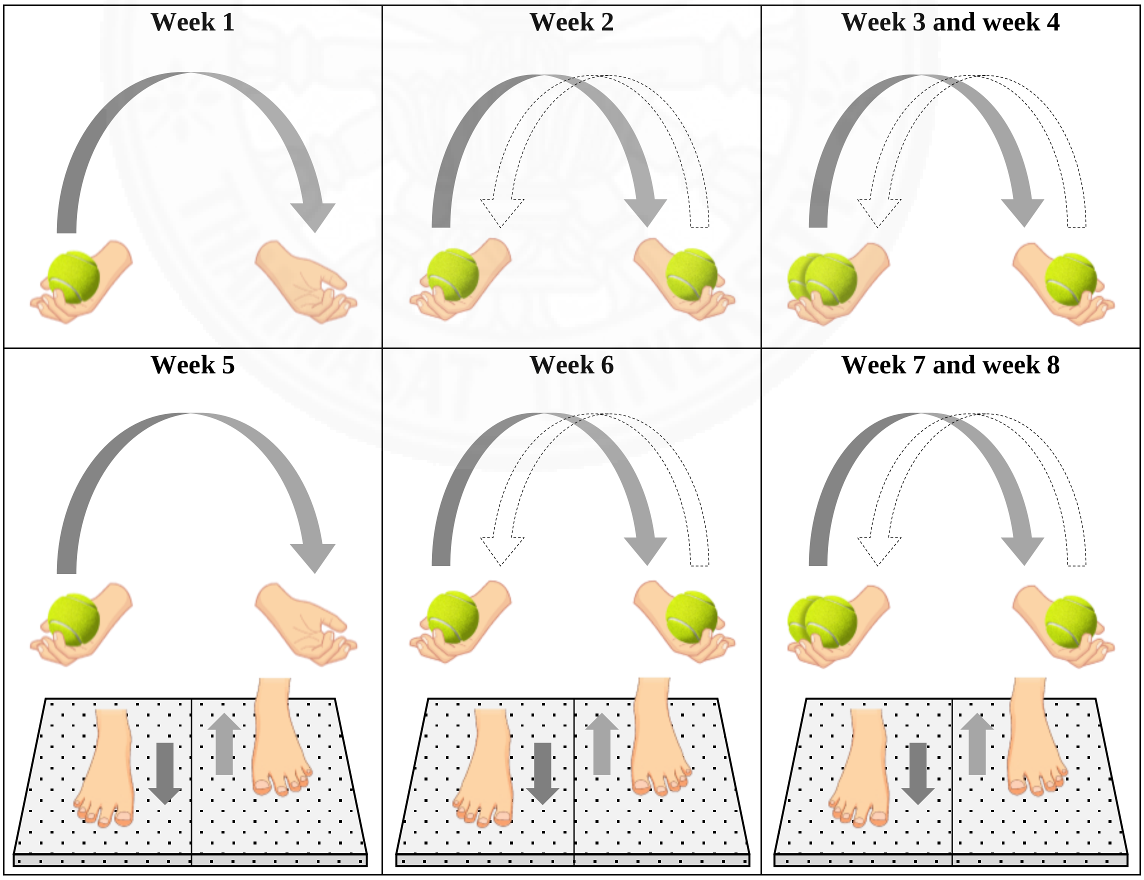


Figure 3.11 The directions of the juggling ball among 8 weeks

Table 3.1 EF training schedule

Week \ Day			Training				Testing
			Monday	Tuesday	Wednesday	Thursday	Friday
Simple tasks			Measurement at pretest				
1	MS	Juggling 1 ball	Day 1	Day 2	Day 3	Day 4	Day 5 Test 1
	AS	Stroop level 1					
2	MS	Juggling 2 balls	Day 6	Day 7	Day 8	Day 9	Day 10 Test 2
	AS	Stroop level 2					
3	MS	Juggling 3 balls	Day 11	Day 12	Day 13	Day 14	Day 15 Test 3
	AS	Stroop level 3					
4	MS	Juggling 3 balls	Day 16	Day 17	Day 18	Day 19	Day 20 Test 4
	AS	Stroop level 4					
Dual tasks			Measurement at midtest				
5	MS	Juggling 1 ball and tramping on pebble wash tiles	Day 21	Day 22	Day 23	Day 24	Day 25 Test 5
	AS	Stroop level 5					
6	MS	Juggling 2 balls and tramping on pebble wash tiles	Day 26	Day 27	Day 28	Day 29	Day 30 Test 6
	AS	Stroop level 6					
7	MS	Juggling 3 balls and tramping on pebble wash tiles	Day 31	Day 32	Day 33	Day 34	Day 35 Test 7
	AS	Stroop level 7					
8	MS	Juggling 3 balls and tramping on pebble wash tiles	Day 36	Day 37	Day 38	Day 39	Day 40 Test 8
	AS	Stroop level 8					
			Measurement at posttest				

MS = Morning session, AS = Afternoon session

Two specialists analyzed the performances on the test day by watching the slow motion videos. The test success was considered from the most completed movements of juggling first, and then the less of time spent to complete the juggling performances. The three best juggling performances on the test day of each week were summarized for statistical analysis.

3.5 Statistical analysis

The participants' characteristics were described by descriptive statistics. Skewness statistic, histogram, and box plot test were used to check the normality of the distributions. The continuous variables were presented in mean with standard deviation (± SD), and in discrete variables presented in number (% of total) by using Chi-square test. Differences between the elderly; the elderly fallers and the elderly non-fallers, (Figure 4.6-4.7, 4.9, 4.11, 4.13, 4.22, 4.36, 4.38, 4.41, 4.49-4.51, 4.60-4.62, 4.71-4.73) were analyzed and compared with the Independent (unpaired) *t*-test. All differences among pretest, midtest, and posttest stages (Figure 4.15, 4.17. 4.19, 4.82, 4.84, 4.86, 4.88-4.90, 4.92, 4.94-4.95), also among 8 weeks/levels (Figure 4.25-4.28, 4.30-4.31, 4.33-4.34, 4.42-4.44) were analyzed and compared with repeated ANOVA except the comparison of differences between pretest and posttest in the two-point discrimination test (Figure 4.15), which was analyzed only with a paired *t*-test. The association at posttest (Figure 4.97-4.102) ran by partial correlations on all variables while age was controlled. The level of significance was set at $P < 0.05$ for all statistical analysis of the present study. The sample size of 28 participants was confirmed by reversely calculating power with 95% power at the 5% significance level (two-sided) to detect the effect of correlations.

3.6 Pilot study

3.6.1 A pilot study of the Stroop test

Participants in this study were 13 elderly Thais aged 60-81 years. It was conducted at the Senior citizens of Thammasat University Hospital club. They were interviewed informal and characterized as the elderly non-fallers (n = 10) and the elderly fallers (n = 3) groups. The pilot study suggested that the traditional paper Stroop test in the English language was not compatible with Thai participants who had relatively low levels of education. Also, inaccuracy and bias could affect the result because time was recorded on a stopwatch and human bias could effect paper test distribution and collection. Therefore, the Stroop test application on tablet in the Thai language was developed for the present study. It has a system to prevent human bias by using random sampling algorithms to govern the chance of possibility in displaying questions equally in every round. The Stroop test content was validated by from a number of professors with I-CVI, S-CVI/UA, and S-CVI/Ave being 1.00, representing the content validity index in the items which were most relevant, as well as a universal agreement and an average on the scale, were excellent (Appendix III).

Figure 3.12 The human-controlled Stroop machine of the pilot study

3.6.2 A pilot study of the associations of fear of falling, stress, and quality of life in adults and older people

The study investigated the relationship of fall-related factors, such as fear of falling (FOF), stress, and quality of life (QOL) in adults and older people via structured questionnaires and informal interviews. A cross-sectional study was conducted in the central region of Thailand with 33 participants (9 males, 24 females) aged 45-86 years. Significant differences were identified between groups in psychological well-being (P = 0.021), and stress (P = 0.034), respectively. QOL was significantly correlated with stress (r = -0.551, P = 0.002), and FOF (r = 0.517, P = 0.002), respectively. FOF was significantly correlated with stress (r = -0.310, P = 0.040) as well. The main evidence obtained from the study suggests that decreasing FOF and/or stress could give prerequisite contribution to improving QOL not only in adults but also in older people. Fall prevention strategies may be more effective if consideration is given to the built environmental design in terms of design for sustainability, in order to reduce the incidence possibility, minimize the chance of consequent injuries in the elderly Thai population, and enhance their life qualities (117).

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Demographic characteristics of all elderly participants

Figure 4.1 Gender of all elderly participants

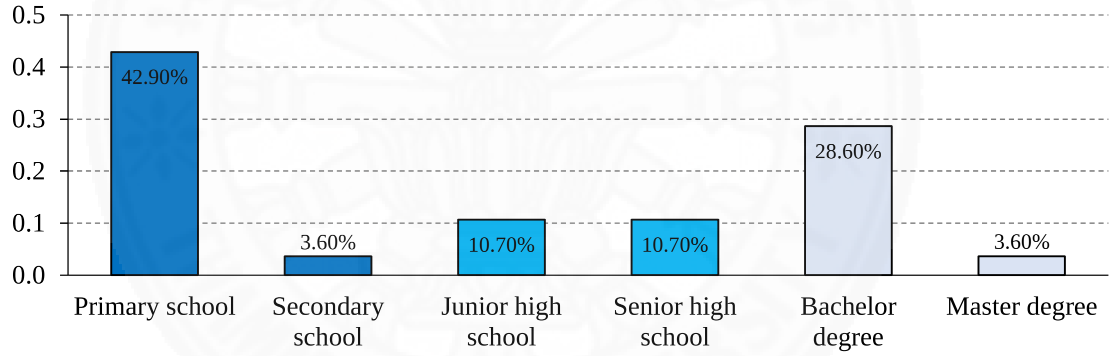


Figure 4.2 Education of all elderly participants

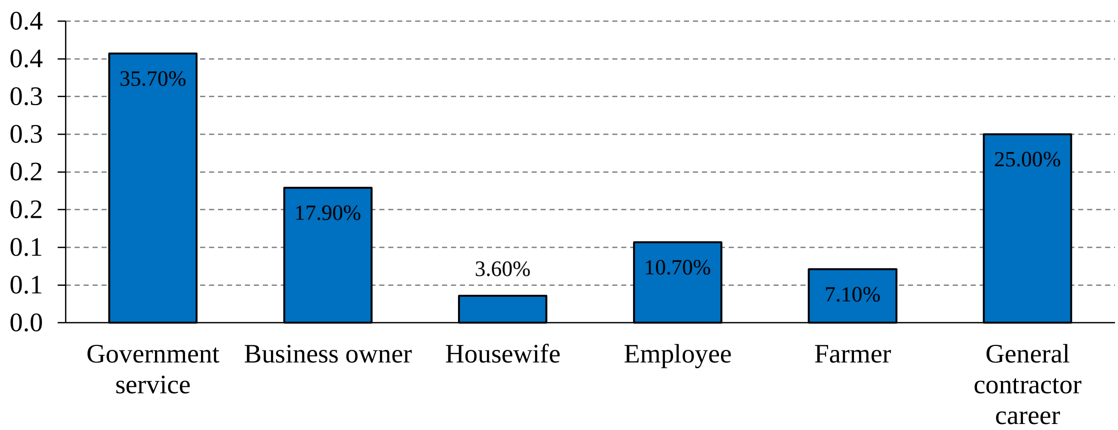


Figure 4.3 Occupation in the past of all elderly participants

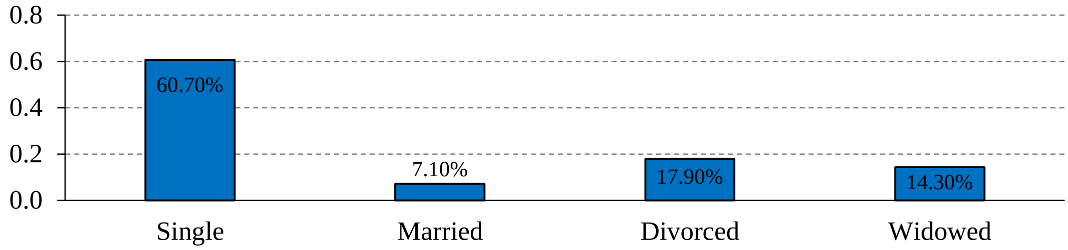


Figure 4.4 Marital status of all elderly participants

4.1.1 Results

The present study of elderly representation the population comprised 71.4% female, and 28.6% male (Figure 4.1). Their highest education level was primary school or grade 4, Bachelor degree, junior high school, senior high school, secondary school or grade 6, and Master degree in the ratio of 42.9%, 28.6%, 10.7%, 10.7%, 3.6%, and 3.6% respectively as shown in Figure 4.2. Previous occupations when they native of were government service, general contractor career, business owner, employee, farmer, and housewife (35.7%, 25%, 17.9%, 10.7%, 7.1%, and 3.6% respectively) as shown in Figure 4.3. Marital status was single, divorced, widowed, and married (60.7%, 17.9%, 14.3%, and 7.1% respectively) as shown in Figure 4.4. And their religion was 100% Buddhist (Appendix IV).

4.1.2 Discussion

The present study had quite a difference in the gender makeup. Most participants were females almost 2-and-a-half-times that of males. Participants were lowly educated. The first half of participants had only elementary education (46.5%). The second half had completed high school education (21.4%), and university education (32.2%). In the elementary and university educated groups, the highest education at level attained by the people in each group (3.6%) was secondary school or grade 6 and Master degree respectively. In between those 2 groups, the high school education group was split evenly 50/50% between those completing junior and senior high school. One-third of participants (35.7%) had had a government service career. Almost all of the participants (92.9%) were living alone. One-third of those living alone participants (34.6%) had been married. All of the participants in the present study were Buddhist. It is suggested that their ADL was uniformly similar as well as their lifestyle.

4.2 Health characteristics of all elderly participants

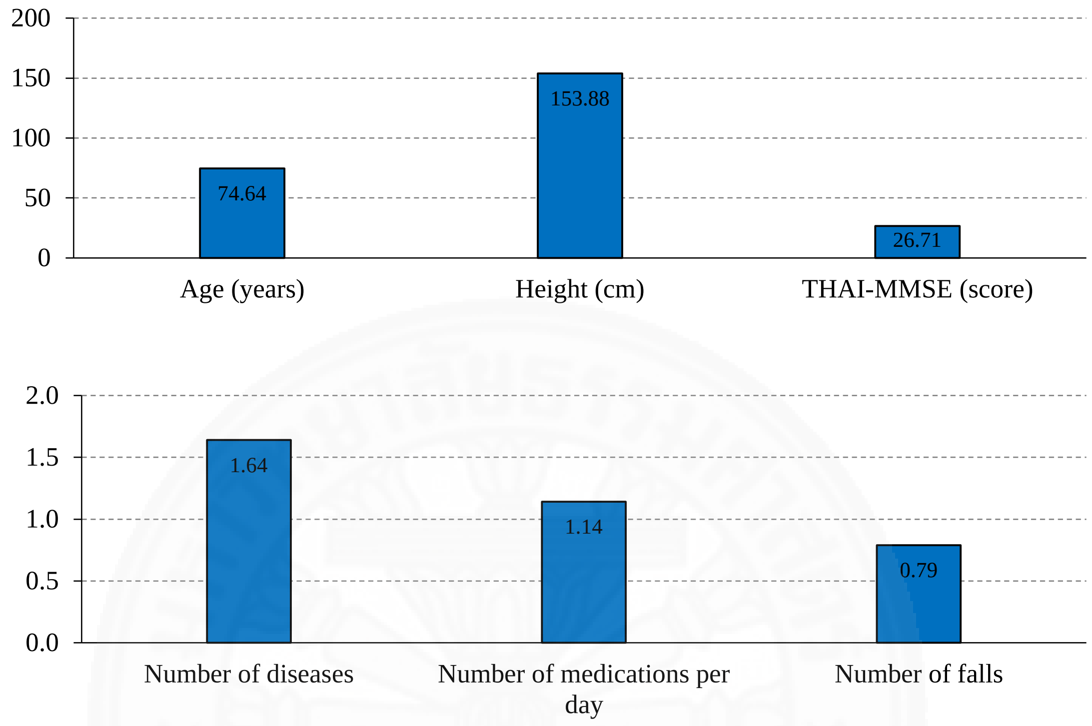


Figure 4.5 Health characteristics of all elderly participants

4.2.1 Results

The study had participants aged 74.64 ±6.64 years old. The height of the body was 153.88 ±7.47 centimeters. The number of diseases was 1.64 ±1.06. The number of medications they had taken per day was 1.14 ±1.01. The number of falls in which they had experienced in the past 12 months was 0.79 ±1.13 times. THAI-MMSE score was 26.71 ±2.55 as shown in Figure 4.5 (Appendix V).

4.2.2 Discussion

The elderly in the present study were classified in the pre-old age group which was aged between 65-74 years old which accorded to the consideration of an aging situation of a developed country (118). The height of participants was shorter than per anthropometric data of elderly population in rural Thailand (119). The present study had a three-fold smaller number of diseases than Chinese participants in a group aged 65-79 (120). The number of medications per day in the present study was low. Compared to participants who fell they were two-and-a-half-times, and almost six-times less than in previous studies of China (120) and Germany (48) respectively. The number of falls in the present study was low. Participants in a previous study from the greater Zurich area in Switzerland had defined that the non-fallers group were participants who had had no or 1 fall within the previous 12 months. Two or more falls were defined as a group of multiple fallers. It could be seen then that the present study had the number of falls closer to a group of non-fallers than multiple fallers in the previous study. However, several studies defined their condition of participants with falls or no falls, as the same as the present study, within the previous 6-24 months (121-124). The THAI-MMSE score in the present study was high. The standard of THAI-MMSE suggested a cut-off score at ≤ 14 for illiterates, ≤ 17 for elementary school, and ≤ 22 for over elementary school out of 30 (125). Previous studies have found an increased risk for falls in the elderly population with a MMSE score that is below 24 (106, 126). It could be seen that the score in the present study of THAI-MMSE was higher than previous studies. It was closer to the global cut-off score of MMSE which is < 26 (127). The evidence was suggested that overall the participants in the present study had clearly no cognitive impairment which was supported by the global cut-off score of MMSE.

4.3 Demographic characteristics between the elderly non-fallers and fallers groups

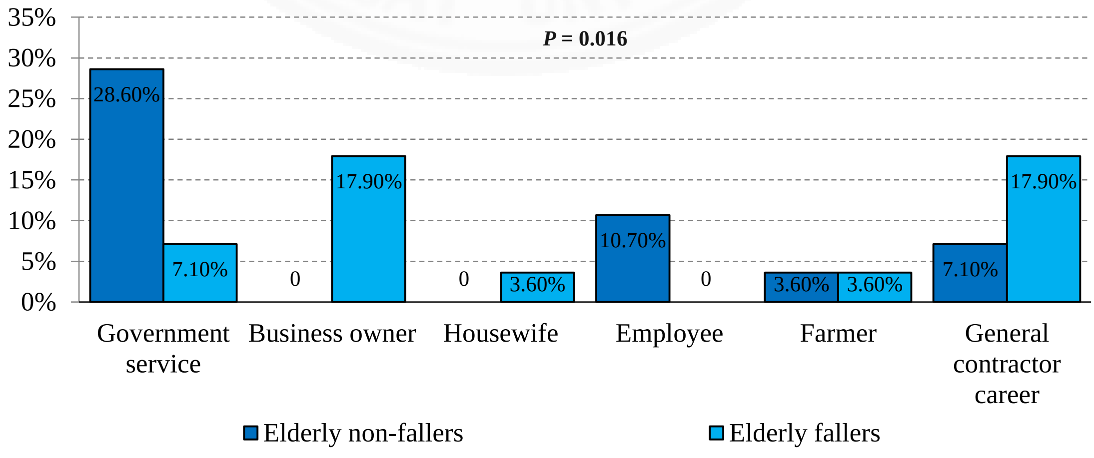


Figure 4.6 Demographic characteristics between the elderly non-fallers and fallers groups

4.3.1 Results

Demographic characteristics were significantly different between the elderly non-faller and faller groups in their previous occupation (*P* = 0.016) as shown in Figure 4.6. In contrast, none of significant differences was found between 2 groups in terms of sex, education, status, and religion (Appendix VI).

4.3.2 Discussion

Past experiences, such as the former occupation, in the elderly non-fallers group, covers a wide range of activities than in the elderly fallers group and could reflect the potential impact of falls in the present study. Interestingly, business owner and housewife careers were found only in the group of elderly fallers (42.85%). The business owner in the past such as grocer and trader, usually worked at their own home. Previous studies indicated that the profile of activities associated with many falls events was related to basic ADL in their home, such as personal hygiene, cleaning, and working in the kitchen (25). Most falls occurred at home during 6:00 AM to 6:00 PM (128) which was related to the working time of business owner in the present study. In addition, previous studies reported that women are more likely to fall indoors (47) when performing household duties (48, 129) as well as activities of housewife in the present study.

Demographic characteristics of the present study were in harmony in the aspect of sex, education, status, and religion. The overall incidence of falls did not differ according to gender, with equivalent proportions of men and women in both groups as well as a previous study of participants (n = 333) at Khon Kaen in Thailand (121). However, this finding is inconsistent with a previous study which has indicated that women are more likely to fall than men (48) and are far more likely to incur fractures when they fall (130). Moreover, the different causes of falls by gender indicated that falls by men (n = 20) most often resulted from slips whereas falls by women (n = 30) most often resulted from trips (47).

The present study found no difference of education between the groups. However, a group of the elderly fallers had lower levels of education than that of the elderly non-fallers. Half of the elderly non-fallers group (50%) had education in the university levels, while the elderly fallers group had only 14.2%. Several previous studies have found that low educational levels were associated with falls (131, 132).

Elderly people with lower levels of education were seen as less aware and less worried about healthcare. They had less ability to engage in health recovery, which resulted in increased risk of further falls (133). Also, the educational level influenced the spatial perception of the elderly adults so that, when performing visual search tasks, individuals with low educational level required more time, made more mistakes, and reached fewer targets when compared to individuals with higher educational levels (131).

For marital status, it is interesting to note that previous studies indicated living alone had an underlying effect on exposure to a poorer diet, greater intake of medication, lower levels of physical activity, diminished social network as well as increased frailty (134). All of these were associated with the growing risk of falls. Being unmarried and/or living alone were also independent fall risk factors, particularly for women (135). The evidence showed that current marital status, rather than marital history, was a determinant of fall risk, with widowed, divorced, and unmarried women having a higher risk of falls compared to those in marriage or cohabitation (136). A possible explanation for this is that marriage has beneficial effects on healthy behavior (137). There are plausible explanations as to mechanisms whereby fall-related factors can maintain health and are thus protective of an adverse health outcome (58). However, the participants in the present study were found to have no difference between the groups with respect to their marital status.

Religion is an important aspect in the life of the elderly people (138). Several studies have been carried out that examine how spirituality and religion affect the elderly people in poor health. Some rituals and experiences are regular daily, weekly, or annual experiences that may provide a set of rhythms to long lives, such as making merit, meditation, and praying. Some are singular observances evoked by events and life course transitions such as ordination, weddings, and funerals. The loss of family and friends mounts in old age in terms of ritual practices and religious frameworks can provide comfort, understanding, and meaning for those stressful events. In the elderly, persisting to the very last period of life, these beliefs may provide an arc of continuity that gives meaning and dignity to the whole life course and enhances QOL even in the context of the impending end of life. As life expectancy continues to increase, understanding the conditions underlying the QOL in these extended trajectories becomes increasingly important (139). Therefore, the QOL in the last year of life is seen to be positively related to religious involvement (140).

A study of the religion and mental health among U.S. elderly adults aged 66-95 years found that men obtain more mental health benefits from religious involvement than women. Women with higher levels of organizational religious involvement have similar levels of mental health as those with moderate and lower levels of organizational religious involvement. Men with very high levels of organizational religious involvement tend to have much higher levels of mental health than all other men (141). Spirituality was also a significant predictor of psychological well-being and moderated the negative effects of frailty on psychological well-being (142). The interconnections between religion and old age are complex, especially the way in which people deal with illness (143). However, the participants in the present study were found to have no difference between the groups with respect of their religious commitment.

4.4 Health characteristics between the elderly non-fallers and fallers groups

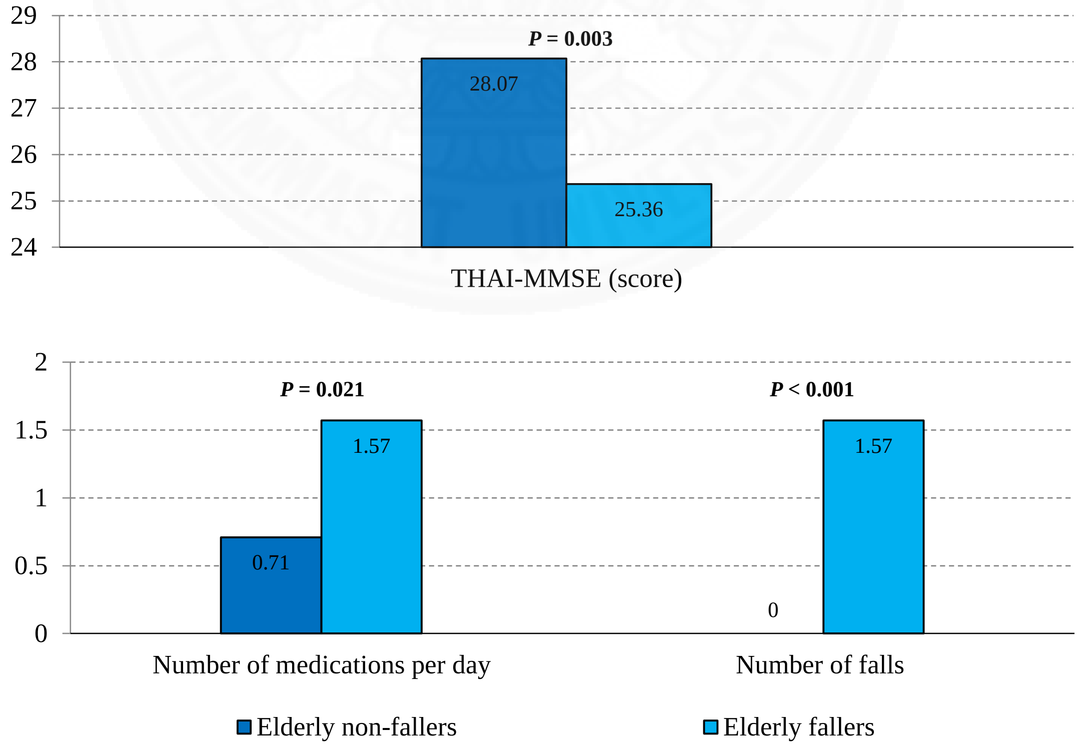


Figure 4.7 Health characteristics between the elderly non-fallers and fallers groups

4.4.1 Results

Participant characteristics were significantly different between the non-faller and faller groups in the number of falls, THAI-MMSE, and the number of medications taken per day (P < 0.001, P = 0.003, and P = 0.021 respectively) as shown in Figure 4.7. In contrast, none of significant differences was found between 2 groups in terms of age, and number of diseases (Appendix VII).

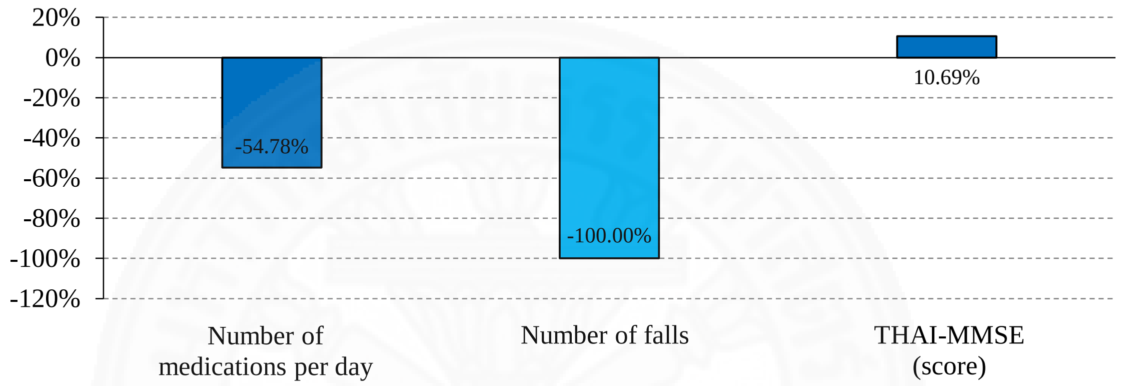


Figure 4.8 Health characteristics of the elderly non-fallers compared to the elderly fallers

To clarify, the elderly non-fallers group had obviously 100% of fall experiences lower than the elderly fallers group. The number of medication per day of the elderly non-fallers group was 54.78% less than the elderly fallers group. And the THAI-MMSE score of the elderly non-fallers group was 10.69% higher than the elderly fallers group (Figure 4.8).

4.4.2 Discussion

The elderly non-fallers group was only taking 0-1 medications per day, while the elderly fallers group where taking 1-2 medications each day. The difference of the regular medication use was related to falls. Regular medication use was defined as using one or more drugs on a daily basis during the previous of 6 months (121). A similar result had been found in a previous study, that the elderly who took more drugs had a higher risk of falls (144). Again, another previous study showed that the risk of falling increased significantly with the number of drugs used per day. After adjustment for a large number of comorbid conditions and disability, polypharmacy remained a significant risk factor for falling. Stratification for polypharmacy with or without at least one drug, which is known to increase fall risk, disclosed that only polypharmacy with at least one risk drug was associated with an increased risk of falling (145). The evidence of the present study agreed that the elderly people who took more regular medication had a higher risk of falls.

In the present study, the elderly non-fallers group had no experience of falls, while the elderly fallers group had approximately 1-3 times. Some previous studies defined that those experiencing 2-3 falls as a recurrent, repeat or multiple fallers group (121-124). The important aspect to be considered about the recurrent falls, several previous studies have found that approximately 50% of all long-term care home residents fall each year, and of these, 40% fall twice or more each year (146, 147). Risk factors associated with recurrent falls were similar to those of single falls (148) but made worse because recurrent fallers were more likely to experience injury from repeated episodes (149). This was reflected in their high impact of first falls. In Canada, approximately 7.4% of the elderly people who were 65 or more years of age experienced 21% of all fall-related hospitalizations. Also, more than 75% of all fall-related injuries for this group were to a major joint; femur, pelvis, hip or thigh (150). However, even falls and repeat falls have occurred and the risk of repeat falling appeared to be greatest in the very old (151). The increased risk of falling and fall-related injury associated with the elderly people appeared to be due to the accumulation of multi-risk factors (152) as people age, rather than only the number of falls itself.

The results indicated that the elderly group that was in the group of faller were those where the score was poorer than the other group on the THAI-MMSE test, even in the upper range of scores. This was related to a previous study which indicated that the association between MMSE and falls persisted across the range of scores from 22 to 29 (153). However, the neurobiological basis for the association between falling and subtle cognitive deficits had demonstrated, that impairments in judgment, attention, or EF may predispose elderly adults to perform unsafe tasks or to execute them in a perilous manner (154). It is possible that the association between falls risk and mild decrements on the MMSE is due directly to the effect of deficits in key cognitive domains, such as EF (153). Previous studies showed that the impairment in EF was associated with decreased ability to modulate gait in the setting of a dual task, and that it was particularly true for the elderly people prone to falls (19, 155, 156). The result in the present study suggested that the elderly people who had lower score on the THAI-MMSE than 28 and/or had a history of falls, where categorized in a group which the risk future falls occurring was high.

4.5 Participant characteristics between the elderly non-fallers and the elderly fallers groups

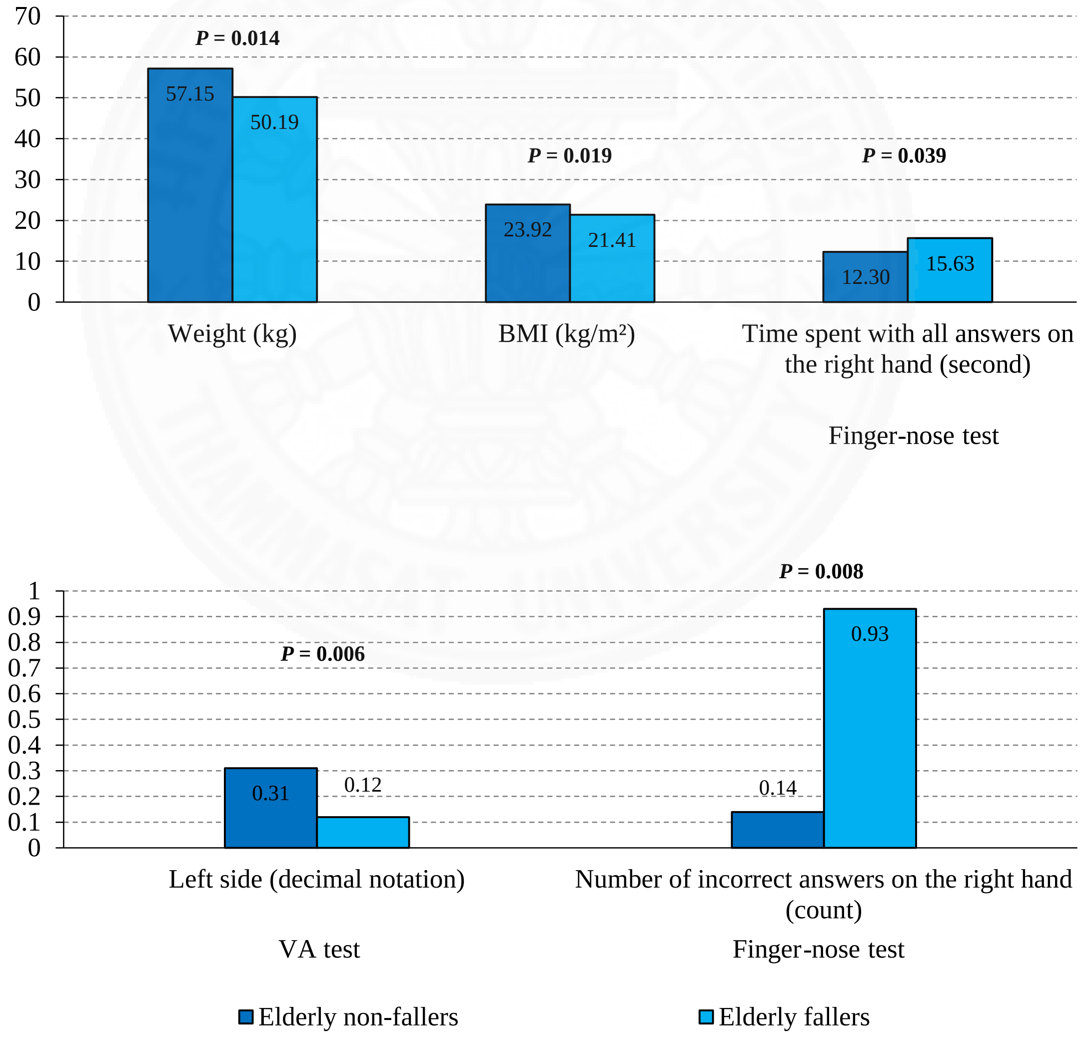


Figure 4.9 Participant characteristics between the elderly non-fallers and the elderly fallers groups at pretest

4.5.1 Results

The characteristics of participant basis data at pretest stage demonstrated significant differences between the elderly groups, in the VA test on the left side, and number of incorrect answers on the right hand in the finger-nose test, weight, BMI, and time spent with all the answers on the right hand in the finger-nose test (*P* = 0.006, *P* = 0.008, *P* = 0.014, *P* = 0.019, and *P* = 0.039 respectively) as shown in Figure 4.9. In contrast, no significant differences were found between the elderly groups in the category of 6MWT, VA test on the right side, VA test on the right side with glasses, VA test on the left side with glasses, number of incorrect answers on the left hand in the finger-nose test, time spent with all answers on the left hand in the finger-nose test, toe position sense test, and TPD test (Appendix VIII).

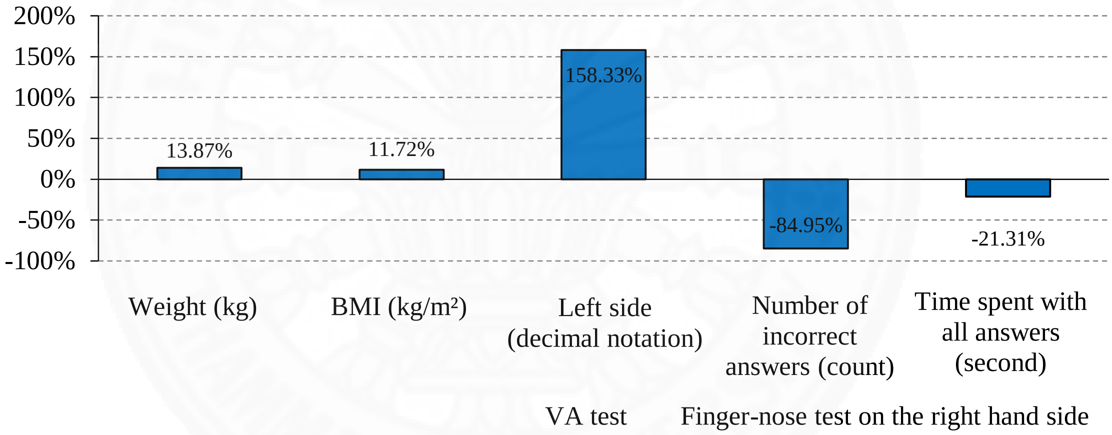


Figure 4.10 Participant characteristics of the elderly non-fallers compared to the elderly fallers at pretest

At pretest, the VA test on the left side of the elderly non-fallers group was 158.33% cleared sight than for the elderly fallers group. The number of incorrect answers on the right hand in the finger-nose test of the elderly non-fallers group was 84.95% less than the elderly fallers group. The time spent with all the answers on the right hand in the finger-nose test of the elderly non-fallers group was 21.31% less than the elderly fallers group. And the elderly non-fallers group had gained more weight and BMI than the elderly fallers group, of 13.87% and 11.72% respectively (Figure 4.10).

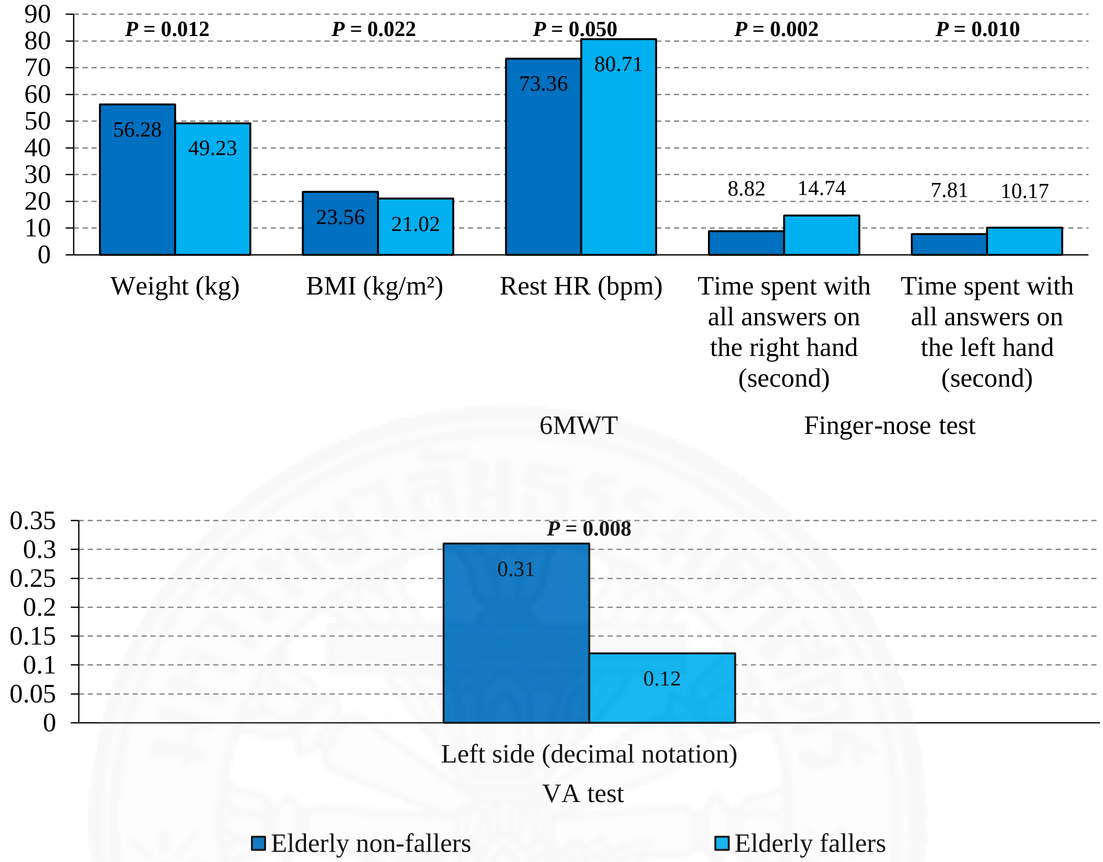


Figure 4.11 Participant characteristics between the elderly non-fallers and the elderly fallers groups at midtest

The intermediate data of participant characteristics at midtest presented significant differences between the elderly groups in the category of time spent with all answers on the right hand the in finger-nose test, VA test on the left side, time spent with all the answers on the left hand in the finger-nose test, weight, BMI, and 6MWT in HR at rest aspect (P = 0.002, P = 0.008, P = 0.010, P = 0.012, P = 0.022, and P = 0.050 respectively) as shown in Figure 4.11. In contrast, no significant differences were identified between the elderly in the category of 6MWT including SBP at rest, DBP at rest, distance, velocity, $VO_{2\ max}$, and MET, and in the category of the VA test on the right side, VA test on the right side with glasses, VA test on the left side with glasses, number of incorrect answers on the right hand in the finger-nose test, number of incorrect answers on the left hand in the finger-nose test as well as the toe position sense test (Appendix IX).

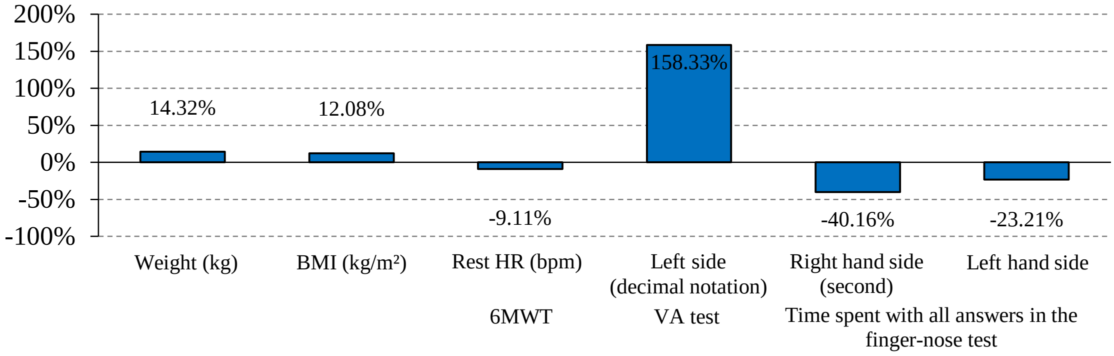


Figure 4.12 Participant characteristics of the elderly non-fallers compared to the elderly fallers at midtest

To clarify at midtest, the VA test on the left side of the elderly non-fallers group was 158.33% clearer sight than the elderly fallers group. The time spent with all the answers on the right hand in the finger-nose test of the elderly non-fallers group was 40.16% less than in the elderly fallers group. The time spent with all the answers on the left hand in the finger-nose test of the elderly non-fallers group was 23.21% less than with the elderly fallers group. The elderly non-fallers group gained more weight and BMI than the elderly fallers group 14.32%, and 12.08% respectively. And the 6MWT in HR at rest of the elderly non-fallers group was 9.11% lower than the elderly fallers group (Figure 4.12).

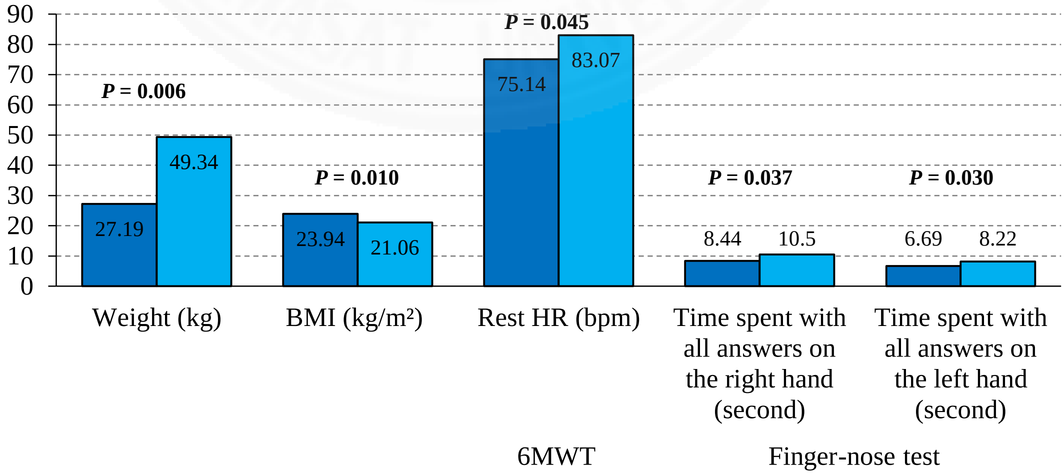


Figure 4.13 Participant characteristics between the elderly non-fallers and the elderly fallers groups at posttest

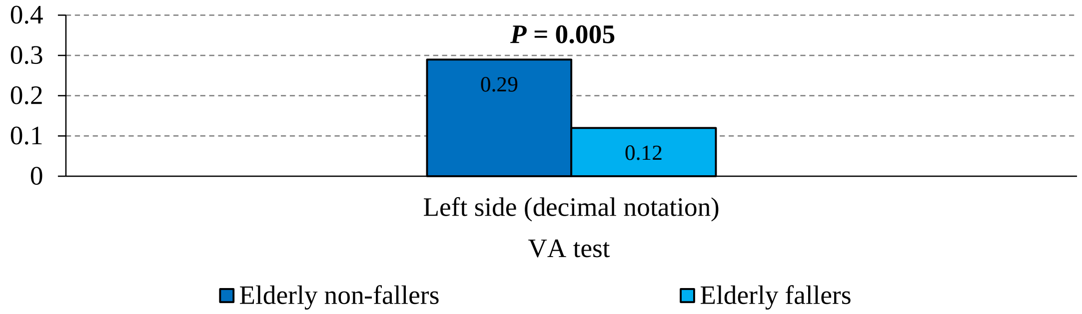


Figure 4.13 Participant characteristics between the elderly non-fallers and the elderly fallers groups at posttest (Cont.)

The hindmost data of participant characteristics at posttest showed significant differences between the elderly groups in the category of the VA test on the left side, weight, BMI, time spent with number of incorrect answers on the left hand in the finger-nose test, time spent with the number of incorrect answers on the right hand in the finger-nose test, and 6MWT in the area of HR at rest (*P* = 0.005, *P* = 0.006, *P* = 0.010, *P* = 0.030, *P* = 0.037, *P* = 0.045 respectively) as shown in Figure 4.13. In contrast, no significant differences were found between the elderly groups in the category of 6MWT including SBP at rest, DBP at rest, distance, velocity, $VO_{2\ max}$, and MET, in the VA test on the right side, VA test on the left side, VA test on the left side with glasses, number of incorrect answers on the right hand in the finger-nose test, number of incorrect answers on the left hand in the finger-nose test, in the toe position sense test as well as TPD test (Appendix X).

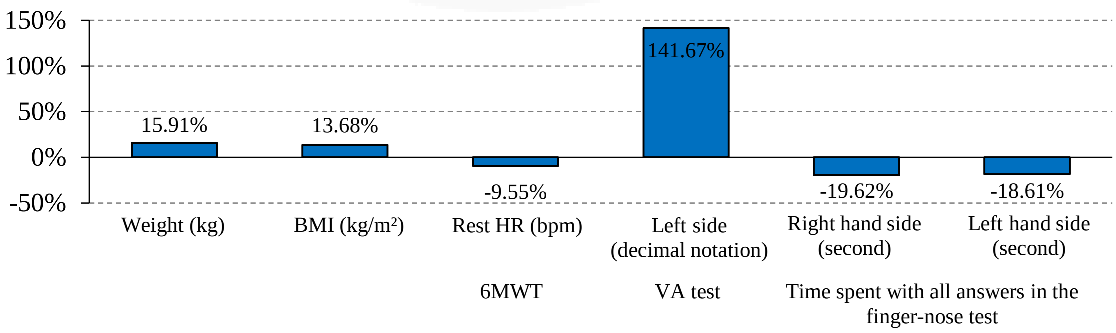


Figure 4.14 Participant characteristics of the elderly non-fallers compared to the elderly fallers at posttest

To clarify at posttest, the VA test on the left side of the elderly non-fallers group was 141.67% clearer sight than the elderly fallers group. The elderly non-fallers group spent less time with all the answers in the finger-nose test on the right hand and on the left hand than the elderly fallers group, 19.62% and 18.61% respectively. The elderly non-fallers group had gained more weight and BMI than the elderly fallers group, 15.91% and 13.68% respectively. And the 6MWT in HR at rest of the elderly non-fallers group was 9.55% lower than of the elderly fallers group (Figure 4.14).

4.5.2 Discussion

The results of the present study differentiated the elderly fallers group from the elderly non-fallers group through weight, BMI, the VA test on the left side, and the time spent with all the answers on the right hand in the finger-nose test. Both groups had continued to reveal some differences in the participant characteristics in the measurements prior to the training through to the end of the sessions. Various and dynamic characteristics may affect the chances of falls across given situations such as before or after the practice. Thus, perhaps it is a complex dimension of what could lead to falls since a fall could be detected at several stages.

This evidence suggested that weight, BMI, the VA test, and the finger-nose test could act as a tool for fall risk assessment in elderly persons. Some past studies such as a degree test in proprioception (16) and BMI of participants in Khon Kean, Thailand (121) nonetheless did not discover significant differences between the elderly fallers and the elderly non-fallers groups. In a similar way, the elderly non-fallers group had weight and BMI higher than the elderly fallers group in all of the tests. A previous study (157) of the BMI in elderly people indicated that the highest of the BMI group was a non-fallers group, then a fallers group, and a recurrent fallers group at 27.2 (SD ±4.5), 26.5 (SD ±5.2), and 26.2 (SD ±4.0) respectively. This was similar to the characteristics of the participants in the present study. This evidence suggested that the elderly people with a high weight and/or BMI have a greater chance to experience falls.

In addition, it was found in the present study that the HR at rest of 6MWT and the time spent with all the answers on the left hand in the finger-nose test could separate elderly fallers from the elderly non-fallers after 4 weeks of training.

HR at rest and the finger-nose test parameters from midtest stage to posttest stage were likely to identify elderly fallers from the elderly non-fallers. A previous study indicated that differences between OH and non-OH in healthy elderly persons was not significant in HR, SBP, and DBP (158). This related well to the results at the baseline in the present study of pretest. The evidence at 4 weeks after training revealed that normal resting HR could show the difference between the elderly groups. This supports the concept that the effectiveness of training (159) could influence functioning ability not only in the physical aspect but also in the cardiovascular system.

4.6 Participants' characteristics among pretest, midtest, and posttest

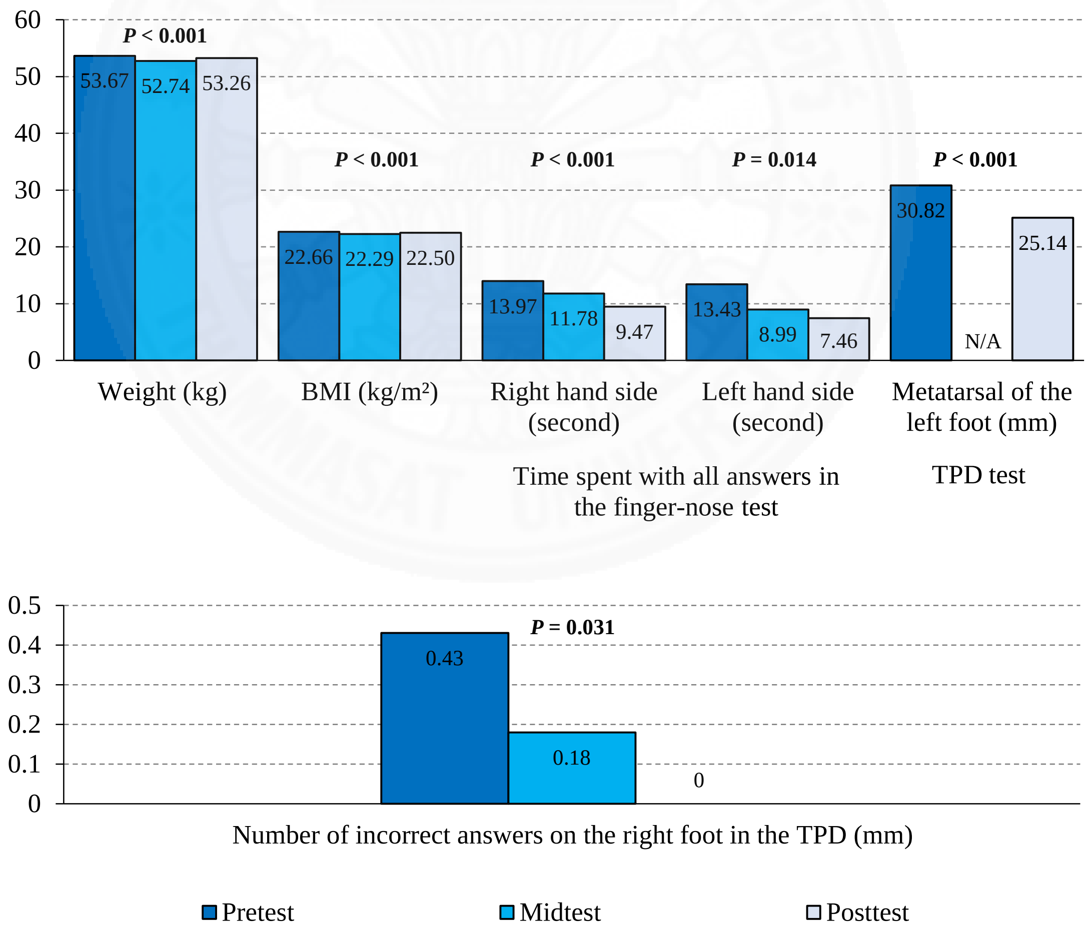


Figure 4.15 All elderly participants' characteristics among pretest, midtest, and posttest

4.6.1 Results

The characteristics of all the elderly participants showed significant differences among the pretest, midtest, and posttest in weight, BMI, total time spent with all the answers in the finger-nose test for the right and left hand sides at $P < 0.001$, between pretest and posttest in the metatarsal area on the left foot of the TPD test at $P = 0.014$, and among pretest, midtest, and posttest in the numbers of incorrect answers on the right foot of the toe position sense test at $P = 0.031$ (Figure 4.15).

In pairwise comparison, there were significant differences between the tests on the following: in weight and BMI at pretest and midtest, the finger-nose test in the total time spent with all the answers on the right hand at pretest and posttest, on the left hand at pretest and midtest, and pretest and posttest at $P < 0.001$. The finger-nose test in the total time spent with all the answers on the left hand at midtest and posttest ($P = 0.002$), and on the right hand at midtest and posttest ($P = 0.032$), plus the number of incorrect answers on the right foot in the toe position sense test at midtest and posttest ($P = 0.067$).

In contrast, no significant differences were found between the tests in the 6MWT, the VA test, the number of incorrect answers on the right and left hand sides in the finger-nose test, or in the number of incorrect answers on the left foot in the toe position sense test, the metatarsal area on the right foot or the toe on the right or left foot in the TPD test (Appendix XI).

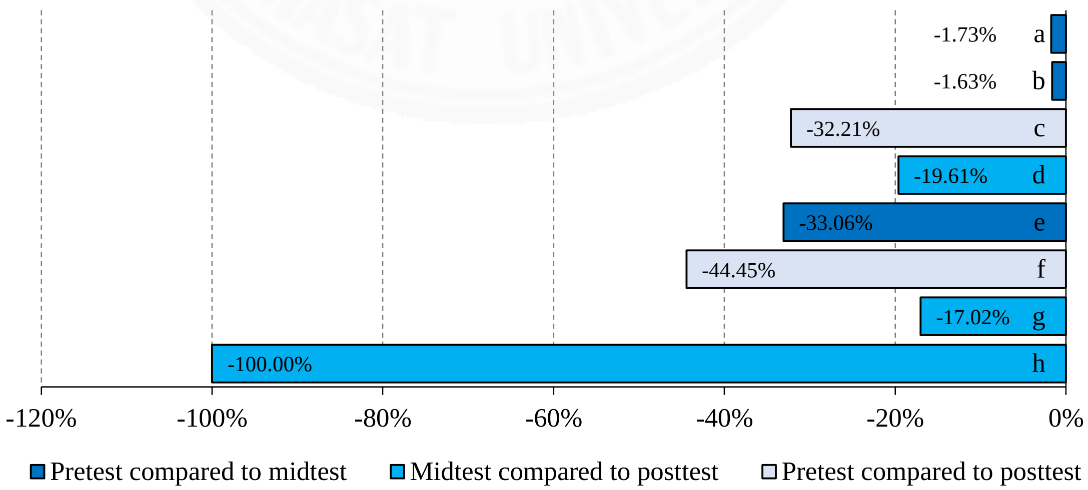


Figure 4.16 Improvement of all elderly participants' characteristics during pretest, midtest, and posttest

To clarify, the development of all the elderly participants' characteristics in pairwise comparison showed considerable improvements with a positive decline in several aspects. The number of incorrect answers on the right foot in the toe position sense test (h) dropped 100%. The time spent with all answers on the left hand in the finger-nose test (f) dropped 44.45%. The time spent with all the answers on the left hand in the finger-nose test (e) dropped 33.06%. The time spent with all the answers on the right hand in the finger-nose test (c) dropped 32.21%. The time spent with all the answers on the right hand in the finger-nose test (d) dropped 19.61%. The time spent with all the answers on the left hand in the finger-nose test (g) dropped 17.02%. Weight (a) dropped 1.73%, and BMI (b) dropped 1.63% (Figure 4.16).

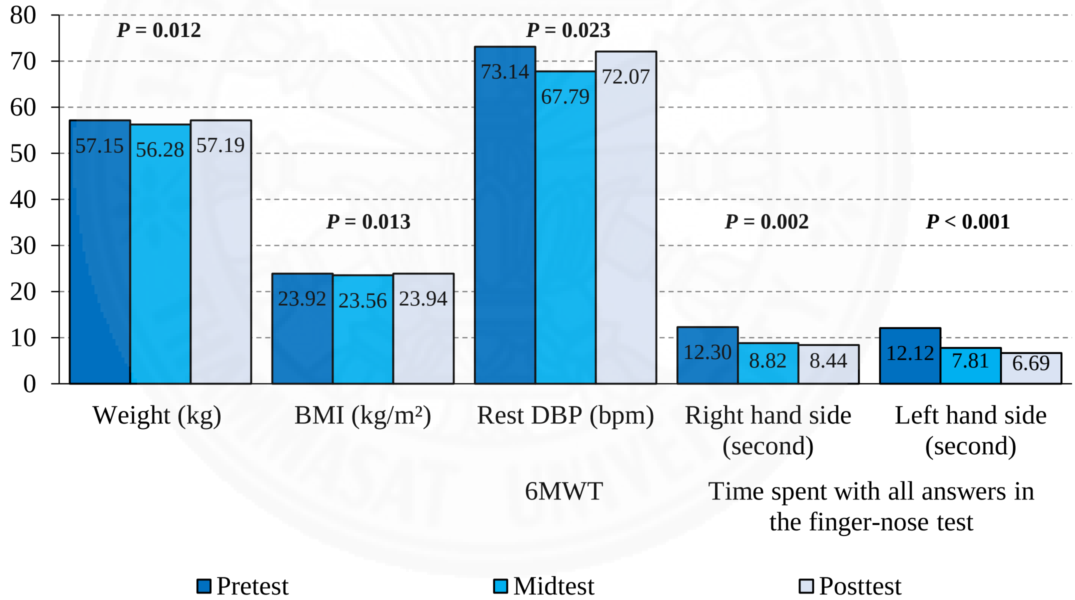


Figure 4.17 Elderly non-fallers' characteristics among pretest, midtest, and posttest

The elderly non-fallers' characteristics data reflected significant differences among pretest, midtest, and posttest stages in the category of the time spent with all the answers on the left hand in the finger-nose test, the time spent with all answers on the right hand in the finger-nose test, weight, BMI, and the 6MWT in the area of DBP at rest ($P < 0.001$, $P = 0.002$, $P = 0.012$, $P = 0.013$, and $P = 0.023$ respectively) as shown in Figure 4.17.

In pairwise comparison, there were significant differences between the tests in weight at pretest and midtest (a; P = 0.008), BMI at pretest and midtest (b; P = 0.010), the 6MWT in the area of resting DBP at midtest and posttest (c; P = 0.050), the time spent with all the answers on the right hand in the finger-nose test at pretest and midtest (d; P = 0.007), and at pretest and posttest (e; P = 0.001), the time spent with all the answers on the left hand in the finger-nose test at pretest and midtest (f; P = 0.006), and at pretest and posttest (g; $P < 0.001$).

In contrast, no significant differences were found among the tests in the 6MWT in the area of HR at rest, SBP at rest, distance, velocity, $VO_{2\ max}$, and MET, in the VA test, the number of incorrect answers on the right and left hands in the finger-nose test, and the toe position sense test as well as the TPD test (Appendix XII).

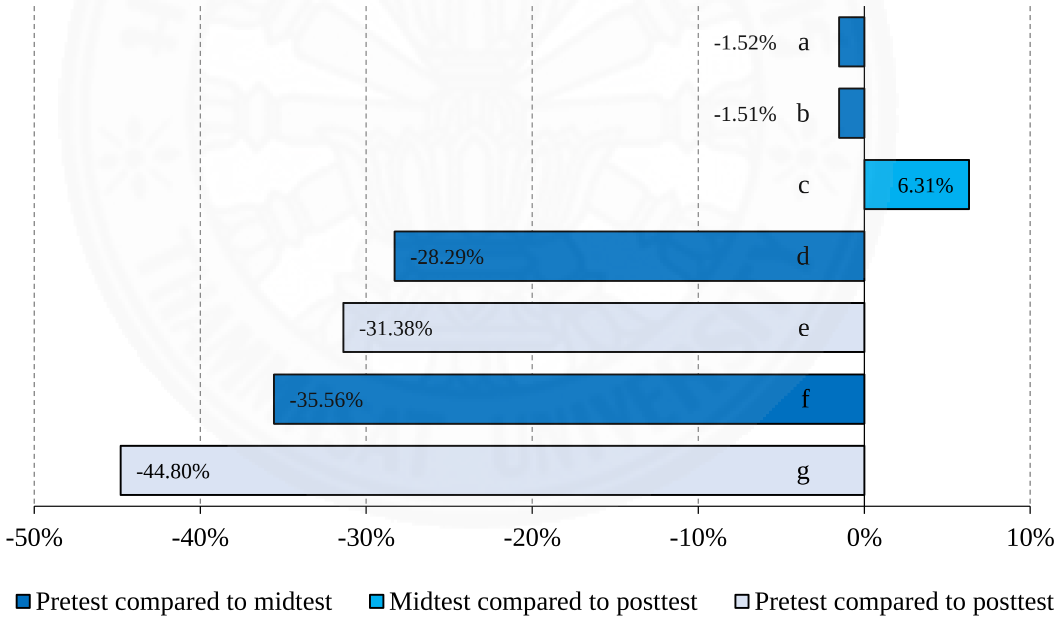


Figure 4.18 Improvement of elderly non-fallers’ characteristics among pretest, midtest, and posttest

The development of the elderly non-fallers’ characteristics in pairwise comparison impressively showed significant improvements. Positive decline had been found in several items. The time spent with all the answers on the left hand in the finger-nose test (g) dropped 44.80%, the time spent with all the answers on the left hand in the finger-nose test (f) dropped 35.56%, the time spent with all the answers on the right hand in the finger-nose test (e) dropped 31.38%, and the time spent with the all answers on the right hand in the finger-nose test (d) dropped 28.29%. The 6MWT in the area of DBP at rest (c) increased 6.31%, weight (a) fell at 1.51% as well as BMI (b) which fell at 1.52% (Figure 4.18).

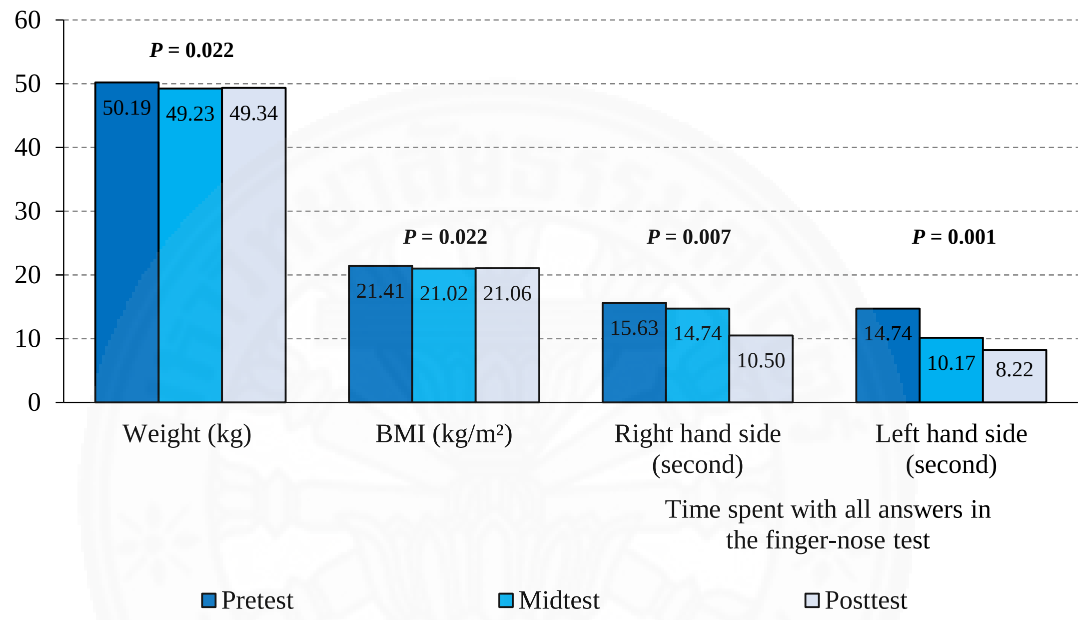


Figure 4.19 Elderly fallers' characteristics among pretest, midtest, and posttest

Regarding the elderly fallers' characteristics, significant differences were identified at pretest, midtest, and posttest in the category of the time spent with all the answers on the left hand in the finger-nose test, the time spent with all the answers on the right hand in the finger-nose test, weight, and BMI (P = 0.001, P = 0.007, P = 0.022, and P = 0.022 respectively) as shown in Figure 4.19.

In pairwise comparison, there were significant differences between the tests in weight at pretest and midtest (a; P = 0.015), and at pretest and posttest (b; P = 0.042), BMI at pretest and midtest (c; P = 0.015), and at pretest and posttest (d; P = 0.048), the time spent with all the answers on the right hand in the finger-nose test at pretest and posttest (e; P = 0.008), and at midtest and posttest (f; P = 0.037), the time spent with all the answers on the left hand in the finger-nose test at pretest and midtest (g; P = 0.002), at pretest and posttest (h; P < 0.001), and at midtest and posttest (i; P = 0.042).

In contrast, no significant differences were found among the tests in the 6MWT, the VA test, the number of incorrect answers on the right and left hands in the finger-nose test, the toe position sense test, and the TPD test (Appendix XIII).

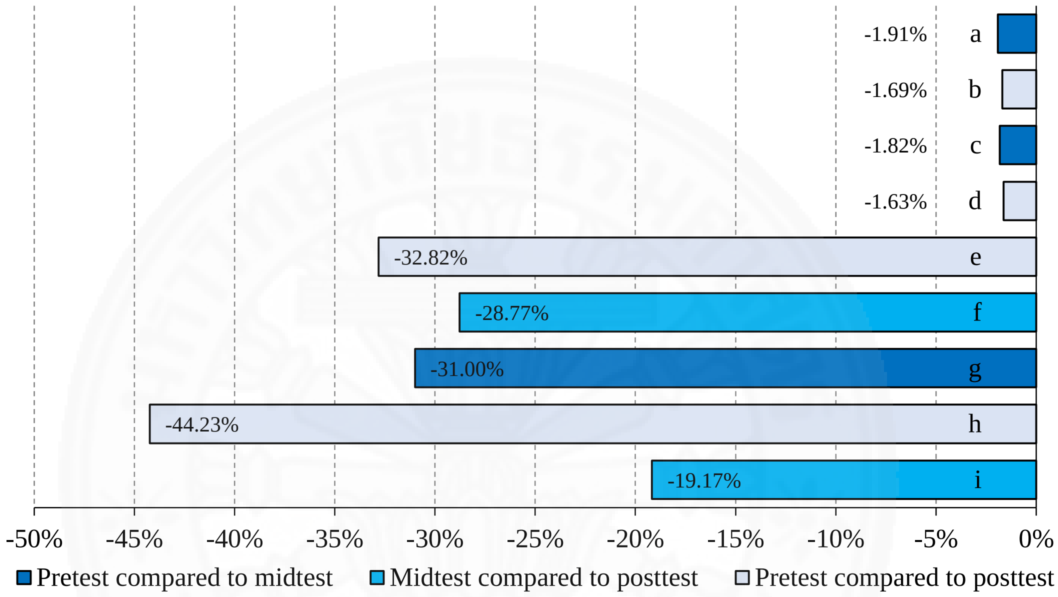


Figure 4.20 Improvement of elderly faller's characteristics among pretest, midtest, and posttest

To clarify, the development of the elderly fallers' characteristics in pairwise comparison showed considerable improvements with a positive decline in several aspects. The time spent with all the answers on the left hand in the finger-nose test (h) dropped 44.23%, the time spent with all the answers on the right hand in the finger-nose test (e) dropped 32.82%, the time spent with all the answers on the left hand in the finger-nose test (g) dropped 31.00%, the time spent with all the answers on the right hand in the finger-nose test (f) dropped 28.77%, the time spent with all the answers on the left hand in the finger-nose test (i) dropped 19.17%, weight (a) dropped 1.91%, BMI (c) dropped 1.82%, weigh (b) dropped 1.69%, and BMI (d) dropped 1.63% (Figure 4.20).

4.6.2 Discussion

The present study showed that the weight and BMI of all the elderly participants were lower at pretest and midtest. Previous studies indicated that BMI is a widely used indicator for obesity in which an Asian person with a BMI greater than twenty-five is obese (160). MMSE and intelligence tests frequently indicated greater scores for normal persons than obese persons (161-163). In men, the negative correlations between BMI and gray matter, including metabolic activity in prefrontal areas and the anterior cingulate cortex could reflect the relationship between obesity and cognition. For goal-directed behaviors, e.g. the ability to flexibly follow a plan, anterior cingulate cortex and prefrontal metabolic activity contain a close relation to EF (164, 165). Therefore, obesity in elderly people affects their health and cognition. Obesity could cause age-related reduction in a number of cognitive abilities (e.g. EF, memory, and speed of processing) by these three possible ways: changing adipose secretions, enriching levels of triglyceride, and impairing insulin regulation to have an effect on the changes of structural and functional brain in the aging process. The findings suggested that exercise gave many advantages on both obesity and cognition, especially aerobic exercise that could make a decline in fat mass and weight. Moreover, in order to increase lean body mass, the importance of which was to boost physical functions and avoid injuries in elderly people, anaerobic exercise was strongly suggested (166).

In addition, all elderly participants in the present study showed that, in the test of the proprioceptive sense, not only did the total time decrease in the dynamic position sense but also the number of incorrect answers in the joint position sense, as well as the number of incorrect answers on the right side at midtest and posttest. Previous studies suggested that by training, postural stability could improve proprioception, and the reduction of the possibility slip-induced falls was caused by the association between the slip-induced falls possibility and ability to integrate weight or balance musculo-skeletal systems while slipping (66). This was particularly helpful as a biomarker in view of the evidence for sensorimotor plasticity and proprioceptive learning (29).

All variables of all the elderly participants in the 6MWT increased. Previous studies indicated that participants with high levels of physical fitness demonstrated high levels of cognition (167), while participants with low levels of fitness were associated with poor EF performance (168, 169). Previous studies showed a relationship between EF and gait speed, as gait speed determined the total distance walked in six minutes (170, 171), which was similarly supported by the present study. Moreover, to sustain an active life, such as doing endurance exercise, the preservation of high cardiorespiratory functions, such as an increased oxygen uptake at anaerobic threshold ($ATVO_2$) could probably help reserve cardiac autonomic nervous system and baroreceptor sensitivity (109).

The overall results for all elderly participants in visual acuity were slightly increased. Even though the present study was concerned with the results of eye-hand coordination training, this was an unexpected major contribution of the present study. The improvement in vision following training was consistent with previous studies that find associations between computer game play and vision improvement and reported that computer skills training improved contrast sensitivity in elderly people (172, 173). The reduction of visual impairment found in the present study improved the participants' quality of life, since poor vision significantly increased postural instability and the risk of falls (11, 13).

Physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure," while *physical exercise* is "a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective" (174). Previous studies indicated that complex physical training such as combined programs were more favorable for cognitive (175) as well as intellectual exercise, and physical activity was linked with better cognitive states in elderly Asian persons (176). More physically active people would perform better hippocampal, prefrontal cortex and basal ganglia volume, better functional brain connectivity, better white matter integrity, more effective brain activity, and superior executive, memory thought-cognitive functioning (177-180). Moreover, short-term aerobic exercise (181) could help neuroplasticity lessen both biological and cognitive aging consequences in order to boost brain health (182). It could also consist of a promising non-pharmaceutical intervention for avoiding age-related cognitive decline and neurodegenerative diseases (183). Clearly, physical training in cognition could mitigate age-associated structural brain changes in those elderly people (184) who can still learn novel motor skills (83). Given the strong association between EF and falls, previous studies indicated that the risk of future falls was identified by performance on the EF (185) and attention tests (186).

All elderly participants in the present study showed that continuing practice of tramping on textured floor tiles five days a week for four weeks could affect TPD in the metatarsal area. This result suggested that the increased foot sensation in elderly people reported to be relevant to falls could be postponed. Thus, elderly people with better foot sensation could have greater stability (15) and lower risk of falls, since they could properly detect when their center of gravity approaches them (14). Several studies have linked the motor (187) and cognitive systems (188) which supported the present study in terms of environmental stimulation's contribution to improving plasticity in elderly people. Interestingly, the environmental benefits could be quantified, so the practical alternative to developing cognitive performance, which relied on particular individual characteristics and needs, could probably be retrieved from the operation of both the environmental stimulation and targeted cognitive intervention (179).

Interestingly, constructive improvement concerning dynamics of body movement coordination did not happen to only the elderly fallers group but also to the elderly non-fallers group. Both groups especially the elderly non-fallers showed the most development in the finger-nose test results. For the finger-nose test after the duration of 8 weeks training, from pretest stage to posttest stage, the highest level of improvement was identified among both groups. The elderly fallers group took more training time to show their improvement. For most areas of improvement, they required 8 weeks of training to exhibit effectiveness. Meanwhile, the elderly non-fallers group mostly portrayed their effectiveness in the first phase of 4 weeks. The elderly fallers group therefore gained higher frequency of improvements than the elderly non-fallers group but the latter group gained the benefits from the combined training more with more convenience and speed. In comparison with the elderly non-fallers group, the elderly fallers group gained a higher frequency of improvements from their combined training. However, the elderly non-fallers group received the training advantages with more ease and in a better time frame.

4.7 Stroop test of elderly participants

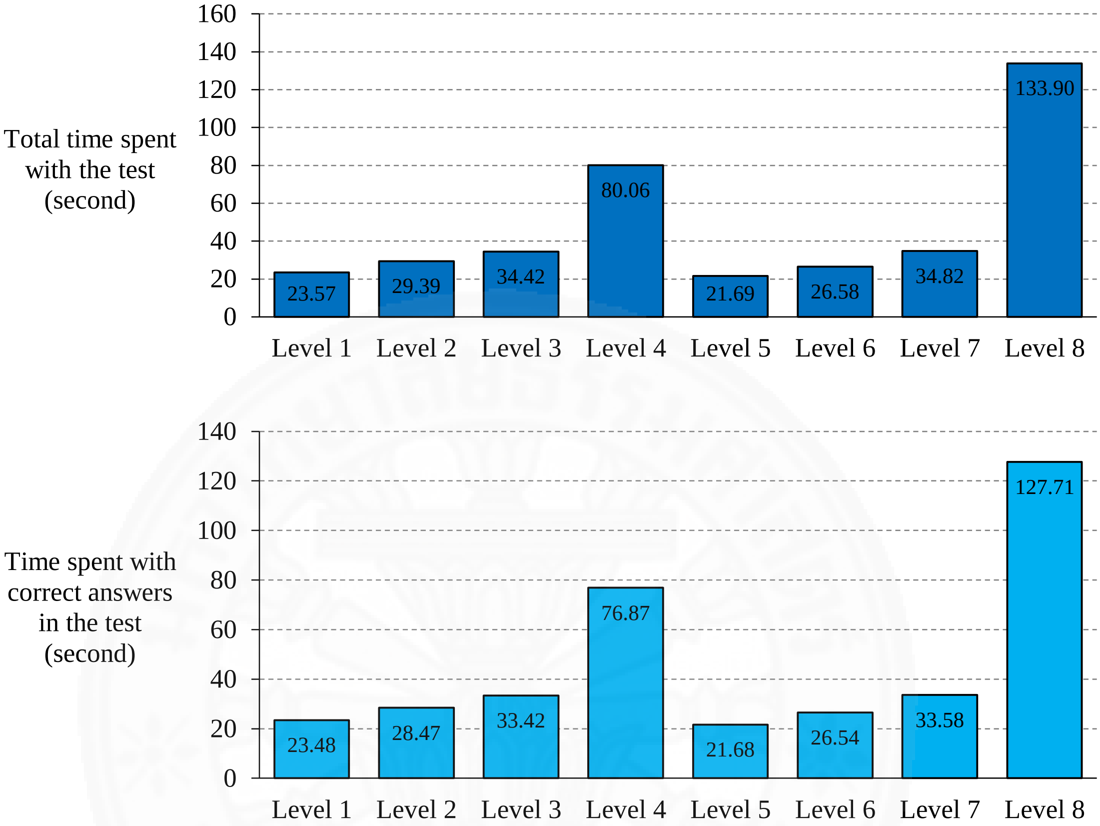


Figure 4.21 Stroop test of all elderly participants

4.7.1 Results

The total time with the Stroop test of all the elderly participants showed that in level 1 they spent 23.57 ±5.62 seconds, at level 2 spent 29.39 ±9.16 seconds, at level 3 spent 34.42 ±14.33 seconds, level 4 spent 80.06 ±30.04 seconds, level 5 spent 21.69 ±4.56 seconds, level 6 spent 26.58 ±8.42 seconds, level 7 spent 34.82 ±17.20 seconds, and at level 8 spent 133.90 ±48.50 seconds. In addition, the time taken attaining the correct answers in the Stroop test of all the elderly participants showed, that in level 1 they spent 23.48 ±5.47 seconds, level 2, 28.47 ±7.06 seconds, level 3, 33.42 ±13.23 seconds, level 4, 76.87 ±29.65 seconds, level 5, 21.68 ±4.55 seconds, level 6, 26.54 ±8.45 seconds, level 7, 33.58 ±16.14 seconds, and level 8 they spent 127.71 ±45.99 seconds as shown in Figure 4.21 (Appendix XIV).

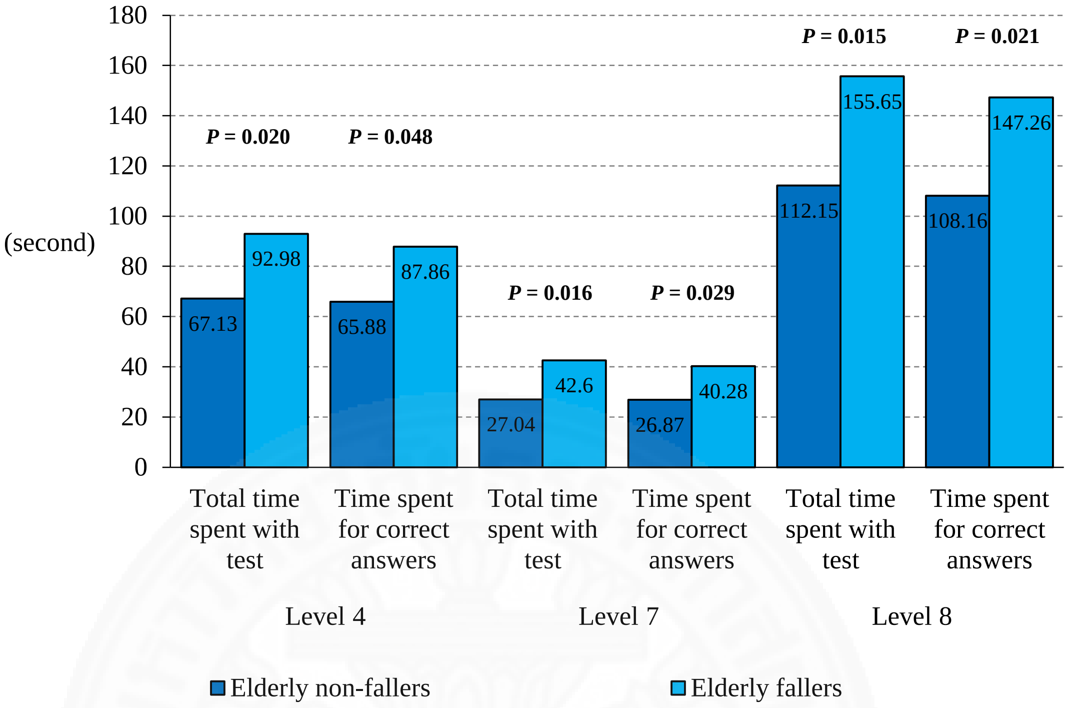


Figure 4.22 Stroop test between elderly non-fallers and fallers groups

The Stroop test performances were significantly different between the groups in level 8 in the total time spent with the test (*P* = 0.015), level 7, at the total time spent with the test (*P* = 0.016), level 4, at the total time spent with the test (*P* = 0.020), level 8 at the time spent attaining the correct answers (*P* = 0.021), level 7 at the time spent attaining the correct answers (*P* = 0.029) and, at level 4 at the time spent attaining the correct answers (*P* = 0.048) as shown in Figure 4.22.

In contrast, no significant differences were found between the groups at level 1, level 2, level 3, level 5, level 6 in the total time spent for the test, the time spent with attaining the correct answers, the number of correct answers, the time spent for incorrect answers, and the number of incorrect answers, and at level 4, level 7, level 8 in the number of correct answer, the time taken for incorrect answers, and the number of incorrect answers.

Interestingly, the differences between the groups at level 7 in the number of correct answers (*P* = 0.051) and the number of incorrect answers (*P* = 0.051), level 5 in the time taken for the correct answers (*P* = 0.052) and the total time spent with the test (*P* = 0.054) were borderline significant (Appendix XV).

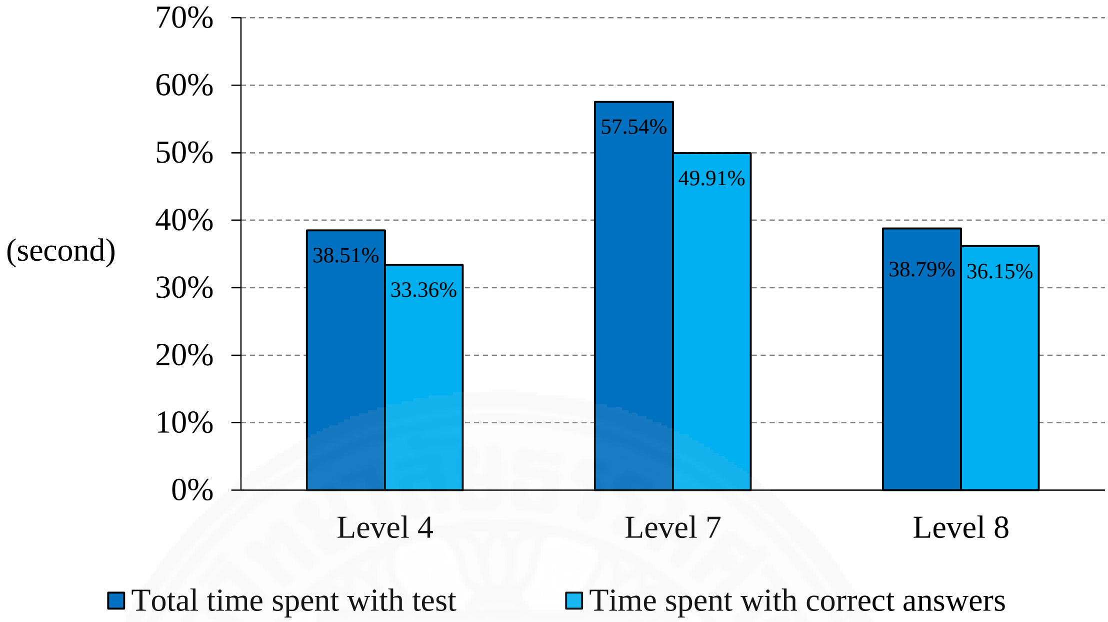


Figure 4.23 Stroop test of elderly fallers compared to elderly non-fallers

To clarify, the elderly fallers group spent more time than the elderly non-fallers group in the Stroop test by 57.54% in the total time spent with the test at level 7, 49.91% in the time spent attaining the correct answers at level 7, 38.79% in the total time spent for the test at level 7, 38.51% in the total time spent for the test at level 4, 36.15% in the time spent attaining the correct answers at level 7, and 33.36% in the time spent attaining the correct answers at level 4 (Figure 4.23).

4.7.2 Discussion

The present study suggested that the time spent on the Stroop test shares characteristics with a range of cognitive functioning measures associated with falls. The total time taken for the test and the time spent attaining the correct answers in the incongruent condition in level 4, 7, and 8 could present a significant risk factor for falls. These items provided additional key information about falls by suggesting that the difference between the elderly non-fallers and fallers groups was not about impaired functional performance. It was rather about making an accurate decision quickly. The results were in agreement with those of previous studies showing that slower cognitive processing and/or poor EF could play an important role in falls (18, 189).

For errors in answers in connection with the chance of falls, several previous studies with Stroop stepping test implied that incorrect answers increased the odds of falling, although this was not found in the present study (16). The results of such tests suggested inhibition as a vital factor when initiating a step and so a deficit could lead to increased error rates and slow reaction time (190, 191). However, some past Stroop stepping studies did not find key fall issues in wrong answers. They found that weak, choice stepping reaction time (CSRT) was a significant and independent predictor of falls (20). This confirmed that the association between slow CSRT and multiple falls was mediated primarily by impaired balance and reaction time, with reduced strength and cognitive processing having indirect mediating roles (17).

Regarding the issue of age, slightly different conclusions come from various studies. Some previous work in Stroop effect proposed that efficient performance in the incongruent condition depended on one's ability to resolve the competition between the two responses evoked by each of the stimulus dimensions. The findings suggested that the age difference in Stroop interference was partially attributable to being slow in general and was also attributable to age-related changes in task specific processes such as inhibitory control (192). Nonetheless, the meta-analyses indicated that there was no specific age-related deficit regarding selective attention. Instead the connection between deficit and dual-task set maintenance was identified (193). With the Stroop test, somehow a prospective study of inpatient falls in an urban rehabilitation hospital predicted falls status by age and functional motor ability (186).

Previous study suggested that being elderly compromises the brain's ability to implement attentional control, allowing greater activation of irrelevant representations and actions capable of decreasing the efficiency of working memory processes. More extensive activation was noted within temporal cortex for elderly participants, indicating deeper processing of the word. In addition, greater activity was noted in ventral prefrontal cortex for elderly participants, reflecting the increased ability of irrelevant representation to gain access to working memory (194). There are examples of the benefits of training in this area. Volunteers who were trained 15 hours a week for 6 months, then exhibited intervention-specific increases in brain activity in the left prefrontal cortex and anterior cingulate cortex. Neural gains were matched by behavioral improvements in executive inhibitory ability. It was designed to bolster memory and EF by exercising working memory skills. These results provided proof of the concept for using dependent brain plasticity in later life and that interventions designed to promote health and function through everyday activity may enhance plasticity in key regions that support EF (195).

In addition, a previous study indicated that the neurotransmitter, dopamine, was implicated in working-memory functioning (196). This was critically involved in the ability to benefit from working-memory interventions and that working-memory was trainable via Stroop (197). The Stroop test in the present study was designed to be fun and exciting, which may motivate elderly people to stick with the training program. The present study suggests that elderly people do not need to be technologically savvy to benefit from training. All elderly participants in this study had no prior experience with a technological device (e.g. video games and computers) and yet they were still able to gain advantages from these novel approaches.

Thus, the results of the present study agreed that among the elderly people, the risk of future falls was predictable by performance on EF and attention tests. The present results links falls among the elderly to cognition, indicating that screening EF will likely enhance fall risk assessment, and that treatment of EF may reduce fall risk (185).

4.8 Stroop test among 8 levels of all elderly participants

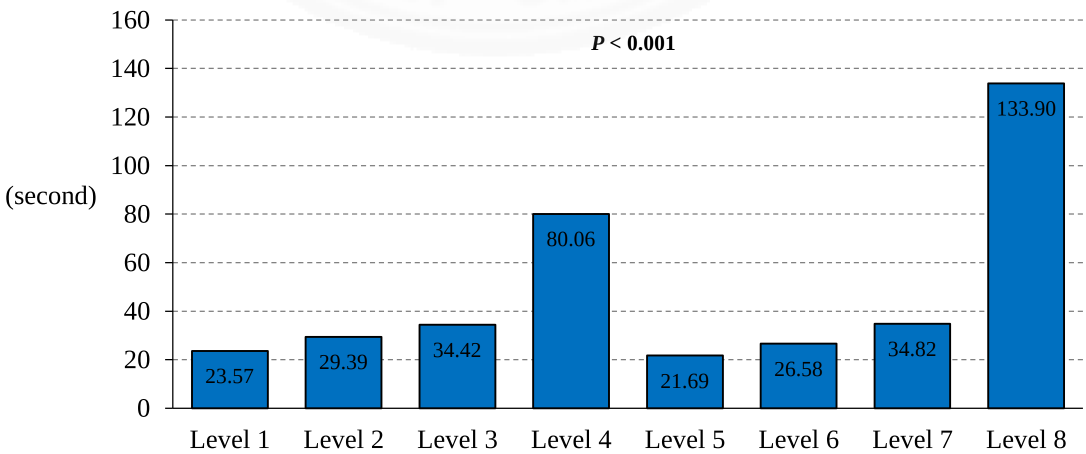


Figure 4.24 Total time spent with Stroop test of all elderly participants

4.8.1 Results

The total time spent with the Stroop test was significantly different among 8 levels of all the elderly participants at $P < 0.001$ (Figure 4.24). In the pairwise comparisons there were significant differences between level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 5, level 2 and 8, level 3 and 4, level 3 and 5, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 4 and 8, level 5 and 8, level 6 and 8, and level 7 and 8 at $P < 0.001$. Level 5 and 7 at $P = 0.001$. Level 1 and 2, and level 1 and 3 at $P = 0.002$. Level 5 and 6 at $P = 0.004$. And level 1 and 7 at $P = 0.008$ (Appendix XVI).

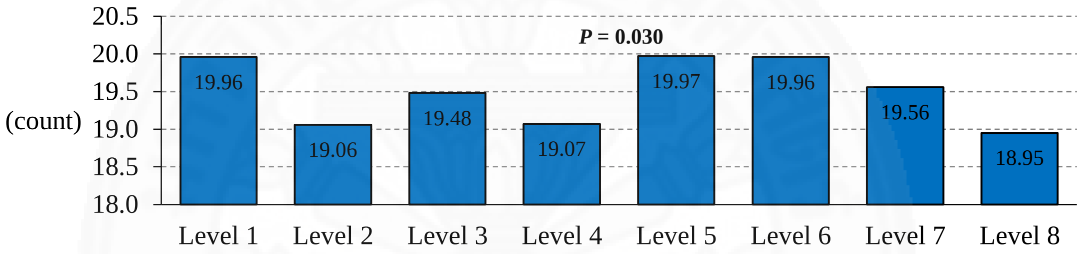


Figure 4.25 Number of correct answers with the Stroop test among 8 levels of all elderly participants

The number of correct answers with the Stroop test was significantly different among 8 levels of all the elderly participants at $P = 0.03$ (Figure 4.25). In the pairwise comparisons there were significant differences between level 1 and 8, level 5 and 8, and level 6 and 8 at $P = 0.006$ (Appendix XVI).

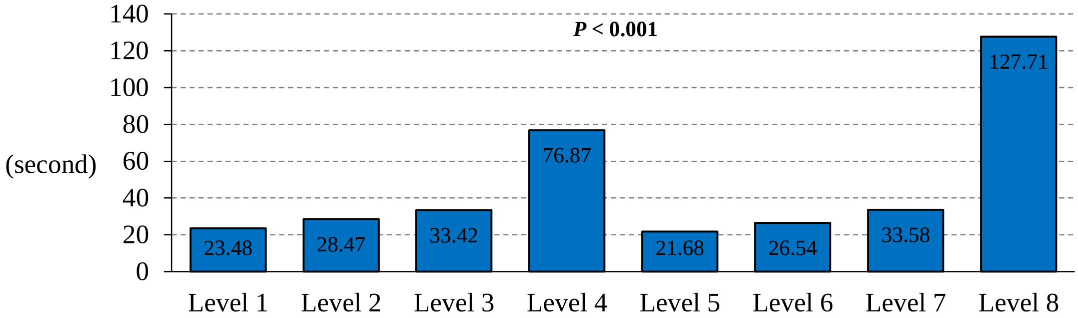


Figure 4.26 Time spent attaining the correct answers in the Stroop test among 8 levels of all elderly participants

The time spent attaining the correct answers of the Stroop test was significantly different among 8 levels of all the elderly participants at $P < 0.001$ (Figure 4.26). In the pairwise comparisons there were significant differences between level 1 and 2, level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 5, level 2 and 8, level 3 and 4, level 3 and 5, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 4 and 8, level 5 and 8, level 6 and 8, and level 7 and 8 at $P < 0.001$. Level 1 and 3, and level 5 and 7 at $P = 0.001$. Level 5 and 6 at $P = 0.005$. And level 1 and 7 at $P = 0.011$ (Appendix XVI).

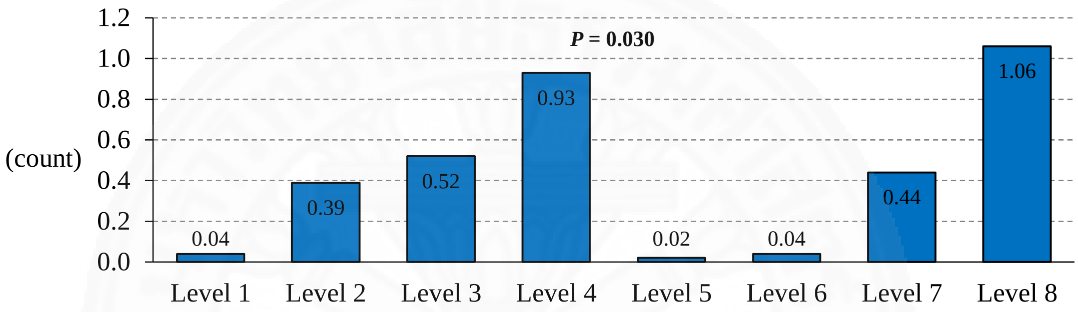


Figure 4.27 Number of incorrect answers with the Stroop test amongst 8 levels of all elderly participants

The number of incorrect answers with the Stroop test was significantly different among 8 levels of all the elderly participants, at $P = 0.03$ (Figure 4.27). In the pairwise comparisons there were significant differences between level 1 and 8, level 5 and 8, and level 6 and 8 at $P = 0.006$ (Appendix XVI).

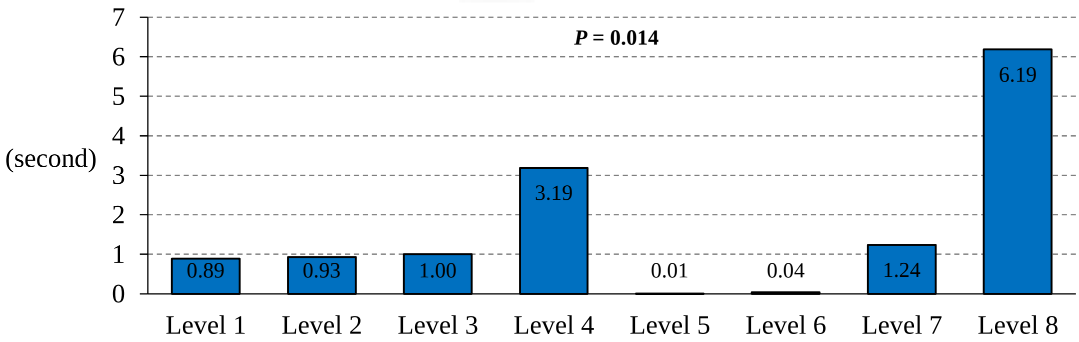


Figure 4.28 Time spent getting the incorrect answers in the Stroop test amongst 8 levels of all elderly participants

The time spent getting incorrect answers of the Stroop test was significantly different among the 8 levels of all the elderly participants at $P = 0.014$ (Figure 4.28). In the pairwise comparisons there were significant differences between level 1 and 8, level 5 and 8, and level 6 and 8 at $P = 0.002$. Level 3 and 8 at $P = 0.009$. And level 7 and 8 at $P = 0.028$ (Appendix XVI).

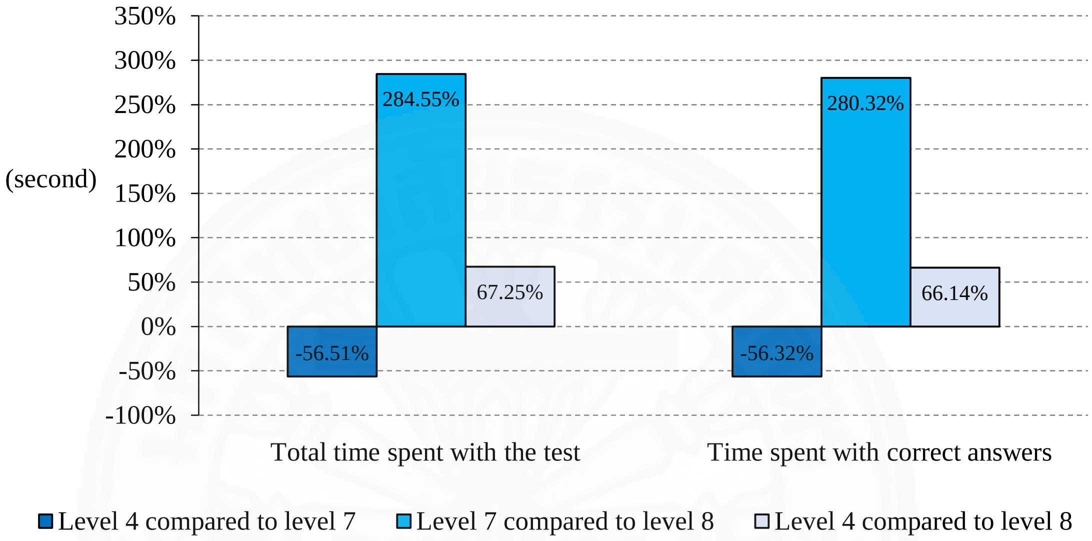


Figure 4.29 Stroop's development in all elderly participants

The Stroop test in levels 4, 7, and 8 of the all elderly participants group showed considerable improvements in several aspects. The total time spent completing the test, from level 4 to 7 dropped 56.51%, from level 7 to 8 increased 284.55%, and from level 4 to 8 increased 67.25%. The time spent attaining the correct answers, from level 4 to 7 dropped 56.32%, from level 7 to 8 increased 280.32%, and from level 4 to 8 increased 66.14% (Figure 4.29).

Both of the levels 4 and 7 were in the incongruent condition. This was the most difficult level of the test. The color-word test in level 4 was more straight forward than the level 7, which was the color-word-background test. By comparing the results between levels 4 and 7, it showed that the total time spent over the test and the time spent attaining the correct answers decreased. It took a shorter time which suggested that the elderly participants group had gained improvements in the total time spent with the test and the time spent getting correct answers.

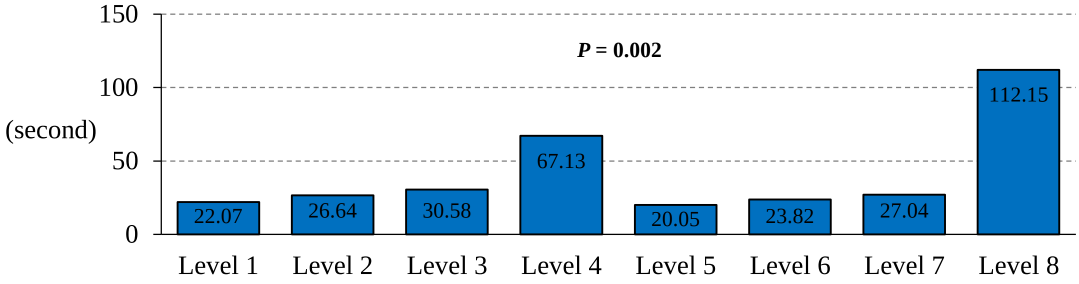


Figure 4.30 Total time spent with Stroop test among 8 levels of elderly non-fallers

The total time spent with the Stroop test was significantly different among the 8 levels of the elderly non-fallers group at $P = 0.002$ (Figure 4.30). In the pairwise comparisons there were significant differences between level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 8, level 3 and 4, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 5 and 8, level 6 and 8, level 7 and 8 at $P < 0.001$. Level 2 and 5, and level 4 and 8 at $P = 0.002$. Level 1 and 2 at $P = 0.011$. Level 5 and 7 at $P = 0.012$. And level 2 and 6 at $P = 0.013$ (Appendix XVII).

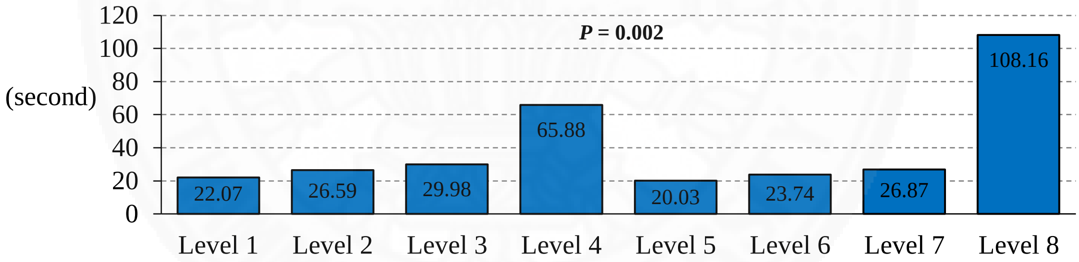


Figure 4.31 Time spent attaining the correct answers of Stroop test among 8 levels of elderly non-fallers

The time spent attaining the correct answers for the Stroop test was significantly different among 8 levels of the non-fallers group at $P = 0.002$ (Figure 4.31). In the pairwise comparisons there were significant differences between level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 8, level 3 and 4, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 5 and 8, level 6 and 8, and level 7 and 8 at $P < 0.001$. Level 2 and 5 at $P = 0.002$. Level 4 and 8 at $P = 0.003$. Level 5 and 7 at $P = 0.009$. Level 1 and 2 at $P = 0.010$. Level 2 and 6 at $P = 0.013$. And level 3 and 5 at $P = 0.027$ (Appendix XVII).

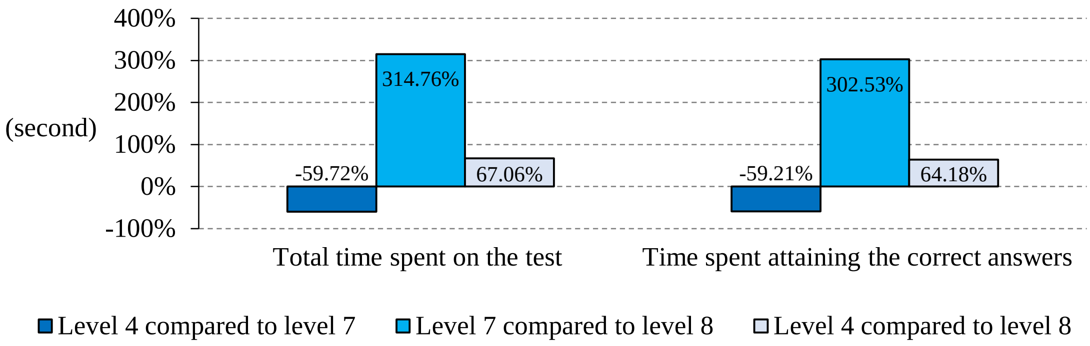


Figure 4.32 Stroop's development of elderly non-fallers

The Stroop test in levels 4, 7, and 8 of the elderly non-fallers group showed considerable improvements in several aspects. The total time spent on the test, from level 4 to 7 dropped 59.72%, from level 7 to 8 increased 314.76%, and from level 4 to 8 increased 67.06%. The time spent attaining the correct answers, from level 4 to 7 dropped 59.21%, from level 7 to 8 increased 302.53%, and from level 4 to 8 increased 64.18% (Figure 4.32).

Both levels 4 and 7 were mentioned previously in the all elderly participants group. This evidence suggested that the elderly non-fallers group had gained improvements in the total time spent on the test and the time spent attaining the correct answers.

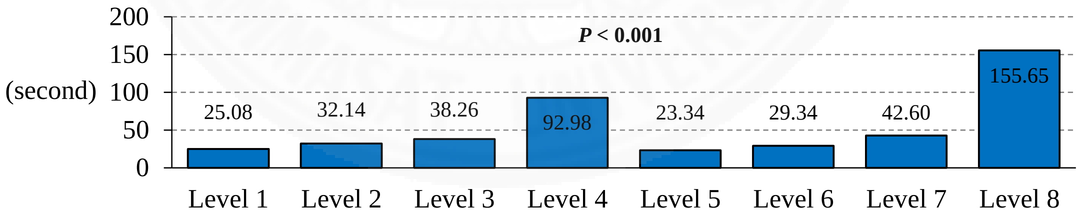


Figure 4.33 Total time spent on the Stroop test among 8 levels of elderly fallers

The total time spent on the Stroop test was significantly different among 8 levels of elderly fallers group at $P < 0.001$ (Figure 4.33). In the pairwise comparisons there were significant differences between level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 8, level 3 and 4, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 4 and 8, level 5 and 8, level 6 and 8, and level 7 and 8 at $P < 0.001$. Level 3 and 5 at $P = 0.018$. And level 5 and 7 at $P = 0.033$ (Appendix XVIII).

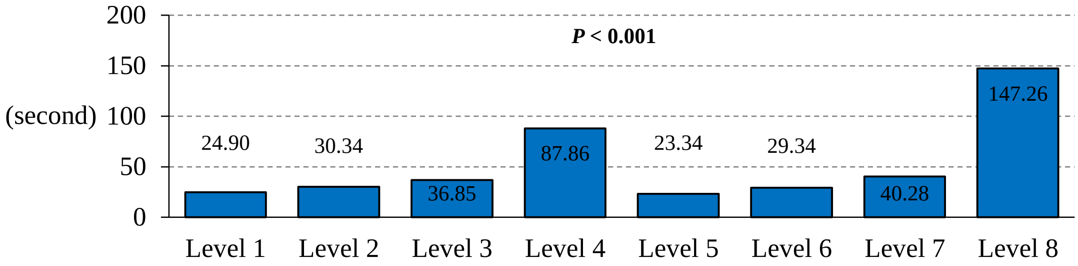


Figure 4.34 Time spent attaining the correct answers of Stroop test amongst 8 levels of elderly fallers

The time spent gaining the correct answers of the Stroop test was significantly different among 8 levels of the elderly fallers at $P < 0.001$ (Figure 4.34). In the pairwise comparisons there were significant differences between level 1 and 4, level 1 and 8, level 2 and 4, level 2 and 8, level 3 and 8, level 4 and 5, level 4 and 6, level 4 and 7, level 4 and 8, level 5 and 8, level 6 and 8, and level 7 and 8 at $P < 0.001$. Level 3 and 4 at $P = 0.001$. Level 1 and 2 at $P = 0.011$. Level 2 and 5 at $P = 0.012$. And level 3 and 5 at $P = 0.025$ (Appendix XVIII).

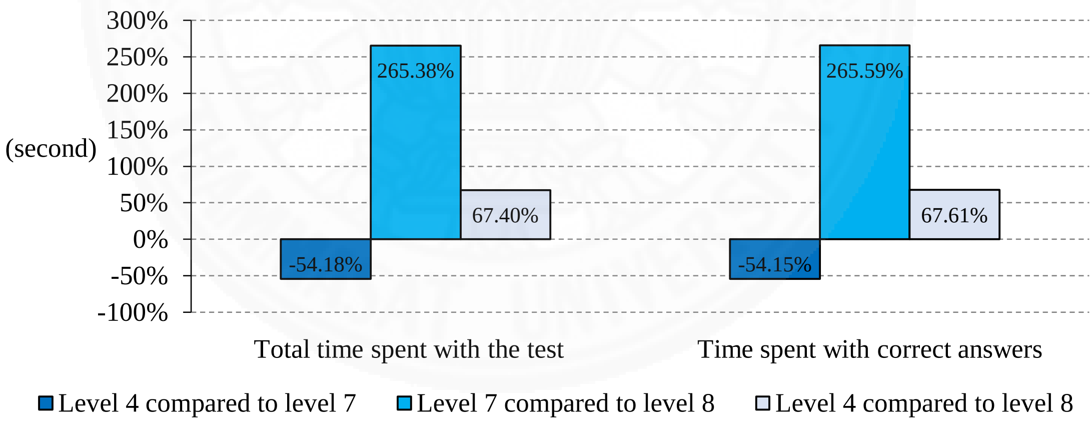


Figure 4.35 Stroop's development of elderly fallers

The Stroop test in level 4, 7, and 8 of the elderly fallers group showed considerable improvements in several aspects. The total time spent with the test, from level 4 to 7 dropped 54.18%, from level 7 to 8 increased 265.38%, and from level 4 to 8 increased 67.40%. The time spent attaining the correct answers, from level 4 to 7 dropped 54.15%, from level 7 to 8 increased 265.59%, and from level 4 to 8 increased 67.61% (Figure 4.35).

Both level 4 and 7 were as well as mentioned previously in the all elderly participants group. This evidence suggested that the elderly fallers group had gained improvements in the total time spent with the test and the time spent attaining the correct answers.

4.8.2 Discussion

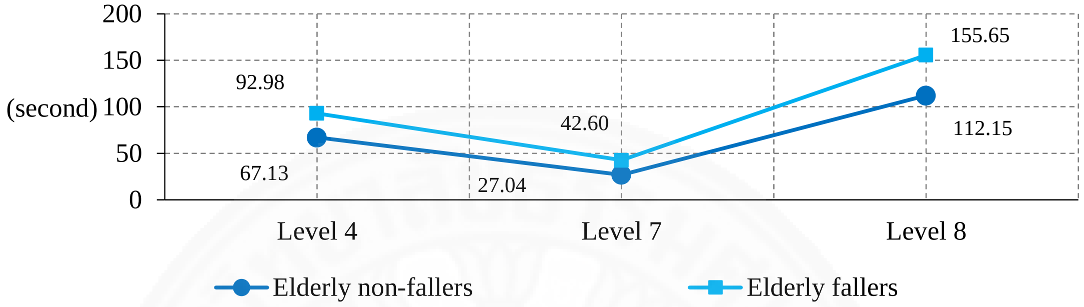


Figure 4.36 Total time spent with Stroop test between the elderly non-fallers and fallers groups

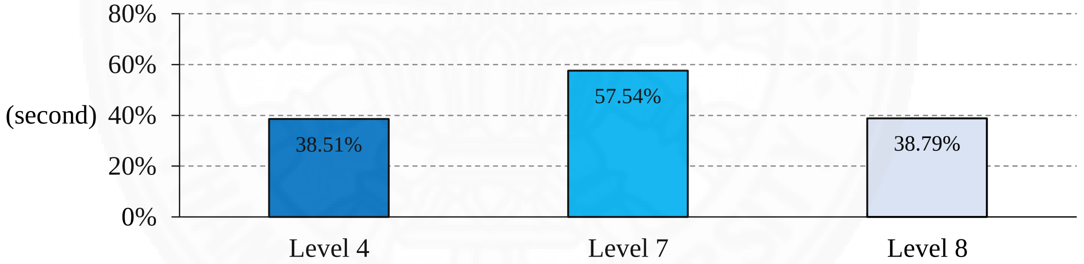


Figure 4.37 Total time spent with Stroop test of the elderly fallers compared to the elderly non-fallers

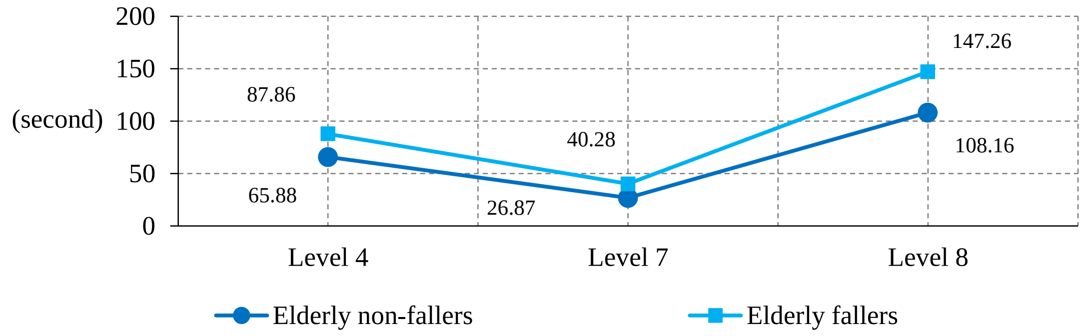


Figure 4.38 Time spent for correct answers with Stroop test between the elderly non-fallers and fallers groups

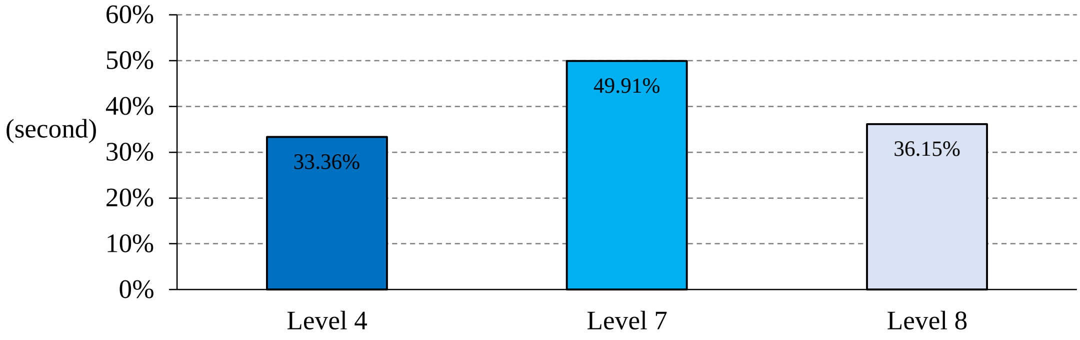


Figure 4.39 Time spent for the correct answers in Stroop test of the elderly fallers compared to the elderly non-fallers

The present study indicated that elderly people were able to improve their attention in the cognition. The elderly non-fallers group gained improvement greater than the elderly non-fallers group. Within that, better performances were found between the groups, especially at level 4, 7, and 8, in the total time spent with the test where the performance raised by 38.51%, 57.54%, and 38.79% respectively (Figure 4.36 and Figure 4.37). And also, at level 4, 7, and 8 in the time spent attaining correct answers were raised by 33.36%, 49.91%, and 36.15% respectively (Figure 4.38 and Figure 4.39).

Previous studies indicated that age-related factors increased in incongruent color-naming (198). The processing speed measures accounted for a significant effect of age. The age difference in Stroop interference was partially attributable to general slowing, but was also attributable to age-related changes in task-specific processes such as inhibitory control (192). In time responding to the Stroop test, a previous study that investigated practice effects on Stroop color-word interference in older and younger adults. Overall response time improved in both control and interference conditions. It suggested that older adults could improve performance in both multiple-and single-item versions of the Stroop task (85).

The results were related to a previous study of cognitive training that assessed elderly people.These results suggested that even in elderly persons with mild cognitive impairment their cognitive performance could improve when provided with cognitive training (199). A previous study of cognitive flexibility indicated that cognitive flexibility is one aspect of EF that encompasses the ability to produce diverse ideas, consider response alternatives, and modify behavior to manage changing circumstances. These processes are likely to be important for implementing cognitive restructuring which is a skill that can be satisfactorily performed by older adults (200). This supported the notion of cognitive plasticity in the present study.

4.9 Juggling performances of elderly participants

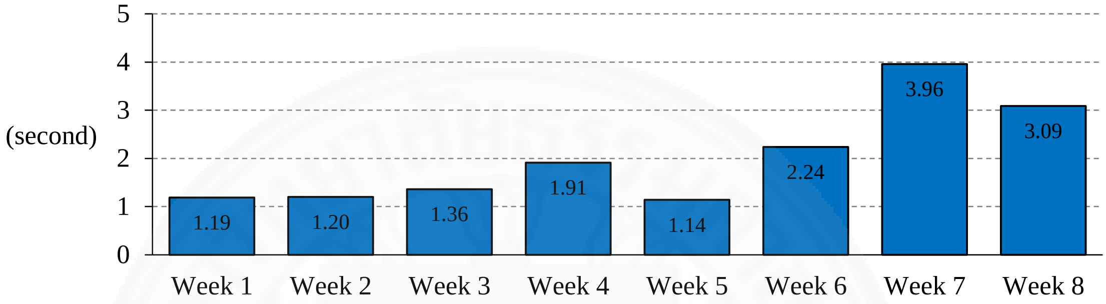


Figure 4.40 Juggling performances of all elderly participants

4.9.1 Results

The juggling performances of the group of all the elderly participants showed that in week 1 they spent 1.19 ±0.22 seconds, in week 2 they spent 1.20 ±0.24 seconds, in week 3 1.36 ±0.45 seconds, in week 4 1.91 ±0.48 seconds, in week 5 1.14 ±0.42 seconds, in week 6 2.24 ±0.87 seconds, in week 7 3.96 ±1.86 seconds, and in week 8 3.09 ±1.66 seconds as shown in Figure 4.40 (Appendix XIX).

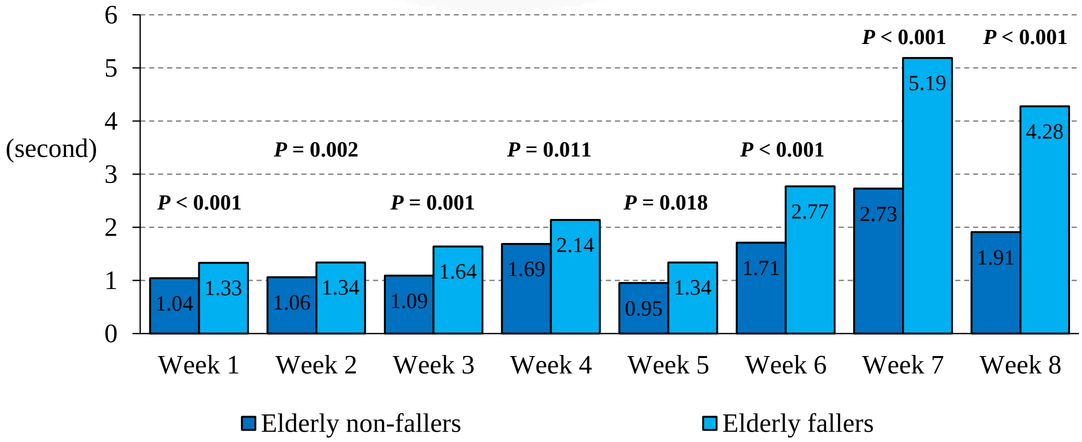


Figure 4.41 Juggling performances between the elderly non-fallers and fallers groups

The juggling performances were significantly different between the elderly non-fallers and fallers groups in week 1, week 6, week 7, week 8, week 3, week 2, week 4, and week 5, (P < 0.001, P < 0.001, P < 0.001, P < 0.001, P = 0.001, P = 0.002, P = 0.011, and P = 0.018) respectively, as shown Figure 4.41 (Appendix XIX).

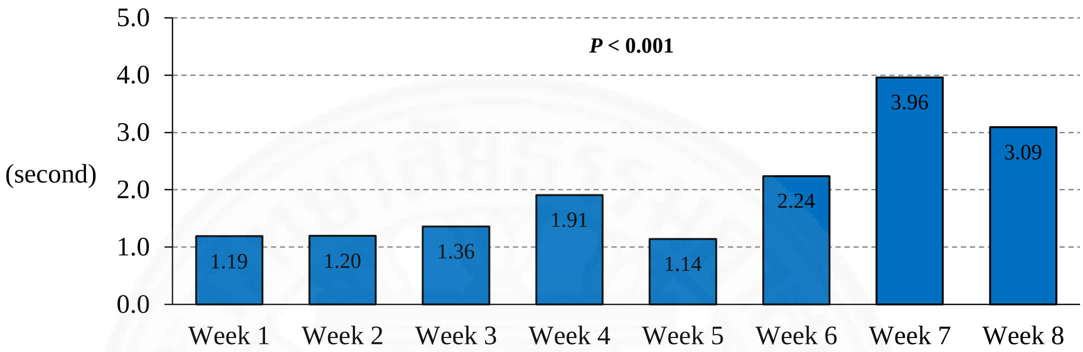


Figure 4.42 Juggling performances among 8 weeks of all elderly participants

The juggling performances of all the elderly participants group were significantly different among the 8 weeks at P < 0.001 (Figure 4.42). In the pairwise comparisons there were significant differences between week 1 and 4, week 1 and 6, week 1 and 7, week 1 and 8, week 2 and 4, week 2 and 6, week 2 and 7, week 2 and 8, week 3 and 4, week 3 and 6, week 3 and 7, week 3 and 8, week 4 and 5, week 4 and 7, week 5 and 6, week 5 and 7, week 5 and 8, and week 6 and 7, at P < 0.001. Week 7 and 8 at P = 0.005. Week 4 and 8 at P = 0.006. And week 6 and 8 at P = 0.036 (Appendix XX).

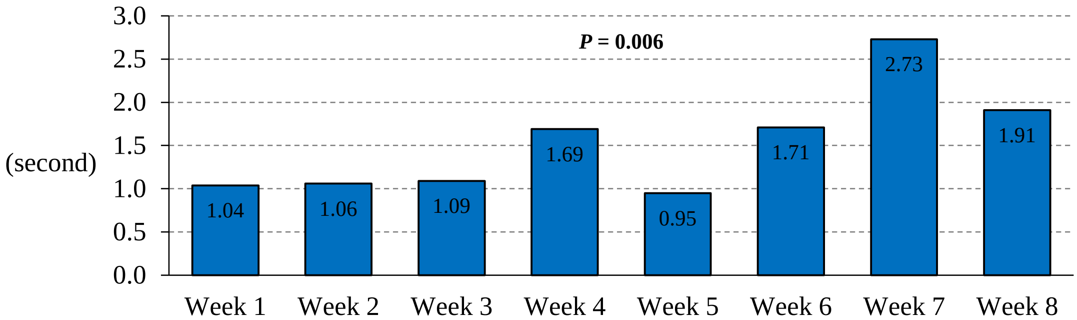


Figure 4.43 Juggling performances over 8 weeks by elderly non-fallers

The juggling performances were significantly different over 8 weeks by the elderly non-fallers group, at *P* = 0.006 (Figure 4.43). In the pairwise comparisons there were significant differences between week 3 and 4, week 3 and 7, week 4 and 5, and week 5 and 7 at *P* < 0.001. Week 1 and 7, week 2 and 4, and week 2 and 7 at *P* = 0.001. Week 1 and 4, and week 5 and 8 at *P* = 0.002. Week 3 and 8, week 4 and 7, and week 5 and 6 at *P* = 0.005. Week 2 and 8, and week 3 and 5 at *P* = 0.008. Week 1 and 6, and week 2 and 6 at *P* = 0.009. Week 1 and 8 at *P* = 0.010. Week 3 and 6, and week 6 and 7 at *P* = 0.012. And week 7 and 8 at *P* = 0.017 (Appendix XX).

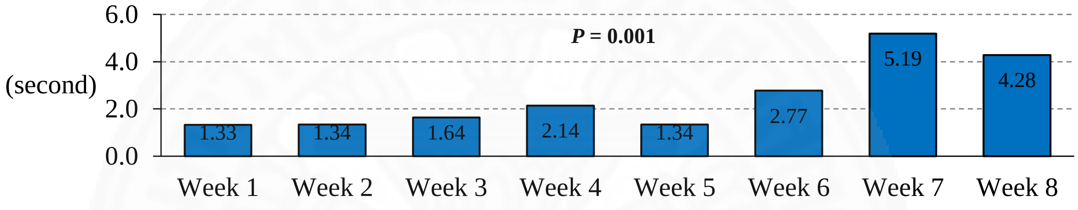


Figure 4.44 Juggling performances over 8 weeks by elderly fallers

The juggling performances were significantly different during the 8 weeks for the elderly fallers group at *P* = 0.001 (Figure 4.44). In the pairwise comparisons there were significant differences between week 1 and 6, week 1 and 7, week 1 and 8, week 2 and 6, week 2 and 7, week 2 and 8, week 3 and 6, week 3 and 7, week 3 and 8, week 4 and 7, week 5 and 7, and week 5 and 8 at *P* < 0.001. Week 1 and 4, week 2 and 4, and week 5 and 6 at *P* = 0.001. Week 6 and 7 at *P* = 0.002. Week 4 and 8 at *P* = 0.004. And week 4 and 5 at *P* = 0.027 (Appendix XX).

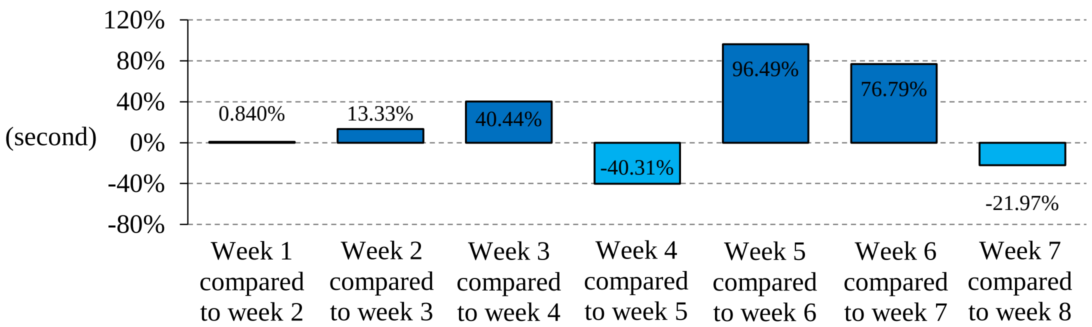


Figure 4.45 Juggling performances between two weeks for all elderly participants

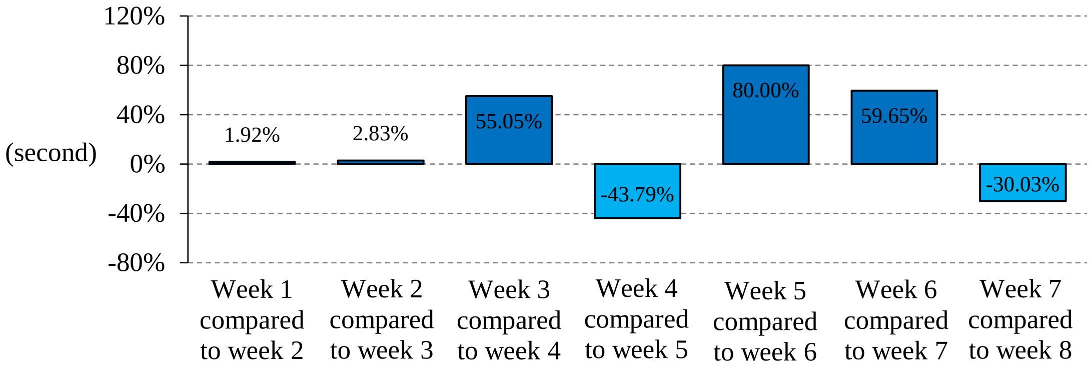


Figure 4.46 Juggling performances between two weeks for the elderly non-fallers

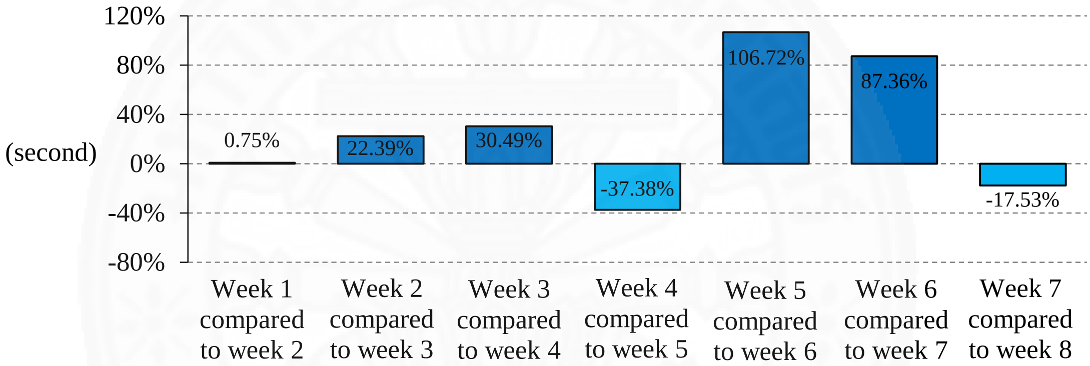


Figure 4.47 Juggling performances between two weeks for the elderly fallers

The juggling performances in week 4 to week 5, and week 7 to week 8 dropped 40.31%, and 21.97% respectively for the all elderly participants groups (Figure 4.45). In the elderly non-fallers group from week 4 to week 5 they dropped 43.79%, and from week 7 to week 8 they dropped 30.03% (Figure 4.46). In the elderly fallers group, from week 4 to week 5 they dropped 37.38%, and from week 7 to week 8 they dropped 17.53% (Figure 4.47).

This result showed that the elderly people had improved their motor skills, except in week 5 and week 8, which were in the dual tasks condition of the training. However, the elderly people had improved their juggling performances from week 5 to week 6 (dual tasks condition) since they dropped during the previous level. This also confirmed that the elderly people could possibly enhance high gross motor skills in the present study.

4.9.2 Discussion

The present study showed that the time used to perform the juggling task increased every week, except for week 5 and 8. This result suggested that juggling 3 balls on week 4 (eye-hand coordination) was more challenging than juggling 1 ball while trampling on pebble wash tiles on week 5 (dual tasks). A comparison between week 1 which is 1 ball juggling (simple eye-hand coordination) and week 5 (dual tasks) indicated that participants did better by spending less time to complete the latter task. While on week 8, the time spent was less than during the previous weeks. This raised the possibility that the participants had improved motor skills in juggling 3 balls while trampling on pebble wash tiles, which required eye-hand coordination (and feet) with dual tasks. Therefore, the present study indicated that elderly people were able to activate their remaining capacities to compensate for motor weakness. With that, better performances were found among the elderly non-fallers group compared to the elderly fallers group, especially from week 4 to week 8 where the performance raised from 26.63% to 124.08% (Figure 4.48).

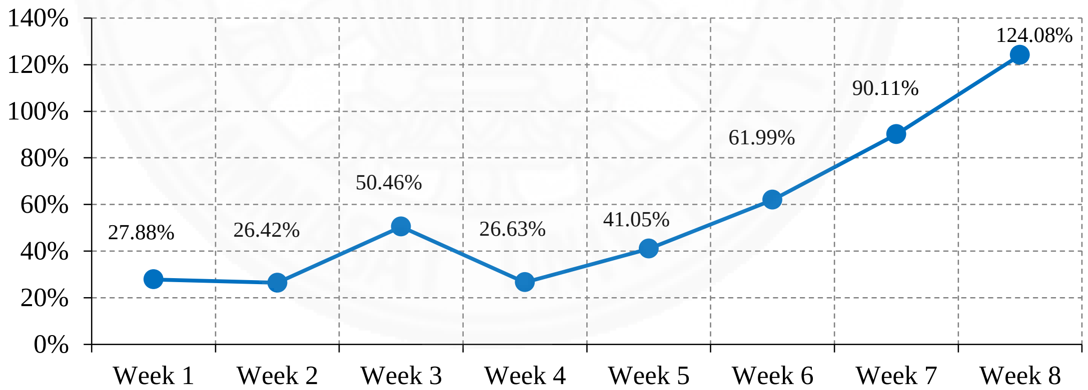


Figure 4.48 Development of juggling performances of the elderly non-fallers compared to the fallers

The results of the present study supported the hypothesis that high plasticity derived from learning motor skills through juggling activity could be an example of "successful aging" (201, 202). There were perceptions of motor adaptability and performance of motor plasticity of gross motor skills which were in line with reaction time, movement speed and eye-hand (and feet) coordination (38).

This complex rhythmic task involves motor skills such as motor learning, inter-limb coordination, and sensory-motor coordination (203). The improved coordination will make ADL easier and help prevent trips and falls. The act of learning how to juggle has developed a high level of coordination (204). However, physical strength should also gain attention because regular exercise focusing on functional fitness is associated with significant reductions in the levels of dependence and disability in elderly people (205). Additionally, the connection among cognition, physical health and physical fitness levels especially aerobic fitness in older people is well established (206, 207). There is also empirical support for exercise that can improve physical fitness, behavior, cognition, communication, as well as function in older people with cognitive impairments (174, 181). Cross-sectional and longitudinal data of previous studies have demonstrated that physically active people have a lower risk of developing Alzheimer's disease and related cognitive disorders compared with sedentary people (208). Aerobic fitness training appears to have an association with reduced brain tissue loss in aging humans (209), and also the meta-analysis supported the positive effect of physical fitness training on cognitive function in older adults (210). All of these support the importance of body strength to cognitive function.

Rather than the structures involved in motor control, such as the cerebral cortex, cerebellum and basal ganglia, learning to juggle seems to stimulate an increase in the size of an anatomical structure, believed to function as a "crossroad" between the limbic and the motor systems, initiating motor responses (38). Previous studies indicated that human brain imaging had identified structural changes in gray and white matter that occur with learning. The participants learning to juggle showed transient increases in gray matter in the hippocampus on the left side and in the nucleus accumbens bilaterally. To learn and master a new skill is certainly rewarding. The nucleus accumbens receives input from the prefrontal cortex, hippocampus, basolateral amygdala, and the ventral tegmental area, and projects to motor areas such as the ventral pallidum (211, 212). It is therefore thought that the nucleus accumbens is a neural interface between limbic and motor systems, turning reward information into motivated action. Thus, a brain plasticity-based training program would potentially promise an improvement in the operational capabilities of elderly people.

4.10 HRV characteristics between elderly non-fallers and elderly fallers groups in sitting position

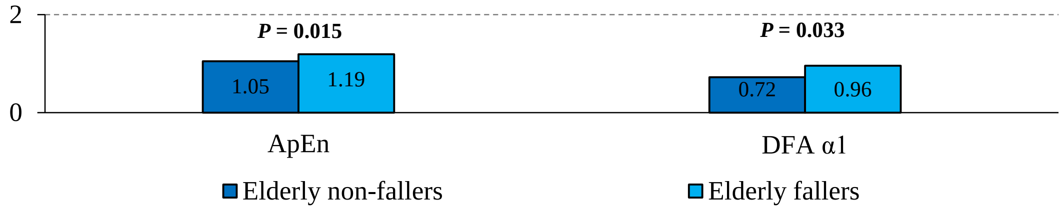


Figure 4.49 HRV characteristics between elderly non-fallers and fallers groups in sitting position at pretest

4.10.1 Results

The HRV between the elderly non-fallers group and the elderly fallers group in the sitting position at pretest showed significant differences in ApEn (P = 0.015), and DFA α1 (P = 0.033) as shown in Figure 4.49. In contrast, no significant differences were found between the groups in the time domain, the frequency domain, SampEn, DFA α2, D2, and PTT (Appendix XXI).

Figure 4.50 HRV characteristics between elderly non-fallers and fallers groups in sitting position at midtest

The HRV between the elderly non-fallers group and the elderly fallers group in the sitting position at midtest showed significant differences in Mean HR (P = 0.019), and Mean RR (P = 0.028) as shown in Figure 4.50. In contrast, no significant differences were found between the groups in SDNN, STD HR, RMSSD, NN50, pNN50, RR triangular index, TINN, the frequency domain, the nonlinear domain, and PTT (Appendix XXII).

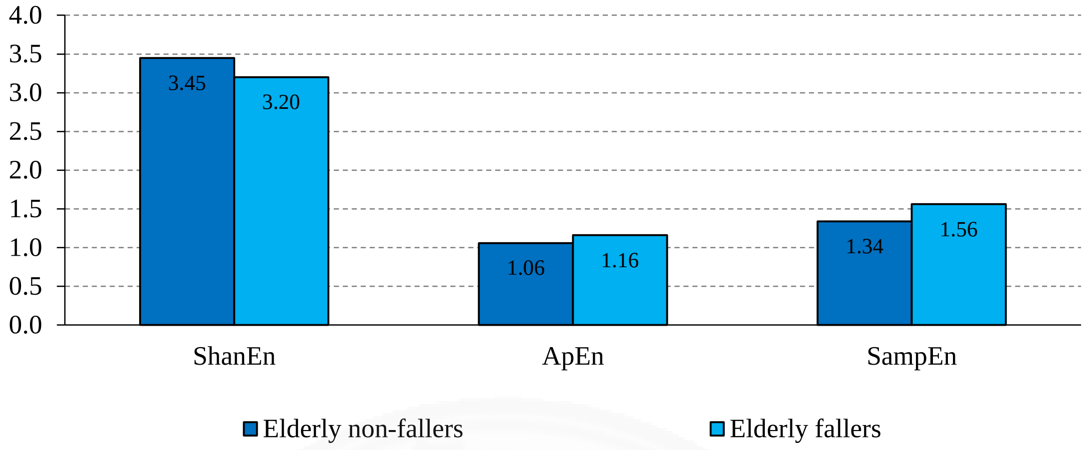


Figure 4.51 HRV characteristics between elderly non-fallers and fallers groups in sitting position at posttest

The HRV between the elderly non-fallers group and the elderly fallers group in the sitting position at posttest found no significant differences in the time domain, the frequency domain, the nonlinear domain, and PTT. However, the differences between the groups in ApEn (*P* = 0.124), SampEn (*P* = 0.131), and ShanEn (*P* = 0.136), were mostly in significant (Figure 4.51 and Appendix XXIII).

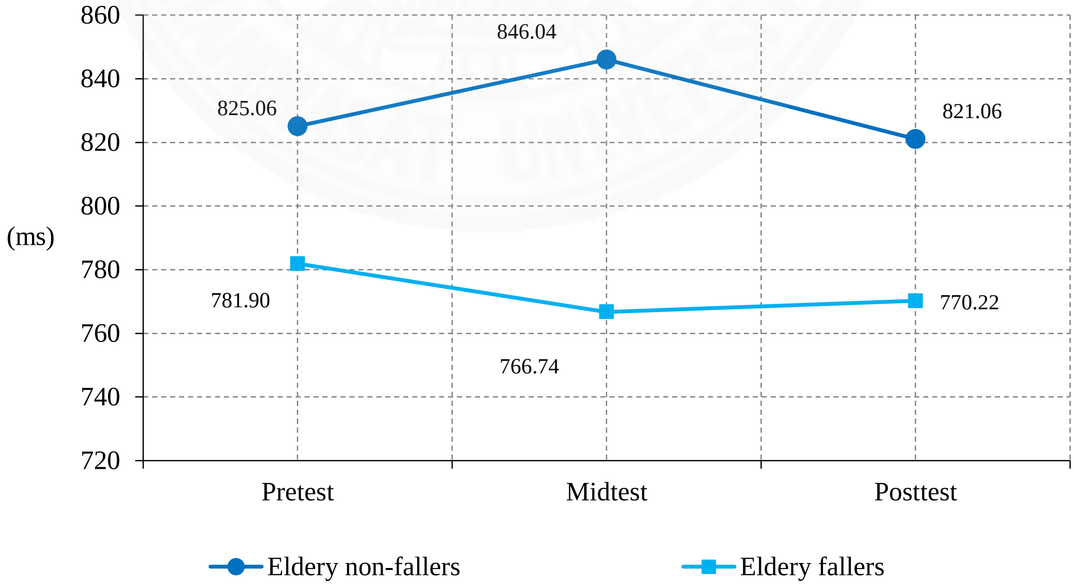


Figure 4.52 Mean RR among pretest, midtest, and posttest between elderly non-fallers and fallers groups in sitting position

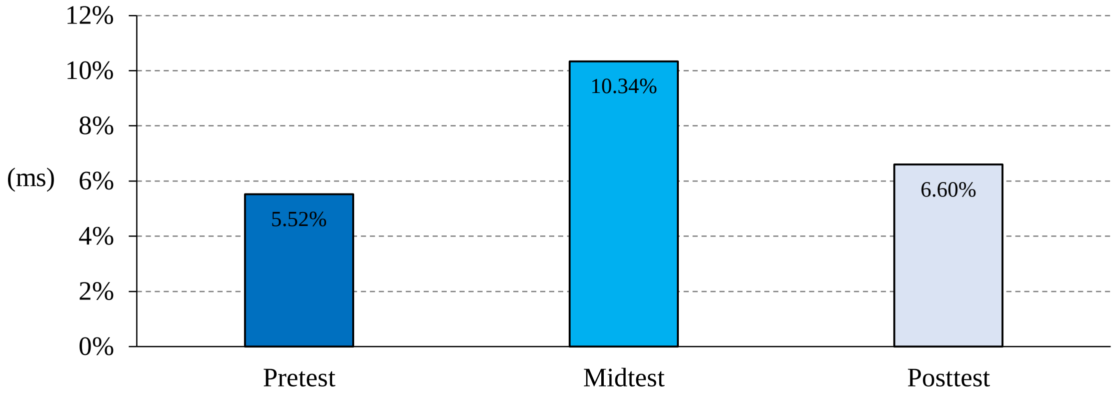


Figure 4.53 Mean RR in sitting position of elderly non-fallers group compared to elderly fallers group

The differences of Mean RR in the HRV between the elderly non-fallers group compared to the elderly fallers group were found higher at the midtest by 9.37%, higher at the posttest by 6.19%, and higher at the pretest by 5.23% (Figure 4.52 and Figure 4.53).

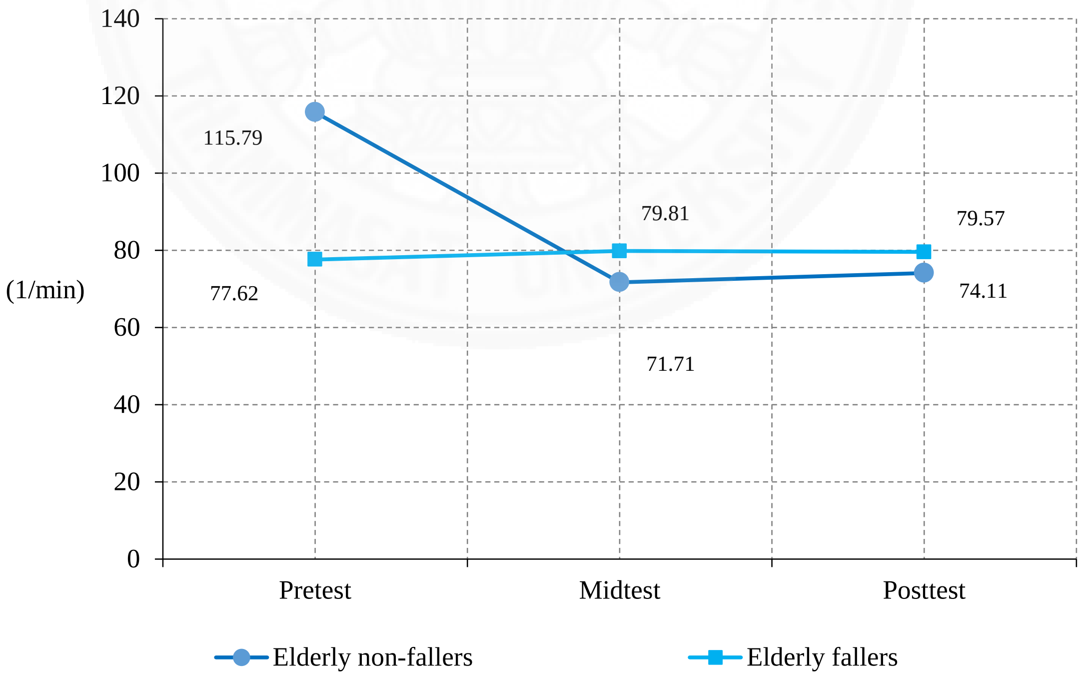


Figure 4.54 Mean HR among pretest, midtest, and posttest between elderly non-fallers and fallers groups in sitting position

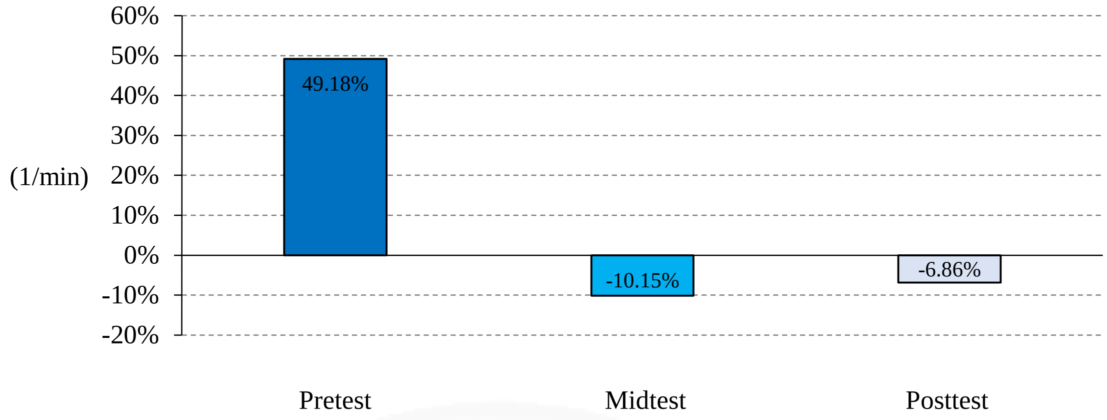


Figure 4.55 Mean HR in sitting position of elderly non-fallers group compared to elderly fallers group

The differences of Mean HR in the HRV between the elderly non-fallers group compared to the elderly fallers group were found higher at the pretest by 49.18%, lower at the posttest by 6.86%, and lower at the midtest by 10.15% (Figure 4.54 and Figure 4.55).

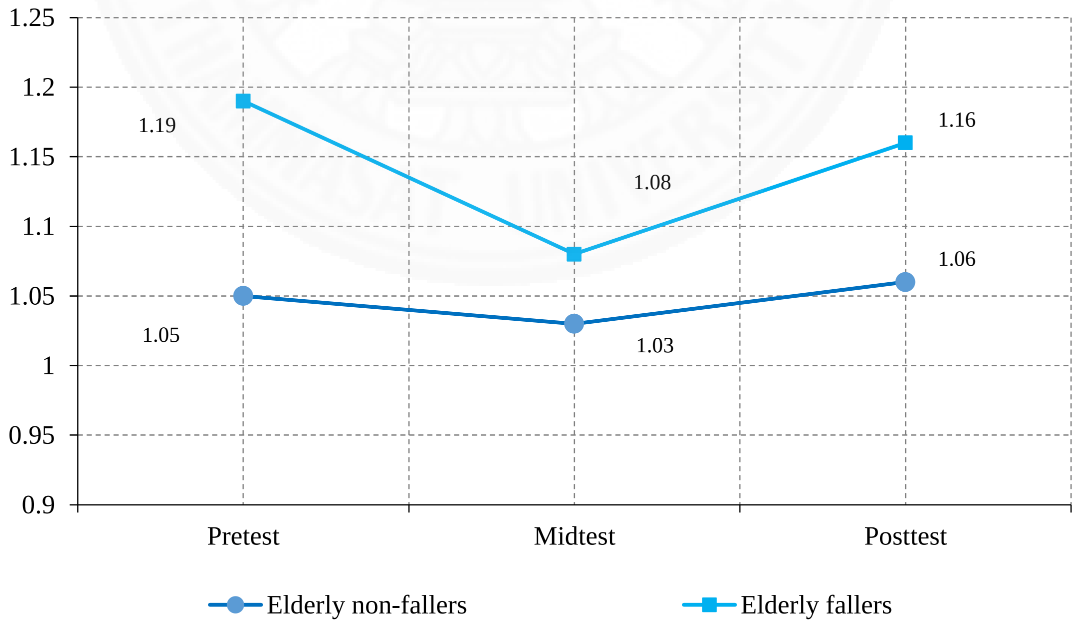


Figure 4.56 ApEn among pretest, midtest, and posttest between elderly non-fallers and fallers groups in the sitting position

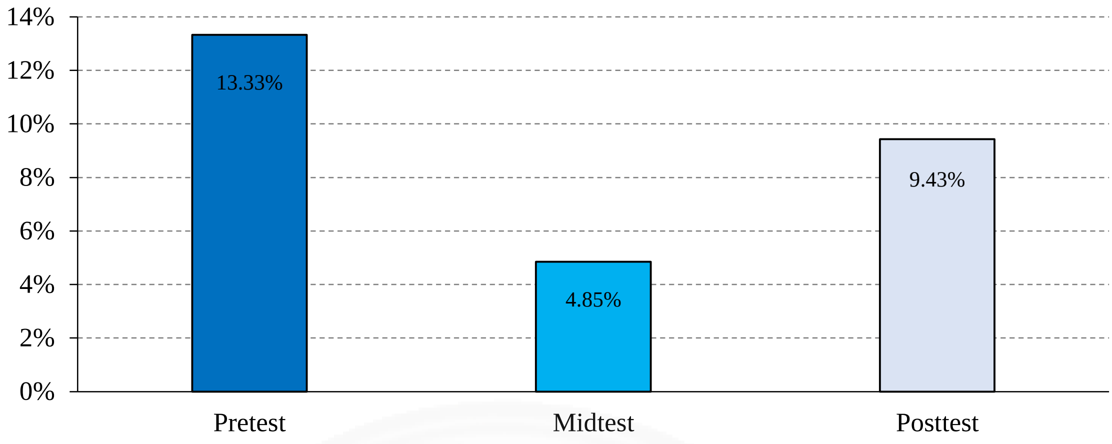


Figure 4.57 ApEn in sitting position of elderly fallers group compared to elderly non-fallers group

The differences of ApEn in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the pretest by 13.33%, higher at the posttest by 9.43%, and higher at the midtest by 4.85% (Figure 4.56 and Figure 4.57).

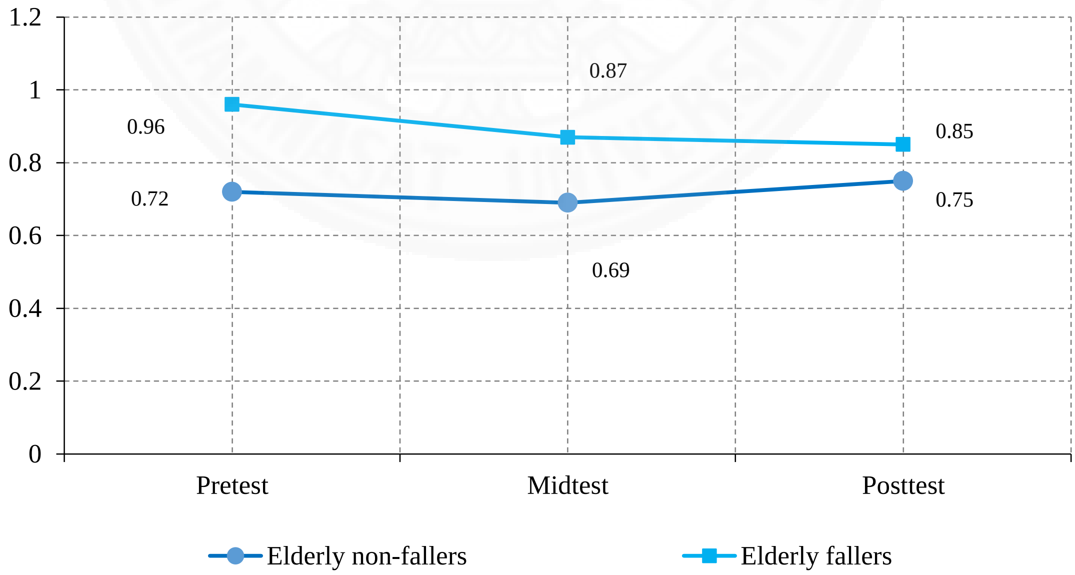


Figure 4.58 DFA α1 among pretest, midtest, and posttest between elderly non-fallers and fallers groups in sitting position

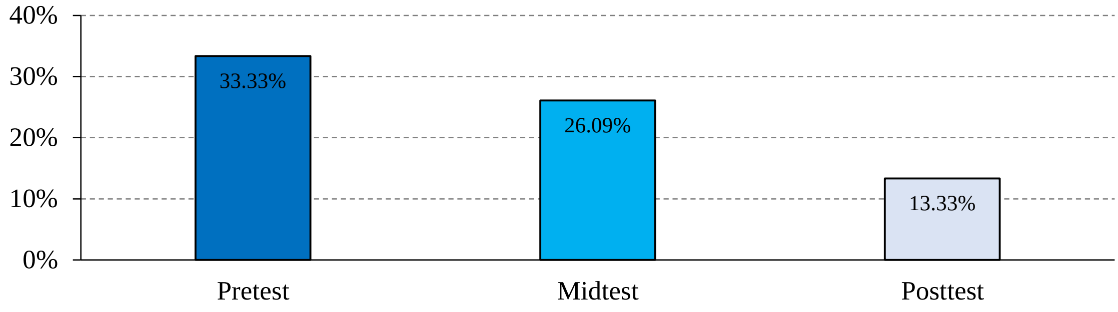


Figure 4.59 DFA α1 in sitting position of elderly fallers group compared to elderly non-fallers group

The differences of DFA α1 in the HRV between the elderly fallers group compared to the elderly non-fallers group were found to be higher at the pretest by 33.33%, higher at the midtest by 26.09%, and higher at the posttest by 13.33% (Figure 4.58 and Figure 4.59).

4.10.2 Discussion

The HRV characteristic differences between the elderly non-fallers group and the elderly fallers group in the sitting position showed considerable improvements in several aspects. Differences were found in ApEn, and DFA α1 at the pretest. And also, Mean RR, and Mean HR at the midtest. Eventually, there no differences were found at the posttest.

This evidence suggested that the differences between the elderly groups in the relaxed sitting position could be found in the nonlinear domain of the HRV prior the EF training. After 4 weeks, the HRV could differentiate the elderly fallers to non-fallers with the time domain in the middle of the training. After 8 weeks, the HRV of the elderly fallers group had an improvement in the same range as the elderly non-fallers group. In the posttest therefore these was found no difference between the elderly groups.

This may be explained by a previous study of age and physical activity on the autonomic control. It indicated that regular physical activity has positive effects on the vagal activity of the heart and consequently attenuates the effects of aging on the autonomic control of HR when it is evaluated by HRV and by RSA indices (213).

The result in the present study related well with previous studies which reported that regular physical activity enhances the HRV evaluation in the time domain for the elderly population (214, 215). Also, a previous study of the relationship between the HRV with daily physical activity in the elderly population indicated that in very old participants a long-term sportive lifestyle, which increases total daily energy expenditure and physical activity intensity, was associated with higher global HRV and vagal-related indexes. Thus may have counteracted the age-related decline in cardiac autonomic control better than a sedentary lifestyle (216).

However, a previous study of exercise HRV in relation to level of physical activity indicated that no significant difference in the resting HRV indexes had been clearly demonstrated between their populations. The effects of the levels of physical activity on HR and HRV were dissociated. Quite a high level of physical training induces resting bradycardia without any changes in HRV indexes. In contrast, during exercise, the assessment of HRV indexes appeared to be more meaningful than at rest. Indeed, a sufficient level of physical training induced a higher sensitivity of sinus node response to exercise stress, which could play a role in thwarting cardiovascular accidents in elderly women (217).

4.11 HRV characteristics between elderly non-fallers and fallers groups in supine position

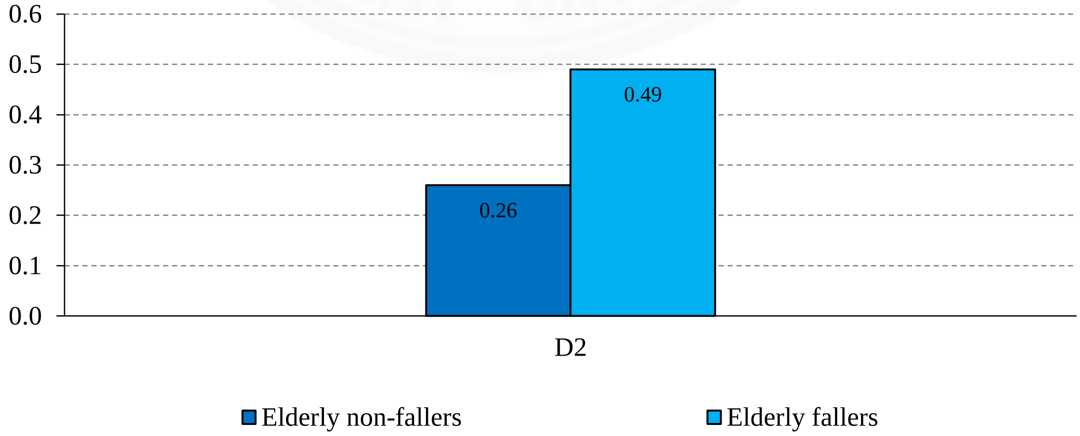


Figure 4.60 HRV characteristics between elderly non-fallers and fallers groups in supine position at pretest

4.11.1 Results

The HRV between the elderly non-fallers group and the elderly fallers group in the supine position at pretest found no significant differences in the time domain, the frequency domain, the nonlinear domain, and PTT. However, the differences between the groups in D2 (*P* = 0.120), Mean RR (*P* = 0.141), and Mean HR (*P* = 0.152), were closely significant (Figure 4.60 and Appendix XXIV).

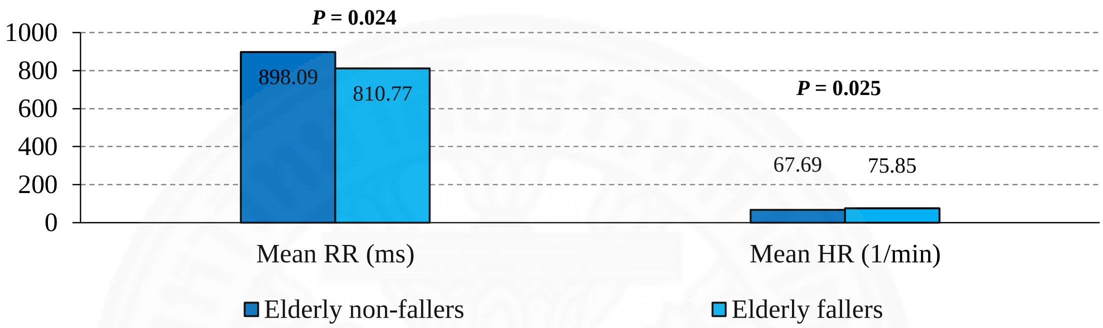


Figure 4.61 HRV characteristics between elderly non-fallers and fallers groups in supine position at midtest

The HRV between the elderly non-fallers group and the elderly fallers group in the supine position at midtest showed significant differences in Mean RR (*P* = 0.024), and Mean HR (*P* = 0.025) as shown in Figure 4.61. In contrast, no significant differences were found between the groups in SDNN, STD HR, RMSSD, NN50, pNN50, RR triangular index, TINN, the frequency domain, the nonlinear domain, and PTT (Appendix XXV).

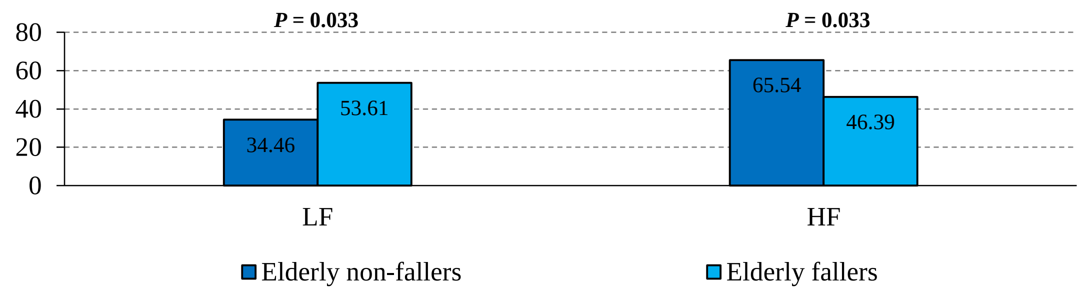


Figure 4.62 HRV characteristics between elderly non-fallers and fallers groups in supine position at posttest

The HRV between the elderly non-fallers group and the elderly fallers group in the supine position at posttest showed significant differences in LF (P = 0.033), and HF (P = 0.033) as shown in Figure 4.62. In contrast, no significant differences were found between the groups in the time domain, LF/HF, the nonlinear domain, and PTT (Appendix XXVI).

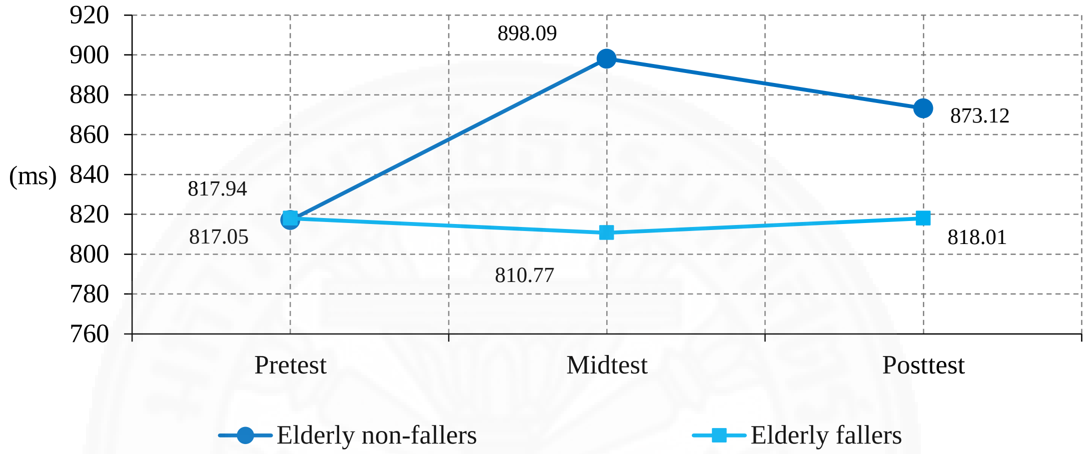


Figure 4.63 Mean RR among pretest, midtest, and posttest between elderly non-fallers and fallers groups in supine position

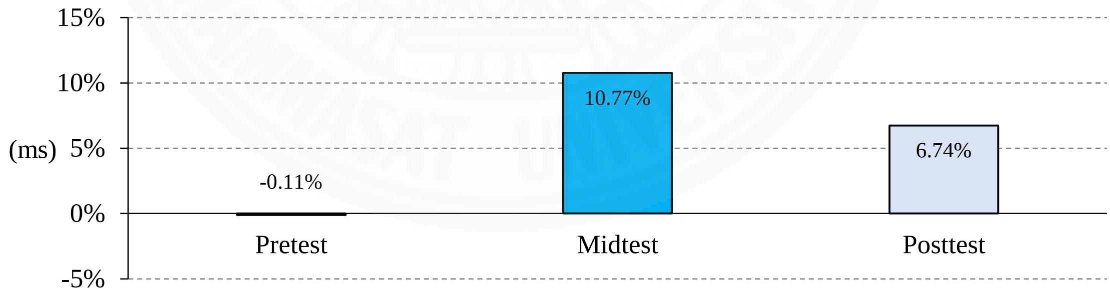


Figure 4.64 Mean RR in supine position of elderly non-fallers group compared to elderly fallers group

The differences of Mean RR in the HRV between the elderly non-fallers group compared to the elderly fallers group were found highest at the midtest 10.77%, higher at the posttest 6.74%, and lower at the pretest 0.11% (Figure 4.63 and Figure 4.64).

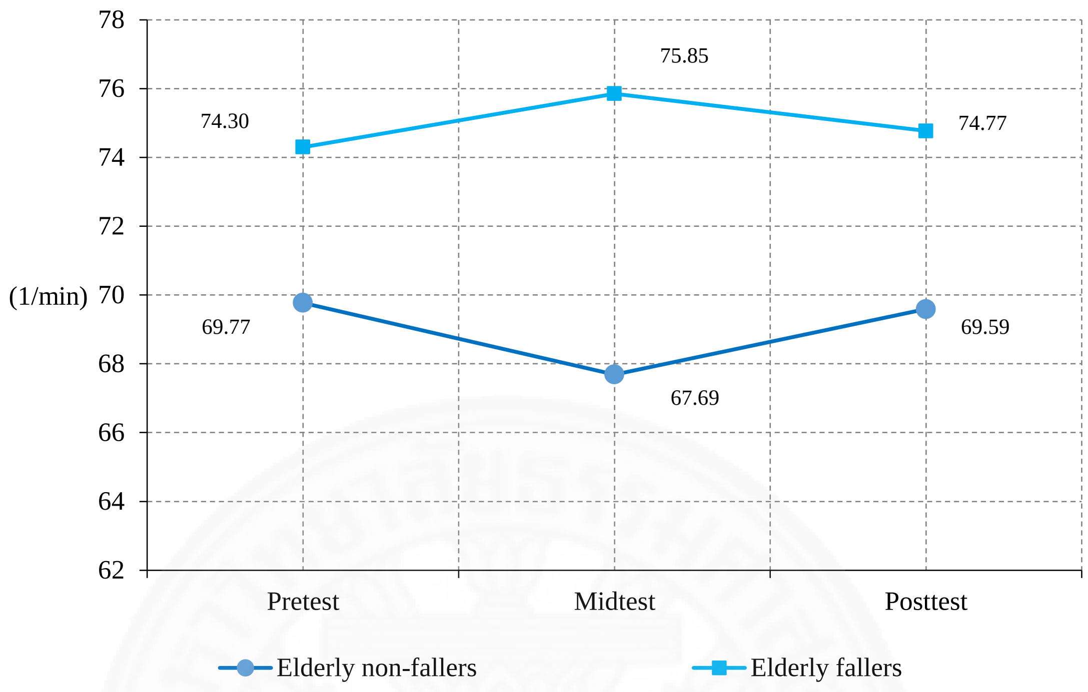


Figure 4.65 Mean HR among pretest, midtest, and posttest between elderly non-fallers and fallers groups in supine position

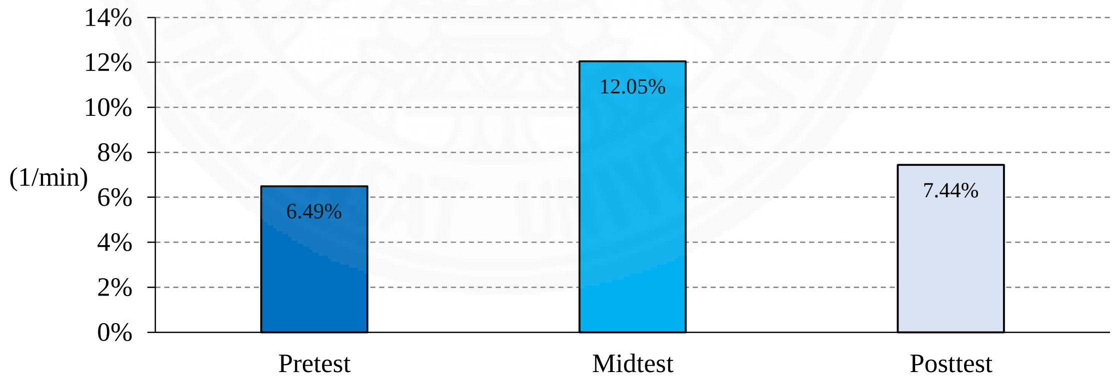


Figure 4.66 Mean HR in supine position of elderly fallers group compared to elderly non-fallers group

The differences of Mean HR in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the midtest 12.05%, higher at the posttest by 7.44%, and higher at the pretest by 6.49% (Figure 4.65 and Figure 4.66).

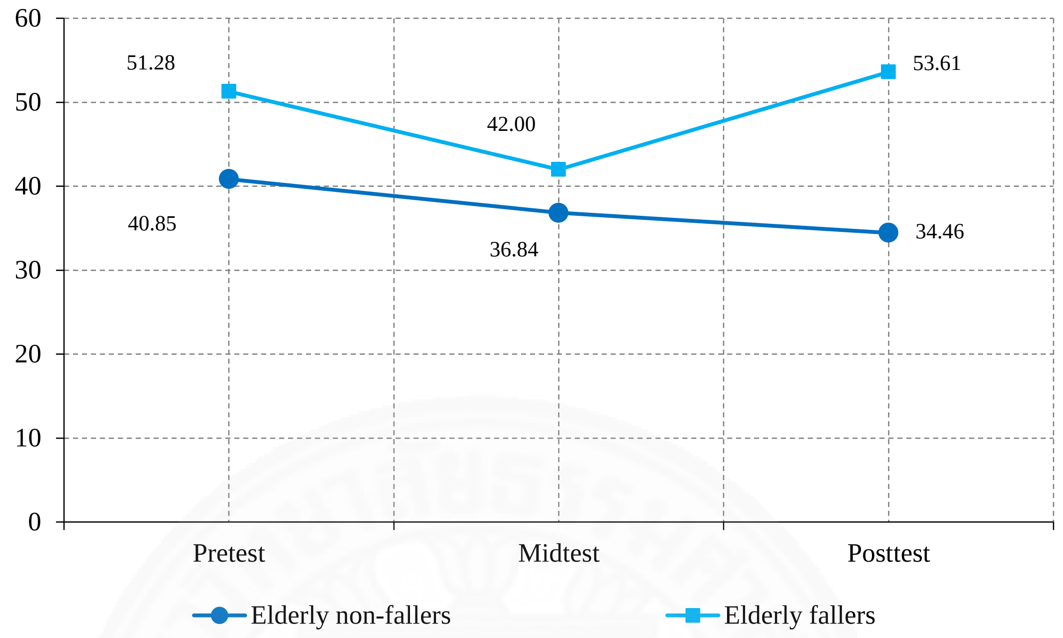


Figure 4.67 LF among pretest, midtest, and posttest between elderly non-fallers and fallers groups in supine position

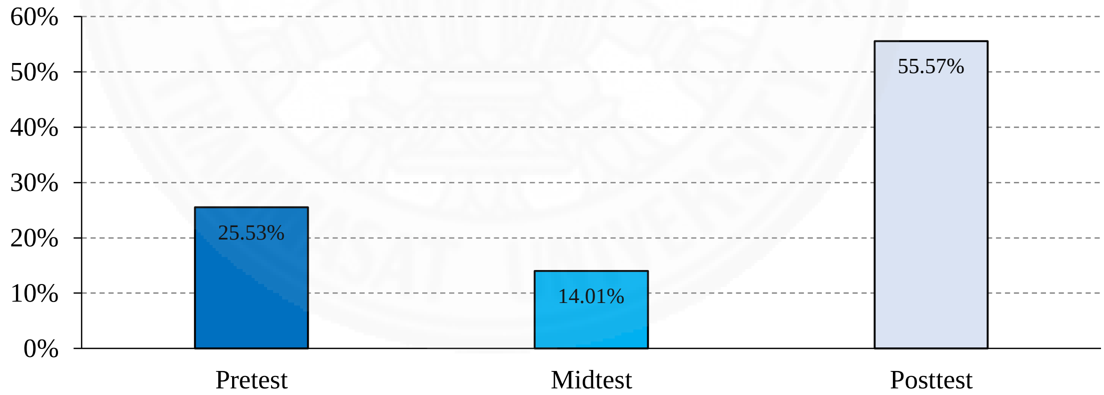


Figure 4.68 LF in supine position of elderly fallers group compared to elderly non-fallers group

The differences of LF in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the posttest by 55.57%, higher at the pretest by 25.53%, and higher at the midtest by 14.01% (Figure 4.67 and Figure 4.68).

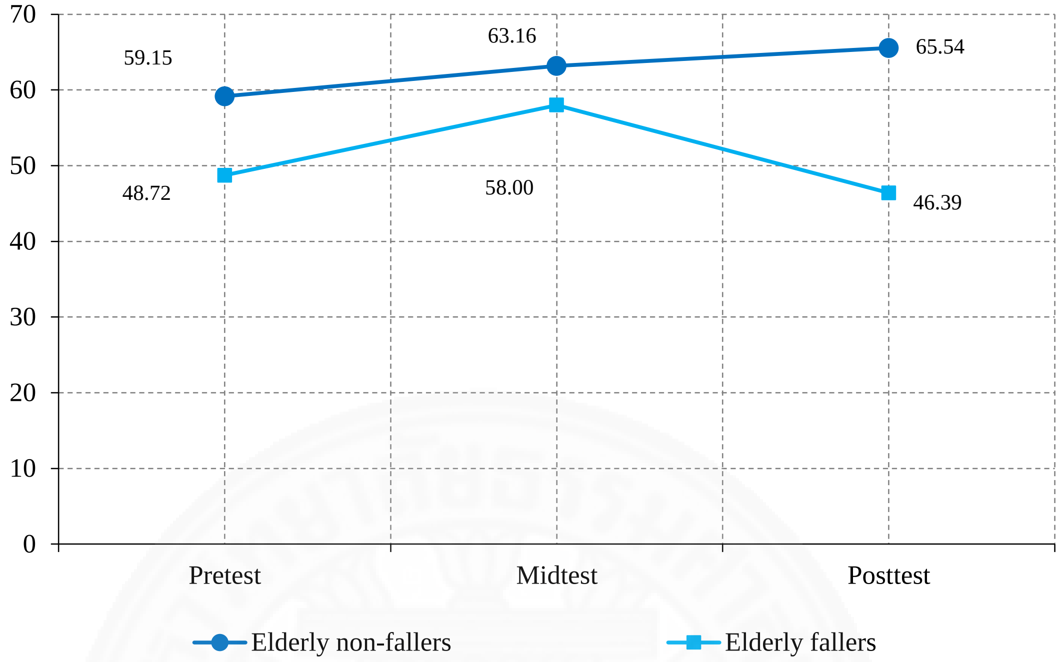


Figure 4.69 HF among pretest, midtest, and posttest between elderly non-fallers and fallers groups in supine position

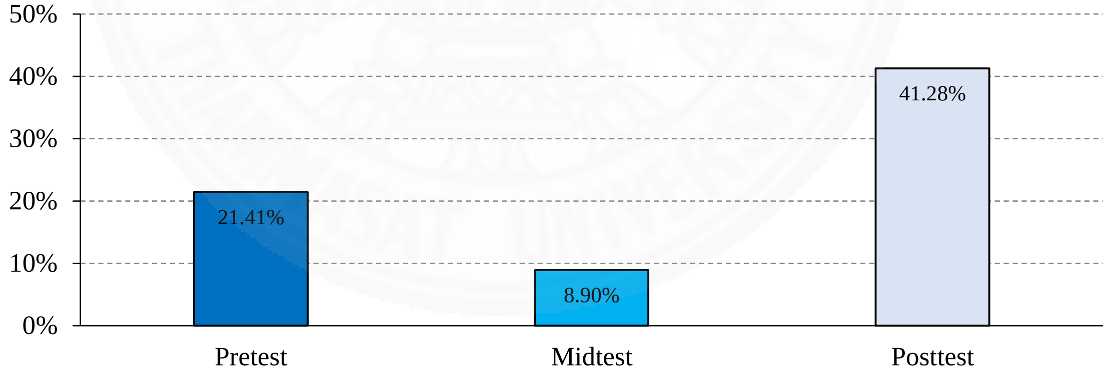


Figure 4.70 HF in supine position of elderly non-fallers group compared to elderly fallers group

The differences of HF in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the posttest by 41.28%, higher at the pretest by 21.41%, and higher at the midtest by 8.90% (Figure 4.69 and Figure 4.70).

4.11.2 Discussion

The HRV characteristic differences between the elderly non-fallers group and the elderly fallers group in the supine position showed considerable improvements in several aspects. There were found to be no differences at the pretest but Mean RR and Mean HR differed at the midtest. And there were also differences in LF, and HF at the posttest.

This evidence suggested that the differences between the elderly groups in the relaxed supine position could not be detected at the baseline. In the middle of the EF training, the time domain in HRV could differentiate between the elderly fallers and non-fallers after 4 weeks. After the training, the difference of HRV changed to be an appearance in the frequency domain at week 8.

Resting HRV is a measure of the modulation of ANS at rest (218). The elderly participants in the present study may have a similarity of the modulation of ANS at the pretest. Thus, the result found no differences between the groups in the HRV measurement. The HRV showed that the time domain could detect differences only after 4 weeks of training. This may be explained by the elderly participants' effectiveness at the training.

During week 1-4 of the training, the elderly non-fallers group gained an improvement over the elderly fallers group in the total time spent with the Stroop test in the mean value of 0.25%, and the number of correct answers with the Stroop test in the mean value of 0.21%. Moreover, the better juggling performances of the elderly non-fallers group were also higher than the elderly fallers group in the mean value of 32.85%. The result of the midtest may be influenced by the training effects of the HRV result.

In a similar way, the training’s improvement of the elderly non-fallers group kept on gaining over the elderly fallers group. During week 5-8, by the mean value of 0.34% in the total time spent with the Stroop test and the mean value of 0.32% in the number of correct answers with the Stroop test. In addition, with almost two-and-a-half-fold increase from the previous weeks in the juggling performances. The elderly non-fallers group compared to the elderly fallers group showed a 79.31% increase of the mean value in the juggling task. The result of the posttest may be influenced by the training effects to the HRV result. Therefore, between the midtest to the posttest the differences found between the groups could be caused by the effectiveness of the elderly groups in the EF training.

4.12 HRV characteristics between elderly non-fallers and fallers groups in standing position

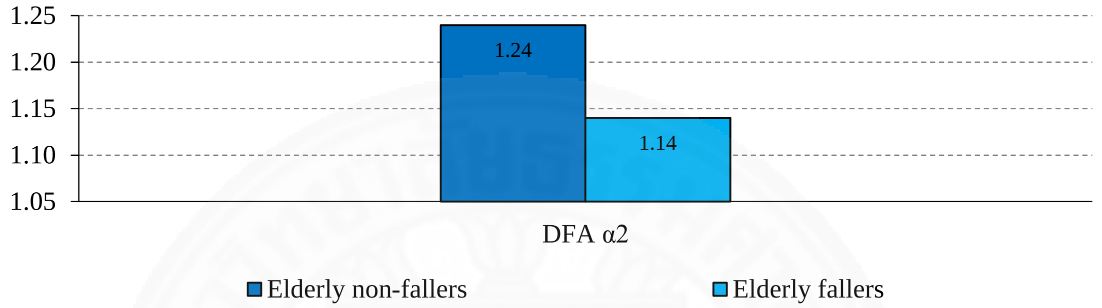


Figure 4.71 HRV characteristics between elderly non-fallers and fallers groups in standing position at pretest

4.12.1 Results

The HRV between the elderly non-fallers group and the elderly fallers group in the standing position at pretest found no significant differences in the time domain, the frequency domain, the nonlinear domain, and PTT. However, the difference between the groups in DFA α2 (P = 0.278) was closely significant (Figure 4.71 and Appendix XXVII).

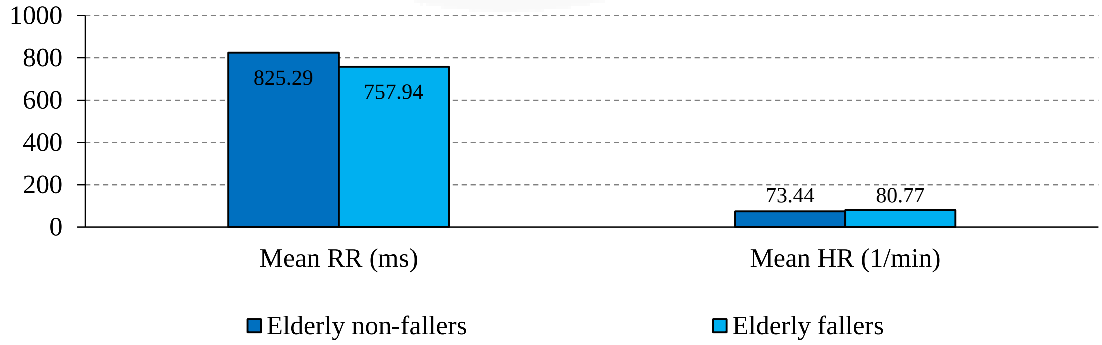


Figure 4.72 HRV characteristics between elderly non-fallers and fallers groups in standing position at midtest

The HRV between the elderly non-fallers group and the elderly fallers group in the standing position at midtest found no significant difference in the time domain, the frequency domain, the nonlinear domain, and PTT. Interestingly, the differences between the groups in Mean HR (*P* = 0.051), and Mean RR (*P* = 0.059) were borderline significant (Figure 4.72 and Appendix XXVIII).

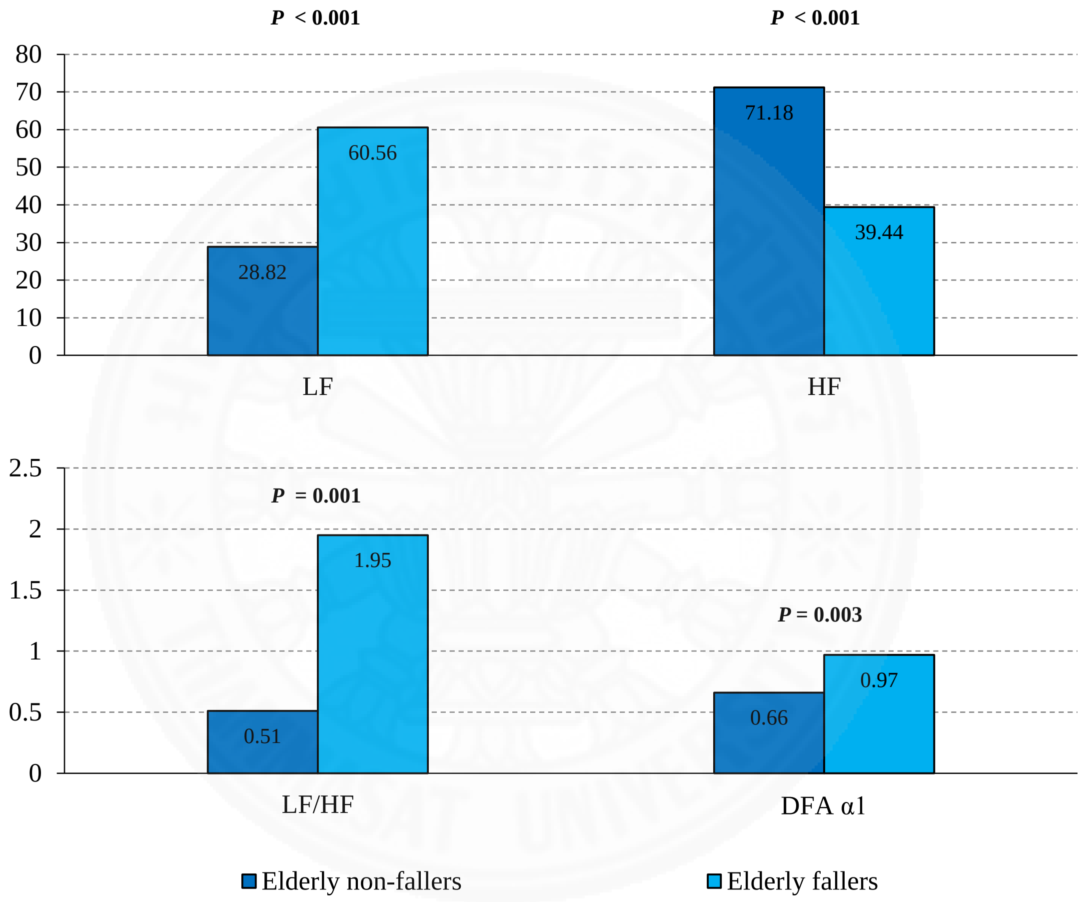


Figure 4.73 HRV characteristics between elderly non-fallers and fallers groups in standing position at posttest

The HRV between the elderly non-fallers group and the elderly fallers group in the standing position at posttest showed significant differences in LF (*P* = < 0.001), HF (*P* = < 0.001), LF/HF (*P* = 0.001), and DFA α1 (*P* = 0.003). In contrast, no significant differences were found between the groups in the time domain, ApEn, SampEn, DFA α2, D2, and PTT (Figure 4.73 and Appendix XXIX).

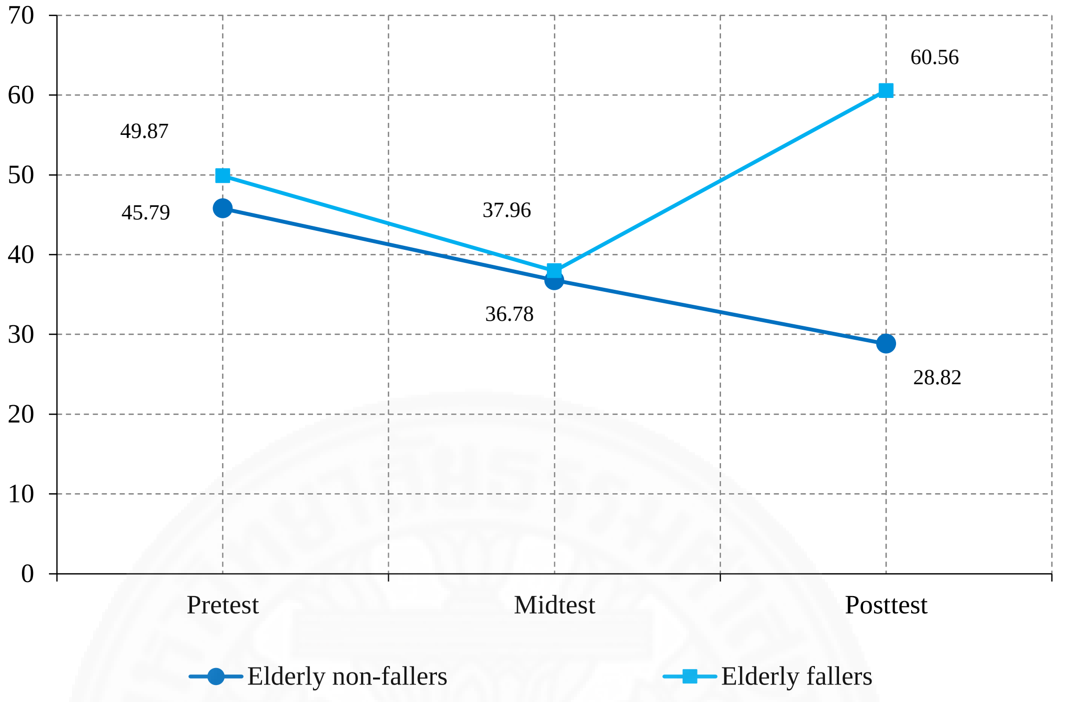


Figure 4.74 LF among pretest, midtest, and posttest between elderly non-fallers and fallers groups in standing position

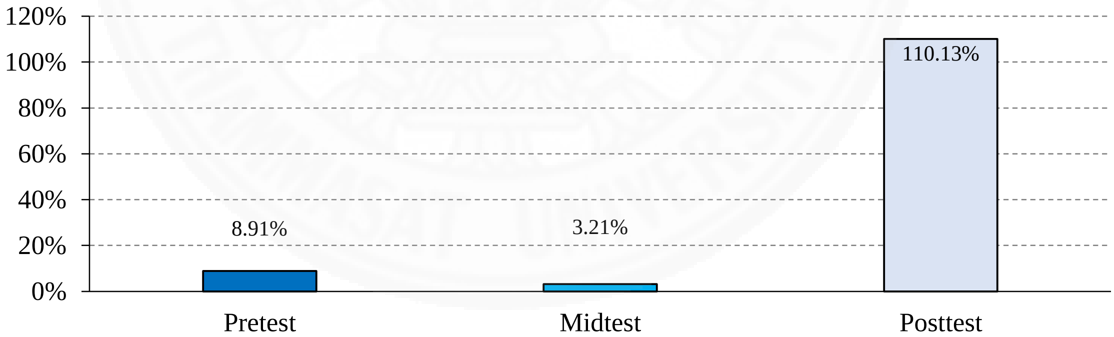


Figure 4.75 LF in standing position of elderly fallers group compared to elderly non-fallers group

The differences of LF in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the posttest by 110.13%, higher at the pretest by 8.91%, and higher at the midtest by 3.21% (Figure 4.74 and Figure 4.75).

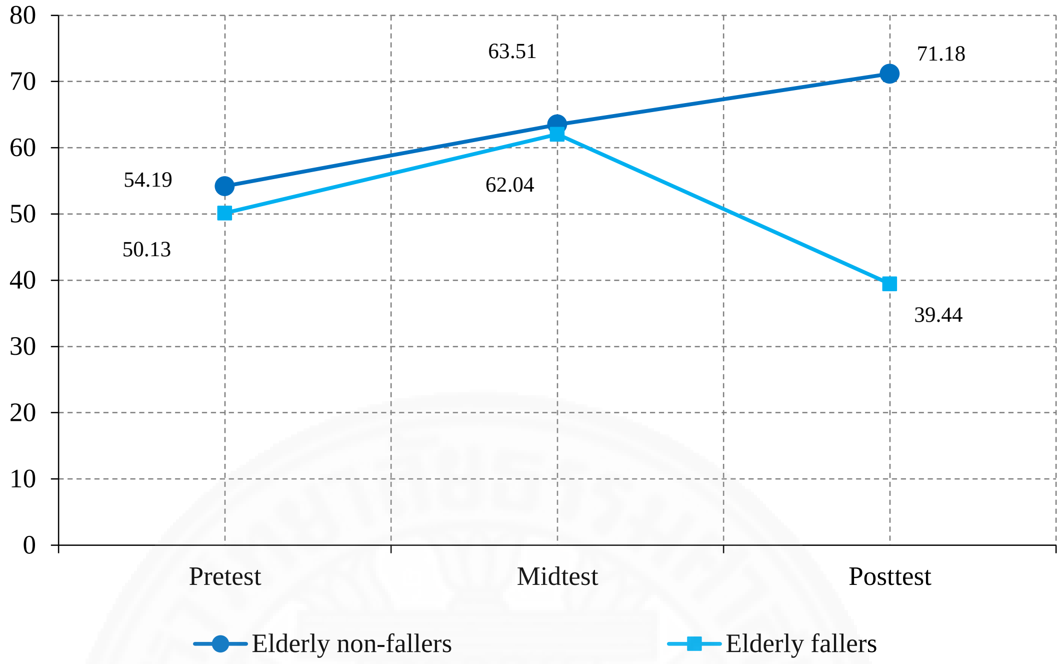


Figure 4.76 HF among pretest, midtest, and posttest between elderly non-fallers and fallers groups in standing position

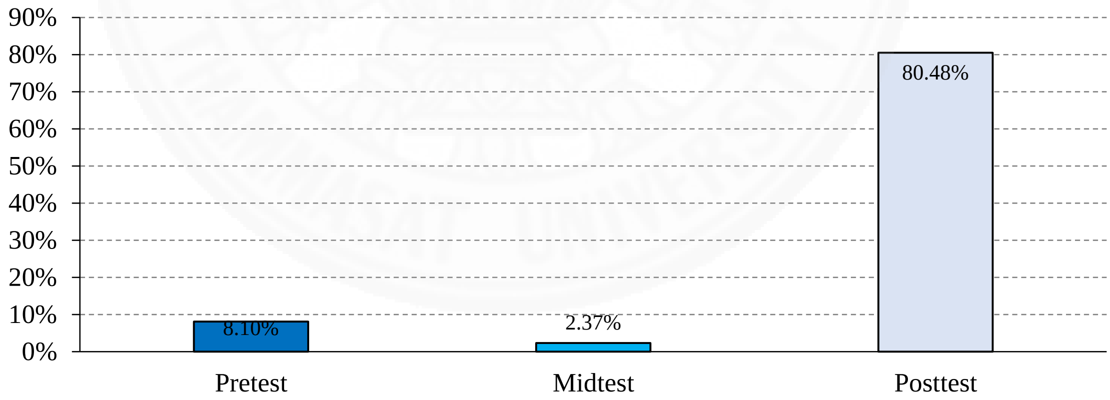


Figure 4.77 HF in standing position of elderly non-fallers group compared to elderly fallers group

The differences of HF in the HRV between the elderly non-fallers group compared to the elderly fallers group were found higher at the posttest by 80.48%, higher at the pretest by 8.10%, and higher at the midtest by 2.37% (Figure 4.76 and Figure 4.77).

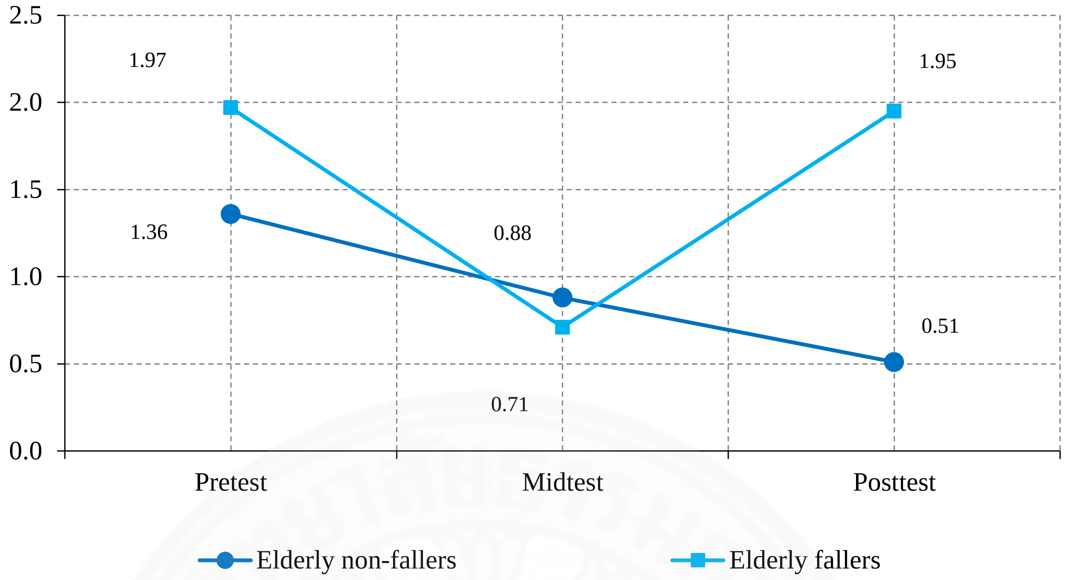


Figure 4.78 LF/HF among pretest, midtest, and posttest between elderly non-fallers and fallers groups in standing position

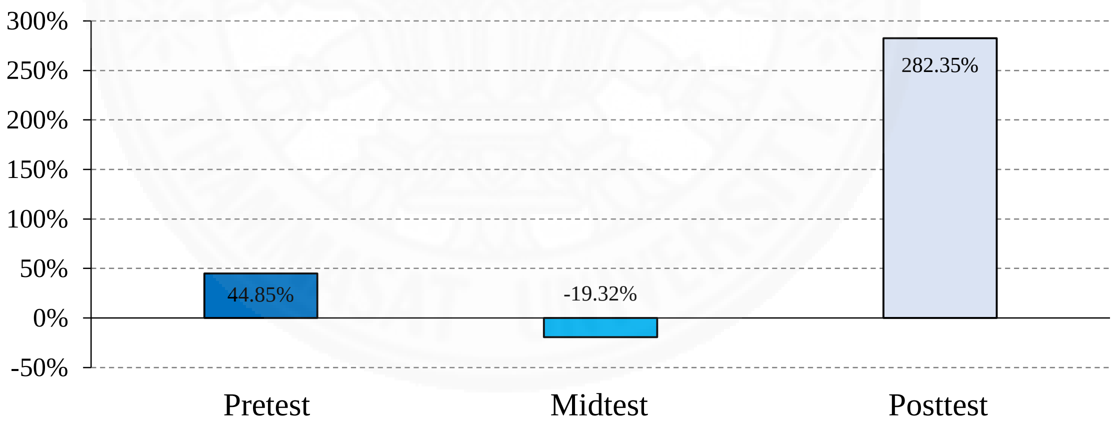


Figure 4.79 LF/HF in standing position of elderly fallers group compared to elderly non-fallers group

The differences of LF/HF in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the posttest by 282.35%, higher at the pretest by 44.85%, and lower at the midtest by 19.32% (Figure 4.78 and Figure 4.79).

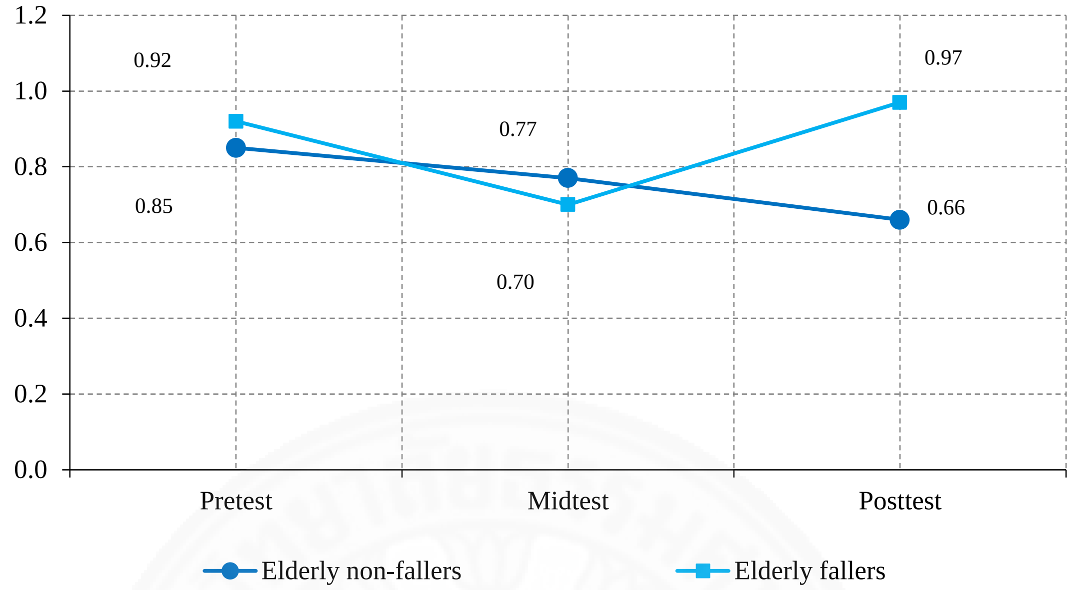


Figure 4.80 DFA α1 among pretest, midtest, and posttest between elderly non-fallers and fallers groups in standing position

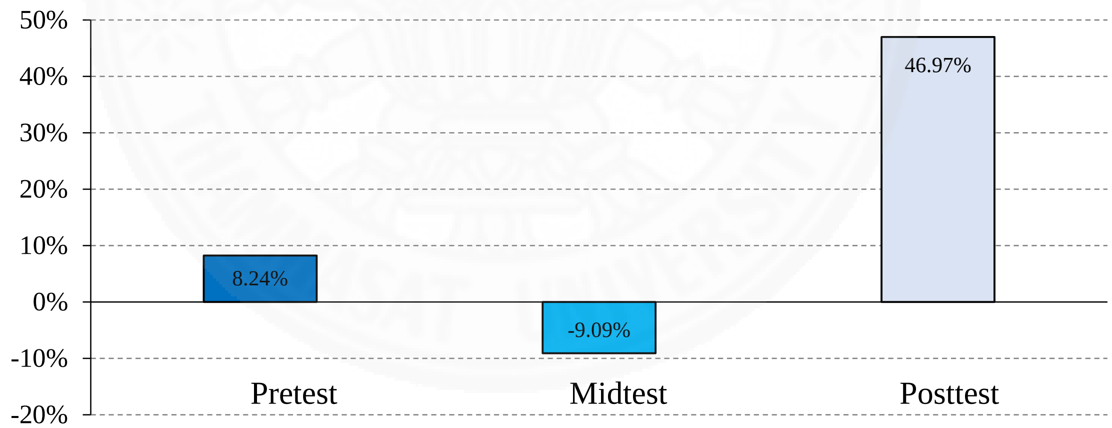


Figure 4.81 DFA α1 in standing position of elderly fallers group compared to elderly non-fallers group

The differences of DFA α1 in the HRV between the elderly fallers group compared to the elderly non-fallers group were found higher at the posttest by 46.97%, higher at the pretest by 8.24%, and lower at the midtest by 9.09% (Figure 4.80 and Figure 4.81).

4.12.2 Discussion

The HRV characteristic differences between the elderly fallers group and the elderly non-fallers group from the supine position to the standing position showed considerable improvements in several aspects. There were found to be no differences during the pretest to the midtest but differences were found in the LF, HF, LF/HF, and DFA α1 at the posttest.

This evidence suggested that in the standing position, the HRV could not differentiate between the elderly fallers to non-fallers. After the training at posttest, the differences of the HRV were mostly found in the frequency domain and the nonlinear domain.

The results in the present study may be explained by the effectiveness of the training of the elderly participants as well as the HRV in the supine position. During week 1-8 of the training, the elderly non-fallers group gained improvement over the elderly fallers group along the way in the total time spent with the Stroop test from 0.14% to 0.39%, and the number of correct answers with the Stroop test from 0.13% to 0.36%. And also, the better juggling performances of the elderly non-fallers group more than the elderly fallers group raised from 27.88% to 124.08%. The HRV's result at the posttest could be influenced by the high improvement due to the training.

Previous studies suggested that during the supine rest, heart rate and blood pressure are lower as the body is in a relaxed state. From supine to standing, a state of high parasympathetic activity and low sympathetic activity, there is a shift in sympathovagal balance characterized by a withdrawal of parasympathetic activity and a concomitant increase in sympathetic activity. Naturally, the body needs to accommodate for postural change forcing the heart to beat harder and faster to pump blood to the brain; a task much less strenuous in the horizontal position (219, 220).

In addition, the HRV is susceptible to saturation when measured at low HR (221). Saturated HF power, expressed as a plateau regardless of the lengthening of the R–R interval, is a common phenomenon among healthy participants (222). Thus, HF power, when measured at low HR level, may be unable to detect changes in cardiac vagal outflow in training intervention studies (223). Additionally, vagal and sympathetic regulation operates in reciprocal fashion during sympathetic orthostatic stimulus (220). Therefore, standing position might be a practical condition to measure cardiac autonomic function since it could detect attenuated vagal outflow related to increased sympathetic activity, as well. Possibly for these reasons, changes in athletic performance have shown to associate to changes in HRV during orthostatic stress rather than at supine rest (224).

A previous study result indicated that endurance training increased HF power measured at standing position but did not change HF power measured at sitting position (225). This supported the notion of the present study that orthostatic stimulus may be a more favorable condition than sitting or supine positions to obtain specific information on the status of cardiac autonomic regulation in exercise intervention settings among relatively healthy participants.

On another aspect, differences of the HRV between the elderly non-fallers group and the elderly fallers group had been found at the pretest in ApEn and DFA α1 in the sitting position. At the midtest they had been found in Mean RR and Mean HR in the sitting and the supine positions. At the posttest differences had been found in LF and HF in the supine position, and LF, HF, LF/HF, and DFA α1 in the standing position.

Overall, the nonlinear domain in the HRV played an important role in differentiating the elderly fallers from non-fallers in the sitting position at pretest. Meanwhile, the time domain in the HRV emerged as a major index in the sitting and the standing positions at the midtest. And the frequency domain in the HRV was seen as a key indicator in the supine and the standing positions at the posttest.

This evidence suggested that each position appeared to provide different indices regarding the testing statuses. The interpretation of the HRV in the present study required to use the time, the frequency, and the nonlinear domains. A previous study suggested using nonlinear indices when relating HR dynamics to cognition as a biomarker of the integrated functioning of the brain. It was concluded that nonlinear rather than linear methods of summarizing the HR times series offered a way of relating brain functioning (226). However, the nonlinear domain could not be found in either the supine position or the midtest in the present study. This might have originated from the relatively small number of the participants which was well related to the limitation of the use of the HRV in a previous study. It also concluded that aging was a significant factor affecting cardiovascular dynamics in healthy individuals, and that gender sometimes produced significant difference as well (227).

4.13 HRV characteristics among pretest, midtest, and posttest of all elderly participants

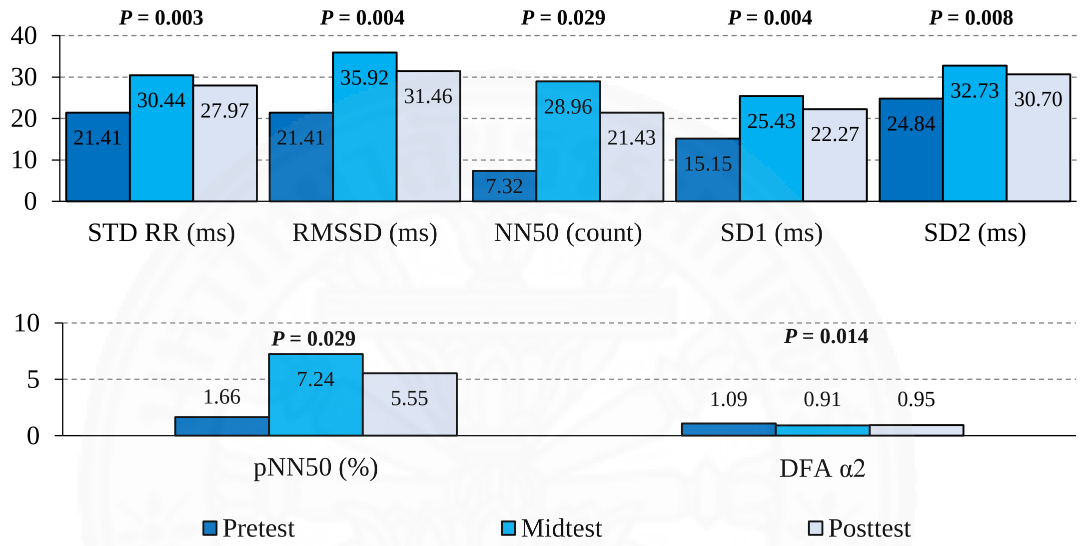


Figure 4.82 HRV characteristics among pretest, midtest, and posttest of all elderly participants in sitting position

4.13.1 Results

The HRV in the sitting position of all the elderly participant group revealed significant differences among the pretest, midtest, and posttest in STD RR (P = 0.003), RMSSD and SD1 (P = 0.004), SD2 (P = 0.008), DFA α2 (P = 0.014), NN50 and pNN50 (P = 0.029) as shown in Figure 4.82. In pairwise comparison, there were significant differences between the tests in STD RR at the pretest and the midtest (a; P = 0.006), RMSSD at the pretest and the midtest (b; P = 0.008), SD1 at the pretest and the midtest (g; P = 0.008), SD2 at the pretest and the midtest (h; P = 0.010), DFA α2 at the pretest and the posttest (j; P = 0.023), NN50 at the pretest and the midtest (c; P = 0.026), pNN50 at the pretest and the midtest (e; P = 0.026), DFA α2 at the pretest and the midtest (i; P = 0.027), pNN50 at the pretest and the posttest (f; P = 0.034), and NN50 at the pretest and the posttest (d; P = 0.037).

In contrast, no significant differences were found among the tests in Mean RR, Mean HR, STD HR, RR triangular index, TINN, the frequency domain, SD2/SD1, Lmean, Lmax, REC, DET, ShanEn, ApEn, SampEn, DFA α1, D2 and PTT (Appendix XXX).

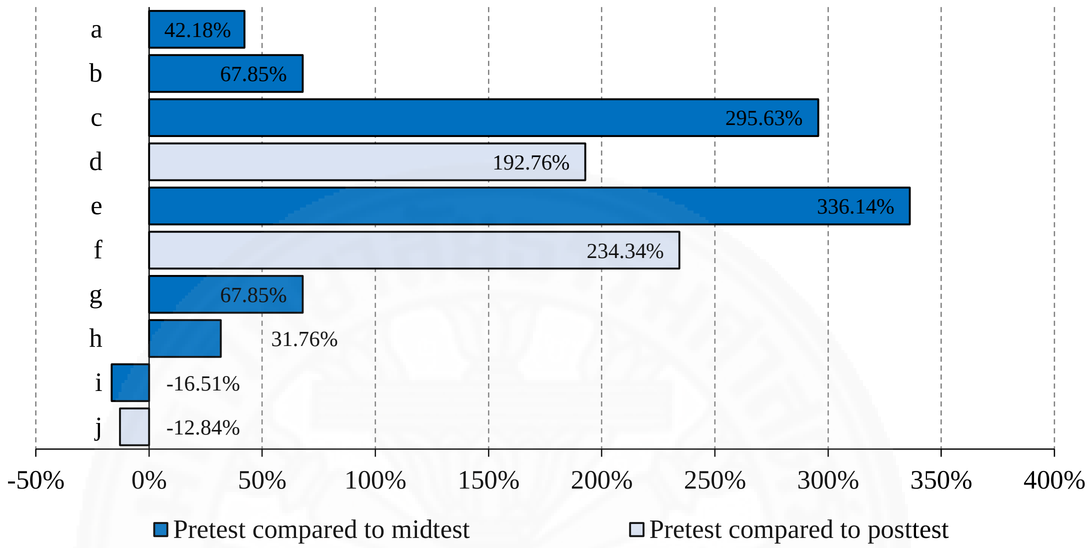


Figure 4.83 Improvement of all elderly participants in sitting position

The change in pairwise comparison of all the elderly participants HRV in the sitting position showed considerable improvements in several aspects. pNN50 (e) increased by 336.14%, NN50 (c) increased by 295.63%, pNN50 (f) increased by 234.34%, NN50 (d) increased by 192.76%, RMSSD (b) increased by 67.85%, SD1 (g) increased by 67.85%, STD RR (a) increased by 42.18%, SD2 (h) increased by 31.76%, DFA α2 (i) dropped by 16.51%, and DFA α2 (j) dropped by 12.84% (Figure 4.83).

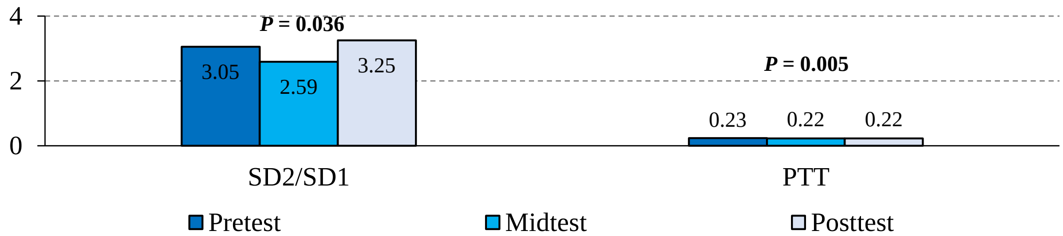


Figure 4.84 HRV characteristics among pretest, midtest, and posttest of all elderly participants in the supine position

The HRV in the supine position of all the elderly participants revealed significant differences among the pretest, midtest, and posttest in PTT (*P* = 0.005), and SD2/SD1 (*P* = 0.036) as shown in Figure 4.84. In pairwise comparison, there were significant differences between the tests in PTT at the pretest and the posttest (*P* = 0.003), and SD2/SD1 at the midtest and the posttest (*P* = 0.046). In contrast, no significant differences were found among the tests in the time domain, the frequency domain, SD1, SD2, Lmean, Lmax, REC, DET, ShanEn, ApEn, SampEn, DFA α1, DFA α2, and D2 (Appendix XXXI).

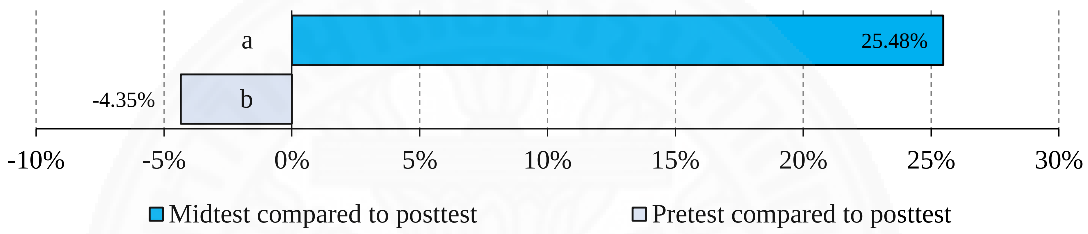


Figure 4.85 Improvement of all elderly participants in supine position

The change in pairwise comparison of all the elderly participants HRV in the supine position showed considerable improvements in several aspects. SD2/SD1 (a) increased 25.48%, and PTT (b) dropped 4.35% (Figure 4.85).

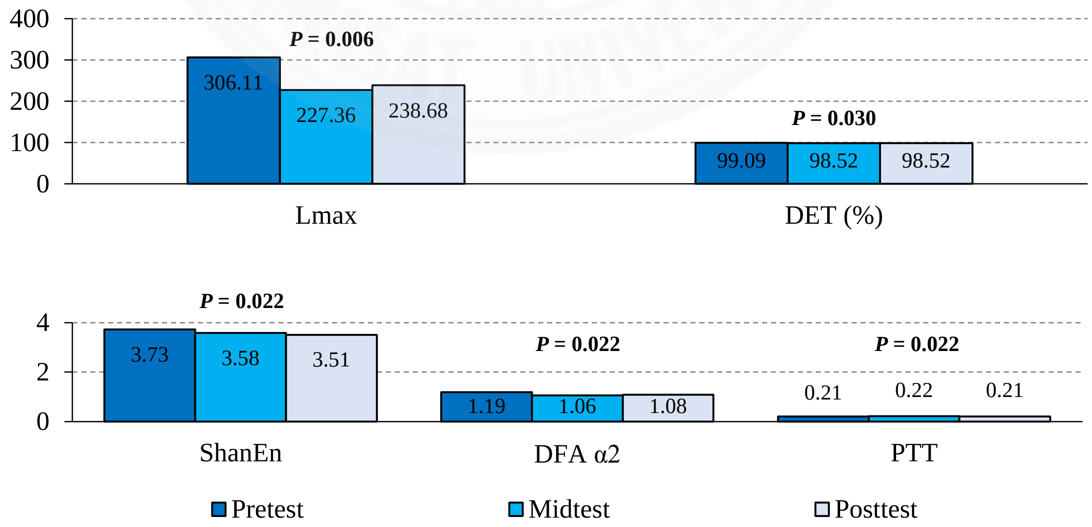


Figure 4.86 HRV characteristics among pretest, midtest, and posttest of all elderly participants in standing position

The HRV in the standing position of all the elderly participant group revealed significant differences among the pretest, midtest, and posttest in Lmax (P = 0.006), ShanEn (P = 0.022), DFA α2 (P = 0.022), PTT (P = 0.022), and DET (P = 0.030) as shown in Figure 4.86. In pairwise comparison, there were significant differences between the tests in Lmax at the pretest and the midtest (P = 0.022), ShanEn at the pretest and the posttest (P = 0.022), Lmax at the pretest and the posttest (P = 0.024), and DFA α2 at the pretest and the midtest (P = 0.032). In contrast, no significant differences were found among the tests in the time domain, the frequency domain, SD1, SD2, SD2/SD1, Lmean, REC, ApEn, SampEn, DFA α1, and D2 (Appendix XXXII).

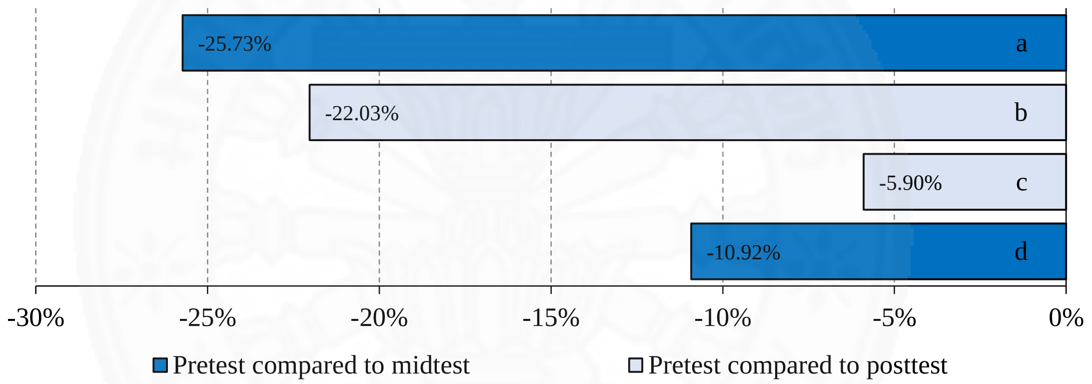


Figure 4.87 Improvement of all elderly participants in standing position

The change in pairwise comparison of all the elderly participants HRV in the standing position showed considerable improvements in several aspects. Lmax (a) dropped 25.73%, Lmax (b) dropped 22.03%, DFA α2 (d) dropped 10.92%, ShanEn (c) dropped 5.90% (Figure 4.87).

4.13.2 Discussion

The HRV of the combined elderly participants group among the pretest, the midtest, and the post showed considerable developments in several aspects. Differences were found in STD RR, RMSSD, NN50, pNN50, SD1, SD2, and DFA α2 in the sitting position. In SD2/SD1, and PTT differences were found in the supine position. And also, in Lmax, DET, ShanEn, DFA α2, and PTT they had been found in the standing position.

The results indicated that the change to HRV of the combined elderly participants group throughout the tests could be found in the time domain, the frequency domain, and the nonlinear domain of the HRV in the relaxed sitting position. Changes in the frequency domain and PTT of the HRV had been detected in the supine position. In the standing position, it was the nonlinear domain, and PTT of the HRV where change appeared.

The HRV of the combined elderly participants group revealed differences in each position but no domain was found stable in all the positions. Two indices of the HRV were found in 2 positions. DFA α2 was found in the sitting position, and in the standing position. Meanwhile, PTT was found in the supine position and the standing position. In pairwise comparison, DFA α2 in the sitting position dropped by 0.17% from the pretest to the midtest and 0.13% from the pretest to the posttest, in the standing it was 0.11% from the pretest to the midtest. PTT in the supine position dropped 0.04% from the pretest to the posttest. Thus, this evidence suggested that the EF training had attentively effect on the HRV of all the elderly participants in DFA α2 during the pretest to the midtest in the sitting and standing positions.

Previous studies suggested that DFA α value was reported to be dependent on variation in factors such as body posture, age, physical activity level, gender and needed at least 20 minutes recording in the elderly population (228). DFA α2 describes long-term correlated fluctuations which reflect the regulatory mechanisms that limit fluctuation of the beat cycle (229). DFA α2 related to the powers in the very low frequency (VLF) band (or VLF/LF ratios) (230). The VLF band is strongly correlated with the SDNN index in the time domain index. There is uncertainty regarding the physiological mechanisms responsible for activity within this band. VLF power may be generated by physical activity. PNS activity may contribute to VLF power because parasympathetic blockade almost completely abolishes it (94).

The changes of DFA α2 in the present study may be generated by the physical activity of the training via the link with VLF. This related well to the results of a previous study of 6 months' regular physical activity in elderly participants which showed that the HRV had been increased, specifically in the VLF, LF (231).

4.14 HRV characteristics among pretest, midtest, and posttest of elderly non-fallers

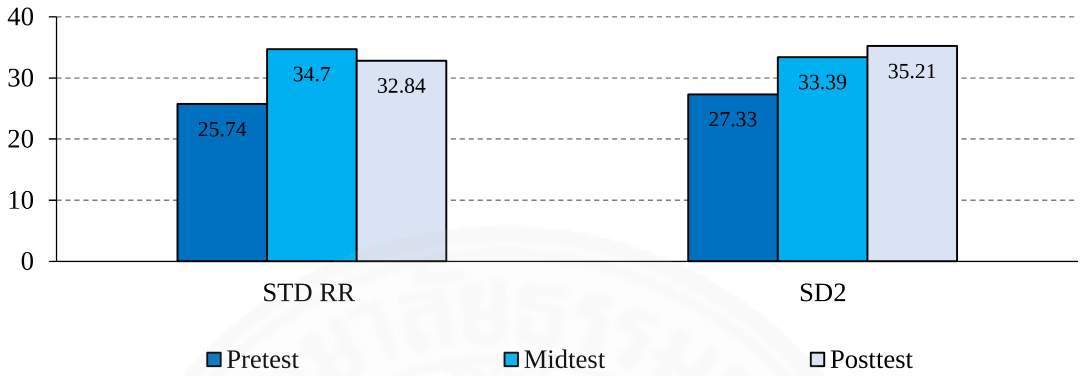


Figure 4.88 HRV characteristics among pretest, midtest, and posttest of elderly non-fallers in standing position

4.14.1 Results

No significant differences in the HRV in the sitting position of the elderly non-fallers group was found among the pretest, midtest, and posttest in the time domain, the frequency domain, the nonlinear domain, and PTT. However, the differences among the tests in STD RR (P = 0.067), and SD2 (P = 0.066) were closely significant (Figure 4.88 and Appendix XXXIII).

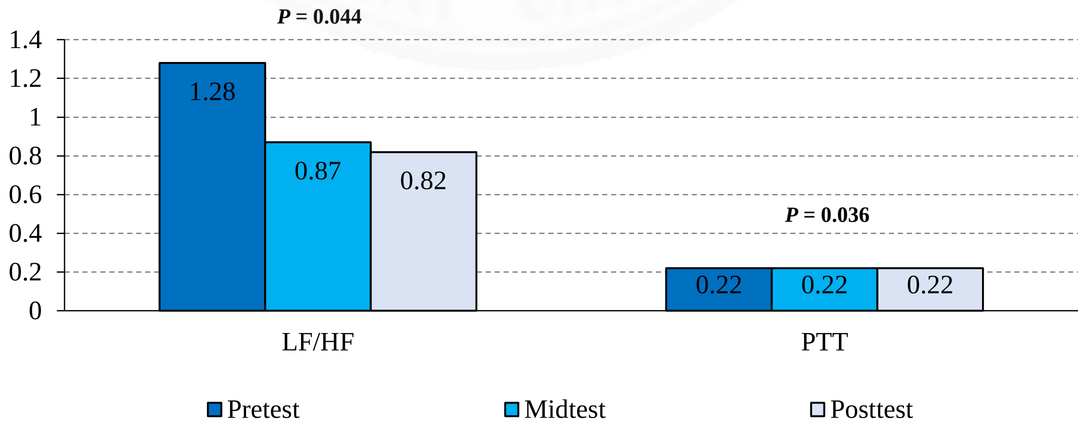


Figure 4.89 HRV characteristics among pretest, midtest, and posttest of elderly non-fallers in supine position

HRV in the supine position of the elderly non-fallers group showed significant differences among the pretest, midtest, and posttest in PTT (*P* = 0.036), and LF/HF (*P* = 0.044) as shown in Figure 4.89. In pairwise comparison, there was significant difference between the tests in PTT at the pretest and the posttest (*P* = 0.045). In contrast, no significant differences were found among the tests in the time domain, LF, HF, ApEn, SampEn, DFA α1, DFA α2, and D2. However, the change in pairwise comparison of the elderly non-fallers' HRV in the supine position showed no improvement in the PTT index (Appendix XXXIV).

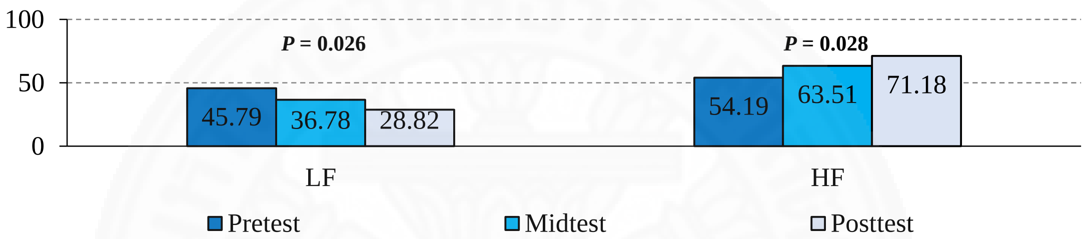


Figure 4.90 HRV characteristics among pretest, midtest, and posttest of elderly non-fallers in standing position

The HRV in the standing position of the elderly non-fallers group showed significant differences among the pretest, midtest, and posttest in LF (*P* = 0.026), and HF (*P* = 0.028) as shown in Figure 4.90. In pairwise comparison, there were significant differences between the tests in LF and HF at the pretest and the posttest (*P* = 0.021). In contrast, no significant differences were found among the tests in the time domain, LF/HF, the nonlinear domain, and PTT. Interestingly, the differences among the tests in LF/HF and DFA α2 (*P* = 0.057) were borderline significant (Appendix XXXV).

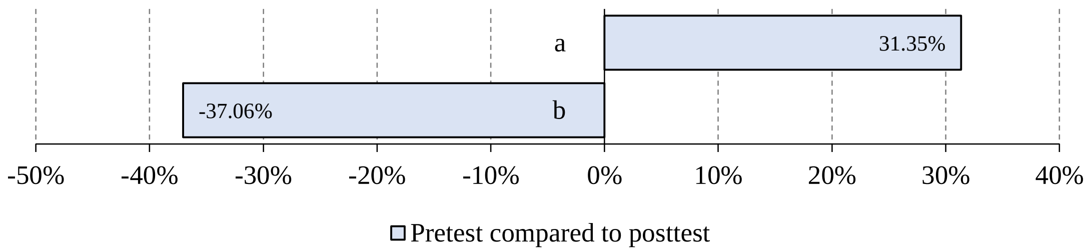


Figure 4.91 Improvement of elderly non-fallers in standing position

The change in pairwise comparison of the elderly non-fallers HRV in the standing position showed considerable improvements in aspects. LF (a) dropped 37.06%, and HF (b) increased 31.35% (Figure 4.91).

4.14.2 Discussion

The HRV of the elderly non-fallers group among the pretest, the midtest, and the post showed considerable developments in some aspects. No differences were found in the sitting position. Differences were found in LF/HF and PTT in the supine position, and in LF and HF were found in the standing position.

The ratio of LF to HF power (LF/HF ratio) is that both PNS and SNS activity contributes to LF power and that PNS activity primarily contributes to HF power. The intent was to estimate the ratio between SNS and PNS activity. The assumptions underlying the LF/HF ratio is that LF power may be generated by the SNS while HF power is produced by the PNS (229). From the pretest to the posttest, LF/HF dropped 0.36% in the supine position, LF dropped 0.37% and HF increased by 0.31% in the standing position. These HRV developments could be influenced by the increased improvement from the training. This suggests that the elderly non-fallers group experienced enhancement of PNS activity which is a part of the ANS functions.

PTT measurements have been used previously to infer changes in autonomic activity and arterial pressure (232). A previous study showed that PTT was only found to change significantly in a tilting position (233). This differed with the results of the present study, that PTT changed in the supine position rather than the standing position. Thus, it may be explained by the influence of the EF training that improves PTT, not the position changes.

Overall, the results indicated that the changes in HRV of the elderly non-fallers group among the tests could be found in the frequency domain and PTT of the HRV in the relaxed sitting position. The frequency domain of HRV had been detected in the standing position as well. It could be seen that the frequency domain of the HRV played an important role in the elderly non-fallers group, especially in the sitting and the standing positions. This was related well to previous studies of HRV and physical exercise that resulted positively, mainly with the frequency domain of the HRV (216, 234).

4.15 HRV characteristics among pretest, midtest, and posttest of elderly fallers

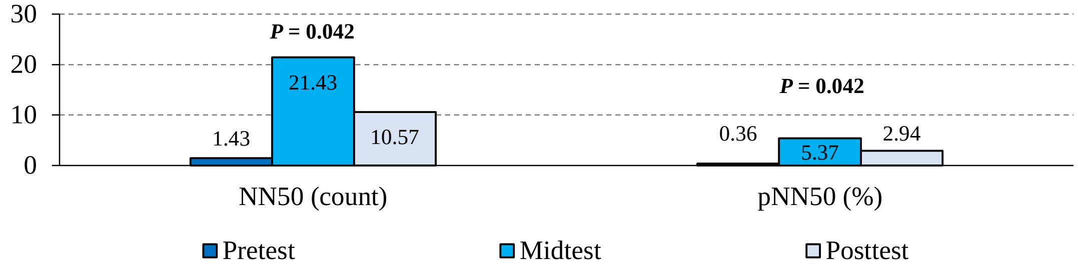


Figure 4.92 HRV characteristics among pretest, midtest, and posttest of elderly fallers in sitting position

4.15.1 Results

The HRV in the sitting position of the elderly fallers group showed significant differences among the pretest, midtest, and posttest in NN50 (P = 0.042), and pNN50 (P = 0.043) as shown in Figure 4.92. In pairwise comparison, there were significant differences between the tests in pNN50 at the pretest and the midtest (P = 0.033), and NN50 at the pretest and the midtest (P = 0.034). In contrast, no significant differences were found among the tests in Mean RR, SDNN, Mean HR, STD HR, RMSSD, RR triangular index, TINN, the frequency domain, the nonlinear domain, and PTT. Interestingly, the differences among the tests in RMSSD and SD1 (P = 0.057) were borderline significant (Appendix XXXVI).

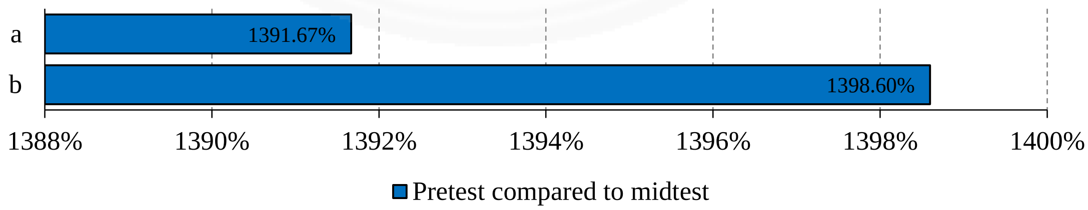


Figure 4.93 Improvement of elderly fallers in sitting position

The change in pairwise comparison of the elderly fallers HRV in the sitting position showed considerable improvements in certain aspects. NM50 (a) increased 1,398.60%, and pNN50 (b) increased 1,391.67% (Figure 4.93).

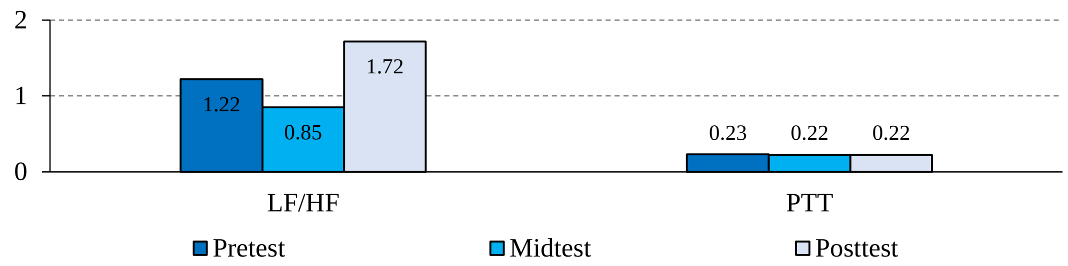


Figure 4.94 HRV characteristics among pretest, midtest, and posttest of elderly fallers in supine position

The HRV in the supine position of the elderly fallers group was recovered no significant differences among the pretest, midtest, and posttest in the time domain, the frequency domain, the nonlinear domain, and PTT. However, the differences among the tests in LF/HF (*P* = 0.081), and PTT (*P* = 0.092) were mostly only slightly significant (Figure 4.94 and Appendix XXXVII).

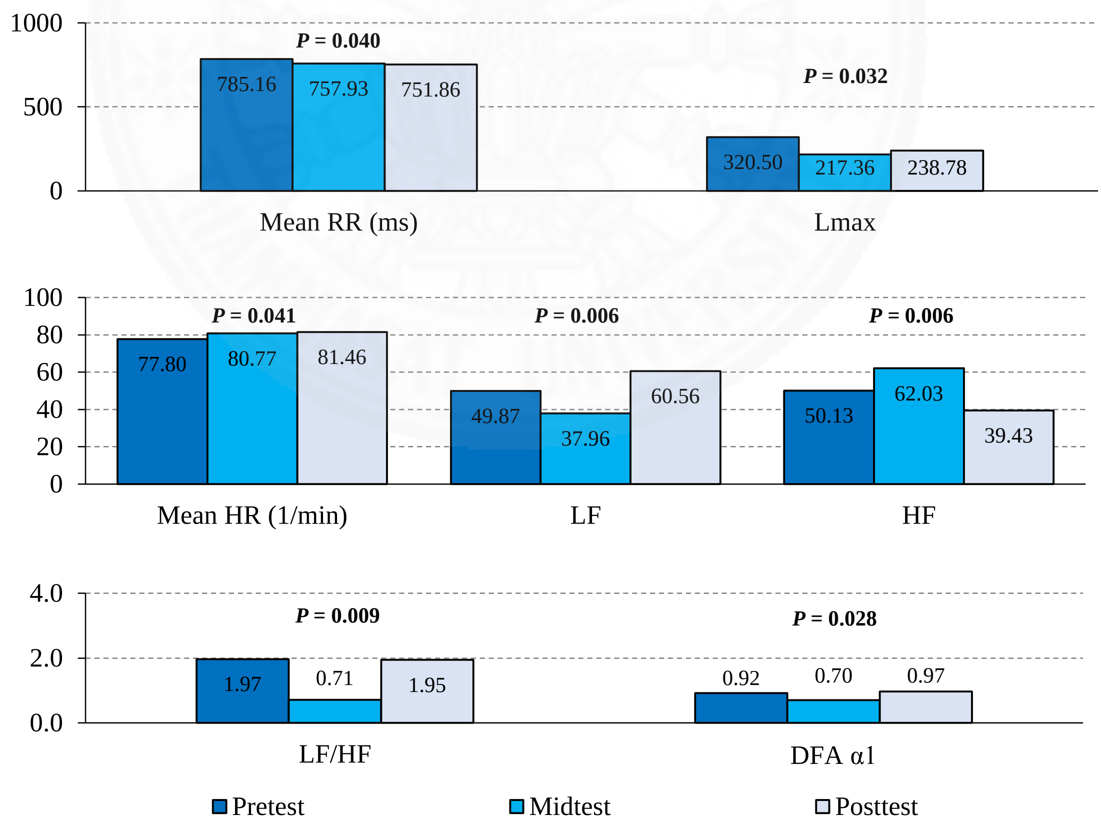


Figure 4.95 HRV characteristics among pretest, midtest, and posttest of elderly fallers in standing position

The HRV in the standing position of the elderly fallers group showed significant differences among the pretest, midtest, and posttest in LF (P = 0.006), HF (P = 0.006), LF/HF (P = 0.009), DFA α1 (P = 0.028), Lmax (P = 0.032), Mean RR (P = 0.040), and Mean HR (P = 0.041) as shown in Figure 4.95. In pairwise comparison, there were significant differences between the tests in LF at the midtest and the posttest (P = 0.003), HF at the midtest and the posttest (P = 0.003), LF/HF at the midtest and the posttest (P = 0.013), DFA α1 at the midtest and the posttest (P = 0.030), Mean RR at the pretest and the posttest (P = 0.042), and Lmax at the pretest and the midtest (P = 0.044).

In contrast, no significant differences were found among the tests in SDNN, STD HR, RMSSD, NN50, pNN50, RR triangular index, TINN, Lmean, REC, DET, ShanEn, ApEn, SampEn, DFA α2, D2, and PTT. Interestingly, Mean HR at the pretest and the posttest (P = 0.055) in the pairwise comparison and the difference among the tests in SD2/SD1 (P = 0.058) were borderline significant (Appendix XXXVIII).

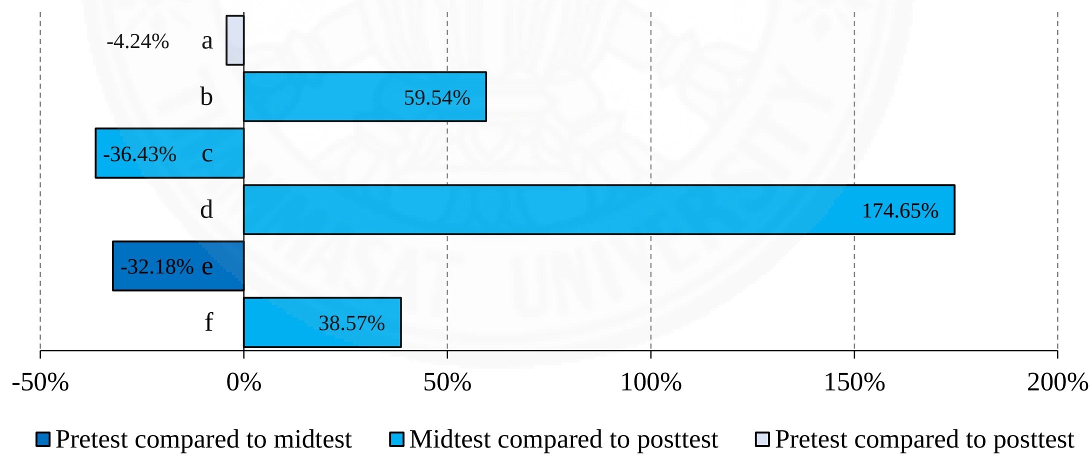


Figure 4.96 Improvement of elderly fallers in standing position

The change in pairwise comparison of the elderly fallers HRV in the standing position showed considerable improvements in several aspects. LF/HF (d) increased 174.65%, LF (b) increased 59.54%, DFA α1 (f) increased 38.57%, HF (c) dropped 36.43%, Lmax (e) dropped 32.18%, and Mean RR (a) dropped 4.24% (Figure 4.96).

4.15.2 Discussion

The HRV of the elderly fallers group among the pretest, the midtest, and the post showed considerable developments in several aspects. Differences were found in NN50, and pNN50 in the sitting position. No differences had been found in the supine position. In the standing position, Mean RR, Mean HR, LF, HF, LF/HF, Lmax, and DFA α1 had been found no differencing.

The results indicated that the changes to HRV of the elderly fallers group among the tests could be found in the time domain in the relaxed sitting position and also, the time domain, the frequency domain, and the nonlinear domain of the HRV in the standing position. It showed that the elderly fallers group had been found to have improved in the 2 positions, especially in the standing position.

It has been seen that the elderly fallers group had found the HRV indices' significant, more than the elderly non-fallers group. The elderly non-fallers group showed improvement in the supine position but not in the sitting position. On the other hand, in the elderly fallers group improvement was found in the sitting position but not in the supine position. This was explained by the HRV's characteristic that the elderly who had fallen differentiated from the non-fallen, through different positions. This related well to a previous prediction study of falls in the elderly, which demonstrated that there was a significant association between a depressed HRV and the risk of falling. It was suggested that a depressed HRV could be a new independent risk factor for falls with an odds ratio of 5.12 (235).

Both the elderly non-fallers and the fallers groups were found to have differences in the standing position, including the all elderly participants group. Significant improvements were shown in all groups. This may be explained by the challenge of the standing position activating the indices of the HRV. This linked to a previous study of autonomic dysfunction in mild cognitive impairment, which showed that the elderly participants exhibited smaller physiological changes in all three HRV indices during active standing, consistent with a dysfunction of the orthosympathetic system (236).

Only within the all elderly participants group had differences been found in all the positions. This might be caused by the relatively small number of the participants in the elderly non-faller and fallers groups. It could be presupposed that the results of the all elderly participants group was influenced by there of the elderly non-faller group. Because the results of the elderly non-faller group contained several indices of the HRV while matched with the results of the all elderly participants group.

4.16 Association among cognitive plasticity, motor plasticity, and HRV of all elderly participants

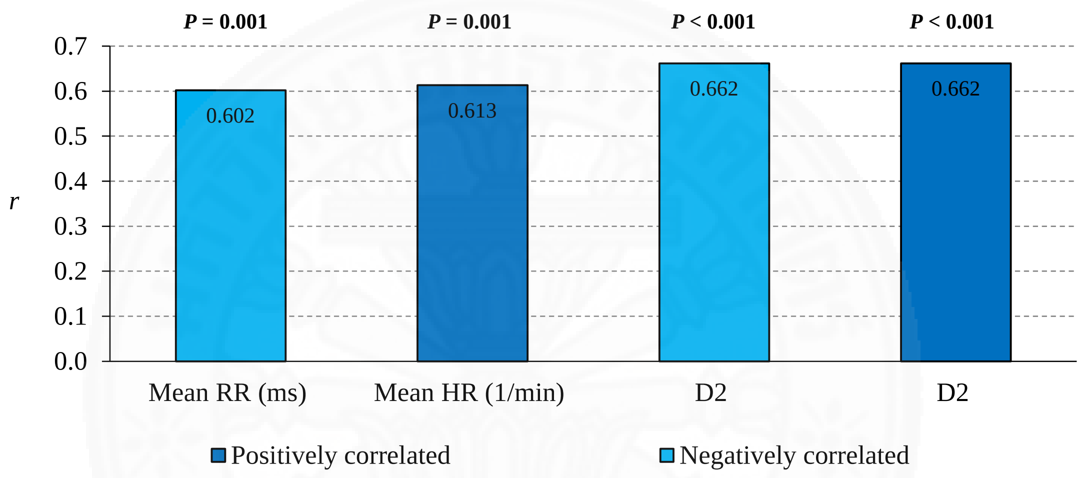


Figure 4.97 HRV and juggling associated with Stroop of all elderly participants

4.16.1 Results

Result for the all elderly participants group significantly correlated at *P* < 0.001 between D2 in the sitting position and the number of incorrect answers in the Stroop test (*r* = 0.662), and D2 in the sitting position and the number of correct answers in the Stroop test (*r* =-0.662) as shown in Figure 4.97.

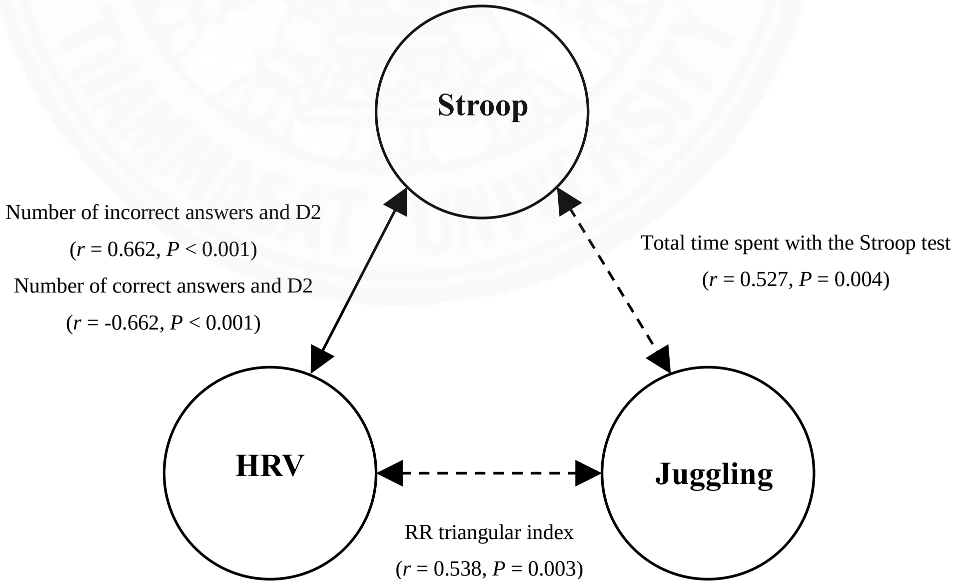
The all elderly participants group results significantly correlated at *P* = 0.001 between Mean HR in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = 0.613). Mean RR in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = -0.602). Mean RR in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = -0.594). Mean HR in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = 0.593). Mean HR in the sitting position and the total time spent with the Stroop test (*r* = 0.590) as shown in Appendix XXXIX.

The all elderly participants group results significantly correlated between Mean RR in the sitting position and the total time spent with the Stroop test (*r* = -0.569, *P* = 0.002). Mean HR in the standing position and the total time spent with the Stroop test (*r* = 0.556, *P* = 0.002). Mean RR in the standing position and the total time spent with the Stroop test (*r* = -0.550, *P* = 0.002). DET in the supine position and the number of correct answers in the Stroop test (*r* = 0.544, *P* = 0.003). DET in the supine position and the number of incorrect answers in the Stroop test (*r* = -0.544, *P* = 0.003). RR triangular index in the standing position and the total time spent with juggling (*r* = 0.538, *P* = 0.003). The total time spent with juggling and the total time spent with the Stroop test (*r* = 0.527, *P* = 0.004). The total time spent with juggling and the time spent obtaining correct answers in the Stroop test (*r* = 0.493, *P* = 0.008). Mean RR in the supine position and the time spent obtaining correct answers in the Stroop test (*r* = -0.490, *P* = 0.008). LF in the standing position and the total time spent with juggling (*r* = 0.487, *P* = 0.009). HF in the standing position and the total time spent with juggling (*r* = -0.487, *P* = 0.009). Mean HR in the supine position and the time spent obtaining correct answers in the Stroop test (*r* = 0.486, *P* = 0.009) as shown in Appendix XXXIX.

In addition, results were significantly correlated between the RR triangular index in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = -0.473, *P* = 0.011). D2 in the standing position and the number of incorrect answers in the Stroop test (*r* = 0.472, *P* = 0.011). D2 in the standing position and the number of correct answers in the Stroop test (*r* = -0.472, *P* = 0.011). Mean HR in the supine position and the total time spent with the Stroop test (*r* = 0.455, *P* = 0.015). Mean RR in the supine position and the total time spent with the Stroop test (*r* = -0.452, *P* = 0.016). LF/HF in the standing position and the total time spent with juggling (*r* = 0.446, *P* = 0.017). RR triangular index in the sitting position and the total time spent with the Stroop test (*r* = -0.439, *P* = 0.019) as shown in Appendix XXXIX.

Moreover, there were significantly correlated results between D2 in the supine position and the number of incorrect answers in the Stroop test (*r* = 0.438, *P* = 0.020). D2 in the supine position and the number of correct answers in the Stroop test (*r* = -0.438, *P* = 0.020). DFA α1 in the standing position and the total time spent with juggling (r = 0.431, P = 0.022). The total time spent with juggling and the time spent obtaining incorrect answers in the Stroop test (r = 0.418, P = 0.027). SD2 in the sitting position and the time spent obtaining the correct answers in the Stroop test (r = -0.408, P = 0.031). SD2 in the sitting position and the total time spent with the Stroop test (r = -0.399, P = 0.035). D2 in the sitting position and the time spent obtaining incorrect answers in the Stroop test (r = 0.396, P = 0.037) as shown in Appendix XXXIX.

Furthermore, there were significantly correlated results between Mean RR in the supine position and the number of incorrect answers in the Stroop test (r = 0.374, P = 0.050). Mean RR in the supine position and the number of correct answers in the Stroop test (r = -0.374, P = 0.050). Mean RR in the standing position and the number of incorrect answers in the Stroop test (r = 0.379, P = 0.047). DFA α2 in the sitting position and the number of correct answers in the Stroop test (r = 0.379, P = 0.047). Mean RR in the standing position and the number of correct answers in the Stroop test (r = -0.379, P = 0.047). DFA α2 in the sitting position and the number of incorrect answers in the Stroop test (r = -0.379, P = 0.047) as shown in Appendix XXXIX.



The significantly correlated at P < 0.001 in continuous line, the significantly correlated at P = 0.01 in dash line

Figure 4.98 Association among Stroop, juggling, and HRV of all the elderly participants

4.16.2 Discussion

4.16.2.1 Overall association of all elderly participants

The results most frequently correlated significant with HRV were found in; the total time spent with the Stroop test, and the time spent with correct answers in the Stroop test at nine correlations. Then, the number of correct answers in the Stroop test and the number of incorrect answers in the Stroop test at seven correlations. After that, the total time spent with juggling at five correlations, and lastly, the time spent obtaining incorrect answers in the Stroop test at two correlations.

The most frequently significant correlations with the Stroop test were found in the time domain of HRV, the nonlinear domain of HRV, and the total time spent with juggling at eighteen, thirteen, and three correlations respectively. And also, the most frequently significant correlations with the total time spent juggling were found in the frequency domain, the time domain, and the nonlinear domain of HRV at three, one, and one correlations respectively.

It could be seen that the correlation of total time spent with the Stroop test was of the same pattern as the time spent with correct answers in the Stroop test with HRV indices. In a similar way, the correlation of the number of correct answers in the Stroop test was of the same pattern as the number of incorrect answers in the Stroop test with HRV indices as well.

Interestingly, the only significant correlation found in the frequency domain of HRV was the total time spent with juggling. Mean RR in the supine position and the standing position were significantly correlated with four indices of the Stroop test as follows: the total time spent taking the test, the number of correct answers from the test, the time spent obtaining correct answers in the test, and the time spent obtaining incorrect answers in the test. Three indices of HRV were found to be significantly correlated in all positions as follows: Mean RR, Mean HR, and D2.

4.16.2.2 Association of D2 between HRV and Stroop of all elderly participants

The correlation dimension (D2) is used to estimate the dimensional complexity or the number of degrees of freedom of a time series. It is calculated after embedding the time series into the phase space (237). A phase space is defined as an ideal, mathematical space with one point for every possible state of the system, having as many dimensions as there are degrees of freedom in the system (238). In non-stationary systems, the number of coupled variables at each time-point is variable, which means that the system's trajectory occupies more or less phase space. The more phase space occupied by the system, the higher is the dimensional complexity. In the presence of chaos, the complexity of HR dynamics therefore could be quantified in terms of the properties of the attractor in phase-space, that is, its D2 (237). This measure is based on the presumption that dynamics is the output of a deterministic dynamical system, whereas time-domain measures assume that the variability is around a stationary mean and is noise (238).

The result of all the elderly participants in the present study found that D2 of HRV in the sitting position was positively associated with the number of incorrect answers and negatively associated with the number of correct answers with the Stroop test (Figure 4.98). This evidence suggested that the more the complexity of HRV with increasing age, the more where the number of incorrect answers with the Stroop test in the same position as the sitting and vice versa. The complexity of HRV could be normalized by meditation (239). The mindfulness meditation neurofeedback boosted aspects of EF that relate to lower error rates of the Stroop test (240). This related well to a previous study of the Stroop interference and meditation. Overall the results suggested that attentional performance and cognitive flexibility were positively related to meditation practice and levels of mindfulness. Meditators performed significantly better than non-meditators on all measures of attention. Furthermore, self-reported mindfulness was higher in meditators than non-meditators and correlations with all attention measures were of moderate to high strength. Therefore, mindfulness was intimately linked to improvements of attentional functions and cognitive flexibility (241).

D2 has been found to be greatly reduced by cholinergic blockade in human studies (242, 243). Previous study found that patients with major depression had significantly lower mean correlation dimension than healthy subjects (238). Previous study of D2 under acute stress indicated that the HR under normal generating system conditions fluctuated between a set of metastable states or attractors ready to adapt to internal or external challenges of an ever-changing environment. The HR under stress may be associated with stronger regularity, decoupling of multimodal integrated networks and deactivation of control-loops within the cardiovascular system. Thus, the reduction in HR complexity during stressful conditions may represent a lower adaptability and fitness of the cardiac pacemaker and a functional restriction of the participating cardiovascular elements (244). The evidence showed that acute and chronic stresses were both associated with decreases in D2.

It has been found in a previous study that D2 could not be used independently especially with healthy participants. The results indicated that D2 was not purely influenced by vagal or sympathetic tone, but that it was the result of a complex interaction of these nerves, regulating heart rate. In this hypothesis, D2 underscores the theory of the existence of a sympathovagal balance. However, one should keep in mind that this theory is questioned. Therefore, D2 could provide additional information on the activity of the ANS to complement the primordial importance information of HRV (245).

4.16.2.3 Association of RR triangular index between HRV and juggling of all elderly participants

Geometric methods provide an analysis of autonomic modulation using the geometric properties of the resulting pattern, and represent an interesting tool in the analysis of HRV (246). The methods involve analysis of the sample density histogram of R-R interval durations. A plot of the distribution typically depicts the main peak as a triangular shape. The triangular index provides an estimate of overall HRV that is more resistant to beat-labeling errors than are its time- and frequency-domain counterparts (247).

The result of the combined elderly participants in the present study found that, with an increasing age HRV triangular index in the standing position was positively associated with the total time spent with juggling 3 balls (Figure 4.97). This related to the result of a previous study that the HRV triangular index has been affected by age. The age related decreases in HRV were initially attributed largely or solely to a decline in parasympathetic activity. However, low frequency power (by frequency-domain analysis) decreases with age as well, suggesting that sympathetic activity also declines with age. Overall HRV declined with increasing age (248). Thus, this evidence suggested that the overall decline of HRV with increasing age was linked to the poor juggling performance in the standing position.

A previous study suggested that the enhanced triangular index of HRV was affected by exercise training patterns. Moreover, the triangular index depended on the level of VO_{2max} in endurance-training (249). The juggling training is an endurance activity (38). Aerobic exercise training leads to enhanced vagal activity at rest, which may contribute in part to the resting bradycardia. Moreover, a significant relationship was found between the levels of maximal oxygen uptake and HRV triangular index. The increase in VO_{2max} is the consequence of endurance training, a result of cardiac and peripheral adaptations. Thus, it is possible that the improvement of aerobic capacity acts beneficially on the cardiac autonomic outflow, as indicated by increased HRV (224).

In contrast, a one-year study of physical training measured the HRV in supine and standing positions. A progressive climbing exertion test till exhaustion was performed to estimate maximal oxygen consumption (VO_{2max}). Results showed a small gain in maximal oxygen consumption and no changes in HRV parameters during the first 6 months of training. In the last six months of training there was a trend towards a decreasing HRV. Also VO_{2max} showed a small decrease after 1 year of training. A correlation between changes in physiological and HRV parameters suggested accordance between VO_{2max} and power spectral analysis. It concluded that HRV was not changed by physical training in elderly population (250).

However, although HRV may be greater in active than sedentary men, any measure of HRV did not appear to be correlated with increasing levels of physical capacity. Furthermore, there was a relationship between the magnitude of parasympathetically mediated modulations in HR and vagal tone or bradycardia. HRV at rest was similar in endurance athletes and their sedentary peers, in spite of a significantly lower HR in athletes (251). Previous studies also showed the presence of low levels of HRV despite the high level of vagal tone (252, 253). The apparent discrepancy may be the result of the support from time domain measurements of HRV analysis which would appear to be markers of modulations in cardiac parasympathetic activity and not vagal tone (254). Thus, it was demonstrated that the endurance training was mediated by decreases in sympathetic tone and non-autonomic intrinsic mechanisms (249).

4.16.2.4 Association of time spent with the test between Stroop and juggling of all elderly participants

The results from all elderly participants in the present study found that the total time spent with the Stroop test was positively associated with the total time spent with juggling 3 balls (Figure 4.97). This evidence suggested that the more time spent with the Stroop test with increasing age, the more time it took to complete juggling 3 balls. The result suggested that processing time is playing an important role in the EF test. This related well to a previous study of the relations between physical functioning and cognitive performance by demonstrating that a collection of simple performance-based tests of physical functioning were specifically associated with processing speed and EF in a sample of independently living elderly adults. The identification of such an association between tests of physical performance and cognition suggested that enhancing physical capacities through physical training may improve cognitive functioning (255).

However, it is likely that age-related changes in the central nervous system, such as reduced white matter integrity or cerebrovascular damage may underlie physical and cognitive dysfunction. Some brain regions have also been identified as being more sensitive to age-related decline. In particular, prefrontal regions that play an essential role in the efficacy of executive functions (256) show larger decrements with advancing age (257). This would partly explain the close link between EF and functional capacities (255).

Moreover, several studies have reported a relationship between physical functioning and cognition in elderly adults. For instance, changes in gait rhythm and pace have been, respectively, associated with decline in episodic memory and executive functions in a non-demented sample of adults aged 70 and older (258). Change in the variability factor of gait was in turn associated with a greater risk of dementia over the 5-year follow-up period. Furthermore, a 20-year longitudinal study of healthy elderly adults showed a steeper gait speed decline 12 years prior to the occurrence of mild cognitive impairment (259). In addition to gait speed, other physical functions of parameters have been linked to cognition.

Muscle strength, also predicts cognitive performance and dementia risk in elderly adults (260) Motor slowing and muscle strength thus appear to be valid markers of cognitive deterioration (255). This suggested the possibility that cognitive training can positively impact motor control functions, such as walking gait. Thereby raising the potential that movement coordination may be enhanced through cognitive training interventions (261).

4.17 Association among cognitive plasticity, motor plasticity, and HRV of elderly non-fallers

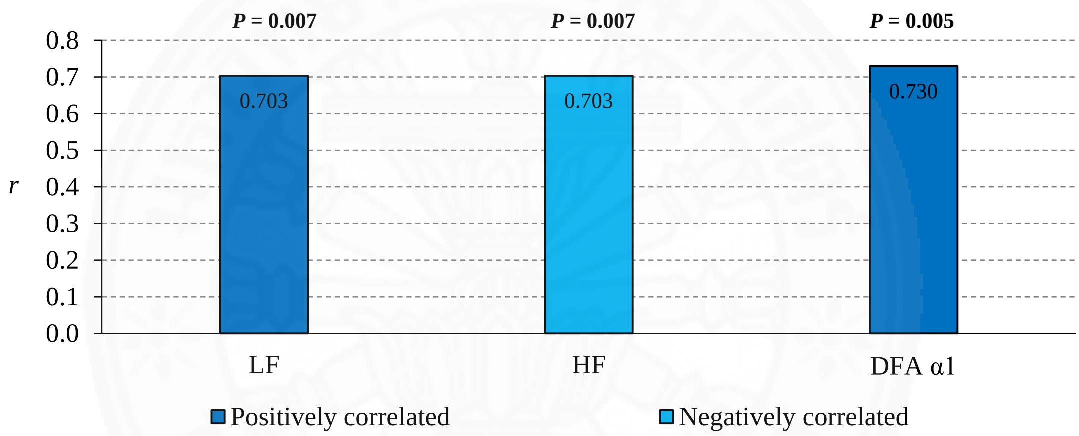


Figure 4.99 HRV and juggling associated with Stroop of elderly non-fallers

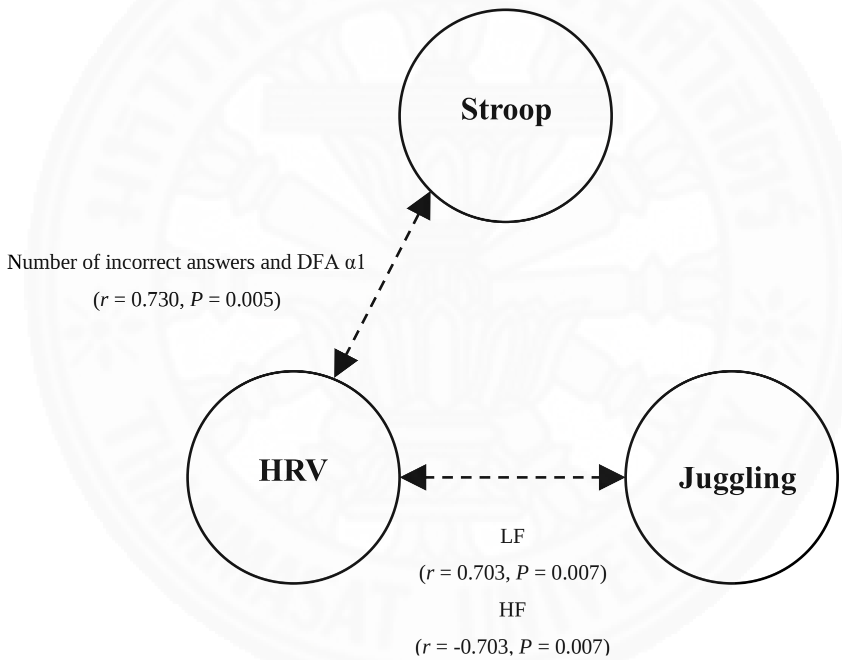
4.17.1 Results

The elderly non-fallers group results significantly correlated between DFA α1 in the standing position and the time spent obtaining incorrect answers in the Stroop test (r = 0.730, P = 0.005). LF in the standing position and the time spent obtaining incorrect answers in the Stroop test (r = 0.703, P = 0.007). HF in the standing position and the time spent obtaining incorrect answers in the Stroop test (r = -0.703, P = 0.007) as shown in Figure 4.99. LF/HF in the standing position and the time spent obtaining incorrect answers in the Stroop test (r = 0.649, P = 0.016). DFA α1 in the supine position and the time spent obtaining incorrect answers in the Stroop test (r = 0.649, P = 0.016). DFA α1 in the standing position and the number of incorrect answers in the Stroop test (r = 0.649, P = 0.016). DFA α1 in the standing position and the number of correct answers in the Stroop test (*r* = -0.649, *P* = 0.016) as shown in Appendix XL.

In addition, there were significant correlations between LF/HF in the standing position and the total time spent with the Stroop test (*r* = 0.606, *P* = 0.028). LF in the supine position and the time spent obtaining incorrect answers in the Stroop test (*r* = 0.595, *P* = 0.032). Mean RR in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = -0.595, *P* = 0.032) HF in the supine position and the time spent obtaining incorrect answers in the Stroop test (*r* = -0.595, *P* = 0.032). LF in the supine position and the total time spent with juggling (*r* = 0.593, *P* = 0.033). HF in the supine position and the total time spent with juggling (*r* = -0.593, *P* = 0.033). Mean RR in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = -0.589, *P* = 0.034). SD2/SD1 in the supine position and the time spent obtaining incorrect answers in the Stroop test (*r* = 0.587, *P* = 0.035). LF in the standing position and the total time spent taking the Stroop test (*r* = 0.585, *P* = 0.036). HF in the standing position and the total time spent taking the Stroop test (*r* = -0.585, *P* = 0.036). REC in the supine position and the time spent obtaining incorrect answers in the Stroop test (*r* = 0.581, *P* = 0.037) as shown in Appendix XL.

Moreover, there were significant correlations between Mean RR in the standing position and the total time spent taking the Stroop test (*r* = -0.571, *P* = 0.041). Mean RR in the sitting position and the total time spent taking the Stroop test (*r* = -0.570, *P* = 0.042). REC in the supine position and the number of incorrect answers in the Stroop test (*r* = 0.564, *P* = 0.045). REC in the supine position and the number of correct answers in the Stroop test (*r* = -0.564, *P* = 0.045). Mean HR in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = 0.563, *P* = 0.045). LF/HF in the supine position and the total time spent with juggling (*r* = 0.561, *P* = 0.046). DFA α1 in the supine position and the number of incorrect answers in the Stroop test (*r* = 0.561, *P* = 0.046). DFA α1 in the supine position and the number of correct answers in the Stroop test (*r* = -0.561, *P* = 0.046). Mean HR in the sitting position and the number of correct answers in the Stroop test (*r* = 0.557, *P* = 0.048). LF in the standing position and the number of incorrect answers in the Stroop test (*r* = 0.554, *P* = 0.049). HF in the standing position and the number of correct answers in the Stroop test (*r* = 0.554, *P* = 0.049). LF in the standing position and the number of correct answers in the Stroop test (*r* = -0.554, *P* = 0.049). HF in the standing position and the number of incorrect answers in the Stroop test (*r* = -0.554, *P* = 0.049) as shown in Appendix XL.

Interestingly, the correlation between Mean HR in the standing position and the total time spent taking the Stroop test (*r* = 0.545, *P* = 0.054), and LF/HF in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = 0.546, *P* = 0.053) were borderline significant as shown in Appendix XL.



The significantly correlated at *P* = 0.01 in dash line

Figure 4.100 Association among cognitive plasticity, motor plasticity, and HRV of elderly non-fallers

4.17.2 Discussion

4.17.2.1 Overall association of elderly non-fallers

The most frequently significant correlations with HRV were found in the time spent obtaining incorrect answers in the Stroop test at nine correlations. Then, the total time spent, the number of correct answers, and the number of incorrect answers in the Stroop test at five correlations. After that, the time spent obtaining correct answers in the Stroop test at four correlations and the total time spent with juggling at four correlations.

In the meantime, the most frequently significant correlations with the Stroop were found in the frequency domain of HRV, the nonlinear domain of HRV, and the time domain of HRV at twelve, ten, and six correlations respectively. Also, the significant correlation with the total time spent with juggling was only found in the frequency domain of HRV at three correlations.

It could be seen that the correlation of the number of correct answers in the Stroop test was similar to the pattern of the number of incorrect answers in the Stroop test with HRV indices.

Interestingly, the only significant correlation found in the frequency domain of HRV was with the total time spent juggling. LF and HF in the standing position were significantly correlated with four indices of the Stroop test as follows: the total time spent taking the test, the number of correct answers in the test, the number of incorrect answers in the test, and the time spent obtaining incorrect answers in the test.

4.17.2.2 Association of DFA α1 between HRV and Stroop for elderly non-fallers

Detrended fluctuation analysis extracts the correlations between successive RR intervals over different time scales. This analysis results in slope α1, which describes brief fluctuations. The short-term correlation extracted using DFA reflects the baroreceptor reflex (229).

The cardiovascular system, central nervous system, endocrine system, peripheral nervous system, respiratory system, and baroreceptors and chemoreceptors influence HRV over a brief time period and contribute to the very low to high frequencies of the HRV spectrum. Baroreceptors, which are BP sensors located in the aortic arch and internal carotid arteries, contribute to HRV. When you inhale, HR increases. BP rises about 5 seconds later. Baroreceptors detect this rise and fire more rapidly. When you exhale, HR decreases. BP falls 5 seconds later. The baroreflex makes possible the respiration-driven speeding and slowing of the heart via the vagus nerves, called respiratory sinus arrhythmia (94). The baroreflex arc is important in enabling people to function in the upright position, as it is the principal mechanism responsible for short-term (seconds to minutes) BP control. BP sensors in the carotid and aortic arch are linked through glossophryngel and vagal nerves to central processing centers in the brainstem, which modulate efferent sympathetic and parasympathetic nervous system activity to the vasculature and heart (262).

Increasing age is associated with increasing BP and reduced baroreflex sensitivity. A previous study described the association between age, BP and baroreflex sensitivity in a sample of 70 normotensive participants aged 22-82 years using several methods. It confirmed that aging is associated with a reduction in baroreflex sensitivity up to the fourth decade (263). Beyond this there is little further decline. Age is the dominant factor associated with reduced baroreflex sensitivity, although increasing BP is associated with further blunting of baroreflex sensitivity in this older normotensive population (262). However, reduced baroreflex sensitivity function modifies the response of elderly participants to vasodilator drugs. The reflex tachycardia and increase in stroke volume in response to vasodilation is reduced, resulting in more marked falls in BP (264), which increase the likelihood that elderly patients will experience drug-induced OH.

The results of the elderly non-fallers group in the present study found that DFA α1 of HRV with an increasing age in the standing position was positively associated with the number of incorrect answers of the Stroop test (Figure 4.100). This evidence suggested that the reduced baroreceptor reflex with increasing age in the standing position correlated with an increase of the number of incorrect answers of the Stroop test.

This related to previous studies that recorded the relationship between attention and cardiac activity (265). The engagement in EF tasks appeared to elicit autonomic activity to support the processing required for the Stroop performance. The performance of EF tasks that evoked attentional control may depend in part on the responsiveness of autonomic control parameters via age-dependent mechanisms (266).

4.17.2.3 Association of LF and HF between HRV and juggling of elderly non-fallers

LF power may be produced by both the PNS and SNS and BP regulation via baroreceptors or by baroreflex activity alone, whereas HF power is produced by the PNS. HF power is highly correlated with the pNN50 and RMSSD time domain measures. HF power is generated by the inhibition and activation of the vagus nerves by breathing at normal rates and is primarily parasympathetic. HF power is an index of the sensitivity of the baroreflex, which regulates BP and HR (94).

The result for the elderly non-fallers group in the present study found that LF of HRV, with increasing age, in the standing position was positively associated with total time spent with juggling 3 balls. Meanwhile, HF of HRV in the standing position was negatively associated with the total time spent juggling 3 balls (Figure 4.99). This evidence suggested that a high activity of the PNS and SNS, with increasing age, in the standing position was linked to the increase of the total time spent juggling 3 balls. In contrast, a high activity of PNS, with an increasing age, in the standing position was linked to a reduction of the total time spent juggling 3 balls.

There are significant age-related changes in autonomic nervous system functions that are responsible for an impaired ability to adapt to environmental or intrinsic visceral stimuli in the elderly. A variety of functional and anatomical changes in the autonomic nervous system occur with age. These changes impair one's ability to "react" to environmental or internal stimuli that would normally be addressed with alterations in autonomic activity and a corresponding change in visceral functioning. The age-related functional decline of the visceral organs involve changes in receptor functions and the loss of some autonomic projections. These end-organ changes cause, or are caused by, increases in activity in the sympathetic division of the ANS, and possibly by increases in activity in the parasympathetic division as well (267).

Previous studies suggested that the functional training had a beneficial impact on autonomic modulation, as characterized by increased parasympathetic activity and overall variability (246). The recovery of heart rate after exercise became blunted with age as a result of sluggish cardiac vagal response to adjust the cardiac activity. Thus, it was suggested that slowing down the decline in sympathetic status could delay the appearance of many geriatric complaints (268). Regular meditation (269) or aerobic exercise has been a tool to arrest the persistent decrease in sympathetic status with age. Common observation may prove people doing regular meditation, like different types of Asana yoga or any other type of meditation, show delayed appearance of geriatric symptoms like OH. In the elderly, aerobic exercises lowered heart rate at rest and plasma catecholamines and where found to improve left ventricular performance during peak exercise (270).

However, there was no significant difference in all the tests of parasympathetic function between the young old and old old indicating no further decline in parasympathetic function after 75 years (271).

4.18 Association among cognitive plasticity, motor plasticity, and HRV of elderly fallers

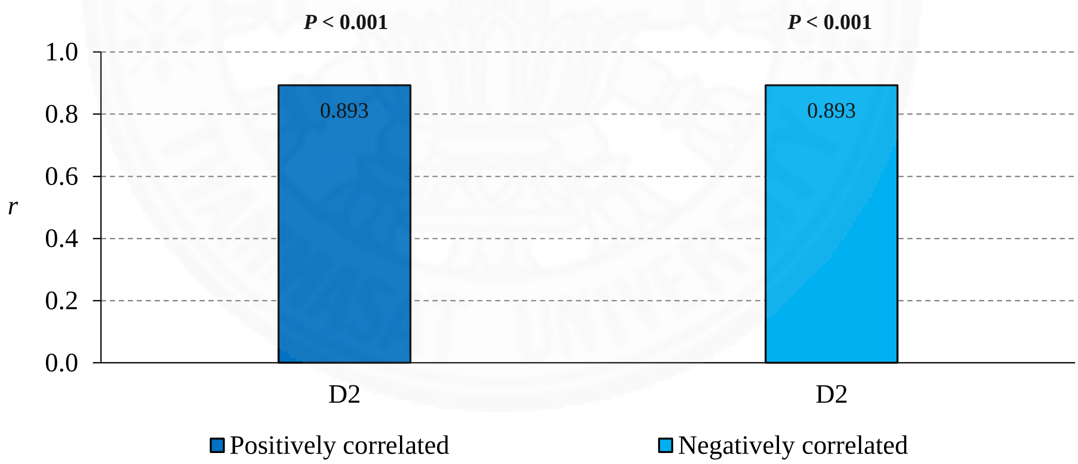


Figure 4.101 HRV and juggling associated with Stroop of elderly fallers

4.18.1 Results

The elderly fallers group significantly correlated at $P < 0.001$ between D2 in the sitting position and the number of incorrect answers in the Stroop test (r = 0.893), and D2 in the sitting position and the number of correct answers in the Stroop test (r = -0.893) as shown in Figure 4.101.

The elderly fallers group significantly correlated between DET in the supine position and the number of correct answers in the Stroop test (*r* = 0.751, *P* = 0.003). DET in the supine position and the number of incorrect answers in the Stroop test (*r* = -0.751, *P* = 0.003). RR triangular index in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = -0.723, *P* = 0.005). SD2 in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = -0.706, *P* = 0.007). Mean HR in the sitting position and the time spent obtaining correct answers in the Stroop test (*r* = 0.703, *P* = 0.007). SD2 in the standing position and the total time spent juggling (*r* = 0.701, *P* = 0.008). RR triangular index in the standing position and the total time spent juggling (*r* = 0.700, *P* = 0.008). Mean HR in the sitting position and the total time spent taking the Stroop test (*r* = 0.691, *P* = 0.009) as shown in Appendix XLI.

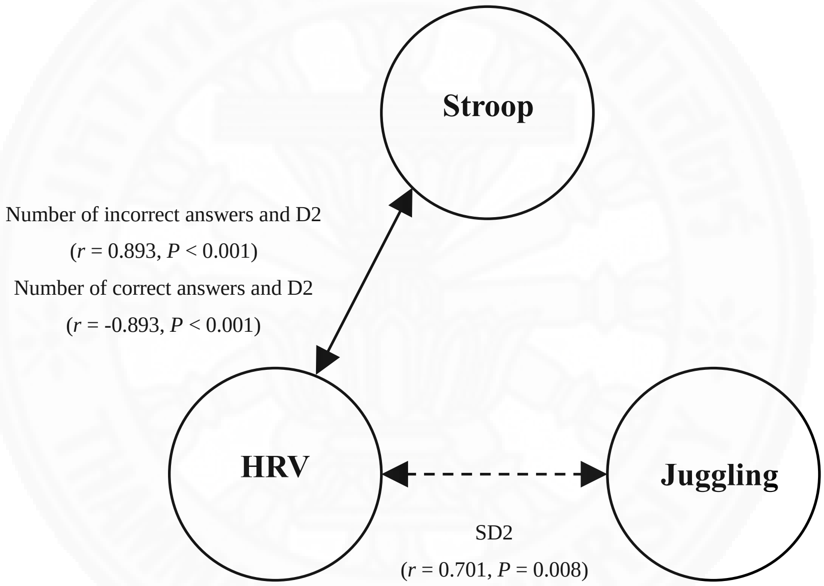
In addition, there were significant correlations between Mean RR in the standing position and the time spent obtaining the correct answers in the Stroop test (*r* = -0.681, *P* = 0.010). Mean HR in the standing position and the time spent obtaining the correct answers in the Stroop test (*r* = 0.680, *P* = 0.011). DFA α2 in the sitting position and the number of correct answers in the Stroop test (*r* = 0.674, *P* = 0.012). Mean RR in the sitting position and the time spent obtaining the correct answers in the Stroop test (*r* = -0.674, *P* = 0.012). DFA α2 in the sitting position and the number of incorrect answers in the Stroop test (*r* = -0.674, *P* = 0.012). STD RR in the standing position and the total time spent juggling (*r* = 0.658, *P* = 0.015). STD HR in the standing position and the total time spent juggling (*r* = 0.655, *P* = 0.015). Mean RR in the sitting position and the total time spent taking the Stroop test (*r* = -0.649, *P* = 0.016). SD2 in the sitting position and the total time spent taking the Stroop test (*r* = -0.648, *P* = 0.017). pNN50 in the sitting position and the time spent obtaining the correct answers in the Stroop test (*r* = -0.644, *P* = 0.018). RR triangular index in the sitting position and the total time spent taking the Stroop test (*r* = -0.640, *P* = 0.018). Mean HR in the standing position and the total time spent taking the Stroop test (*r* = 0.637, *P* = 0.019) as shown in Appendix XLI.

Moreover, there were significant correlations between NN50 in the sitting position and the time spent obtaining the correct answers in the Stroop test (*r* = -0.634, *P* = 0.020). RR triangular index in the supine position and the total time spent juggling (*r* = 0.632, *P* = 0.020). ApEn in the standing position and the total time spent juggling (*r* = -0.631, *P* = 0.021). Mean RR in the standing position and the total time spent taking the Stroop test (*r* = -0.627, *P* = 0.022). pNN50 in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = -0.618, *P* = 0.025). pNN50 in the sitting position and the number of incorrect answers in the Stroop test (*r* = 0.616, *P* = 0.025). pNN50 in the sitting position and the number of correct answers in the Stroop test (*r* = -0.616, *P* = 0.025). NN50 in the standing position and the time spent obtaining correct answers in the Stroop test (*r* = -0.612, *P* = 0.026). RR triangular index in the sitting position and the number of incorrect answers in the Stroop test (*r* = 0.608, *P* = 0.027). RR triangular index in the sitting position and the number of correct answers in the Stroop test (*r* = -0.608, *P* = 0.027). DET in the standing position and the time spent obtaining the incorrect answers in the Stroop test (*r* = -0.596, *P* = 0.032). D2 in the sitting position and the time spent obtaining the correct answers in the Stroop test (*r* = -0.591, *P* = 0.033). TINN in the supine position and the total time spent juggling (*r* = 0.589, *P* = 0.034). NN50 in the sitting position and the total time spent taking the Stroop test (*r* = -0.582, *P* = 0.037). pNN50 in the sitting position and the total time spent taking the Stroop test (*r* = -0.581, *P* = 0.037). TINN in the standing position and the total time spent juggling (*r* = 0.580, *P* = 0.038) as shown in Appendix XLI.

Furthermore, there were significant correlations between Mean RR in the supine position and the time spent obtaining correct answers in the Stroop test (*r* = -0.574, *P* = 0.040). SD2 in the supine position and the total time spent juggling (*r* = 0.570, *P* = 0.042). DET in the standing position and the number of correct answers in the Stroop test (*r* = 0.563, *P* = 0.045). DET in the standing position and the number of incorrect answers in the Stroop test (*r* = -0.563, *P* = 0.045). DFA α2 in the standing position and the number of correct answers in the Stroop test (*r* = 0.561, *P* = 0.046). DFA α2 in the standing position and the number of incorrect answers in the Stroop test (*r* = -0.561, *P* = 0.046). Mean HR in the supine position and the time spent obtaining the correct answers in the Stroop test (*r* = 0.555, *P* = 0.049) as shown in Appendix XLI.

Interestingly, there were borderline significant correlations between DET in the sitting position and the number of correct answers in the Stroop test

(r = 0.551, P = 0.051). DET in the sitting position and the number of incorrect answers in the Stroop test (r = -0.551, P = 0.051). TINN in the sitting position and the time spent obtaining the correct answers in the Stroop test (r = -0.548, P = 0.052). Mean RR in the supine position and the total time spent taking the Stroop test (r = -0.547, P = 0.053). Mean RR in the standing position and the number of incorrect answers in the Stroop test (r = 0.547, P = 0.053). Mean RR in the standing position and the number of correct answers in the Stroop test (r = -0.547, P = 0.053). DFA α2 in the standing position and the total time spent taking the Stroop test (r = 0.544, P = 0.055) as shown in Appendix XLI.



The significant correlations at $P < 0.001$ in continuous line, the significant correlations at $P = 0.01$ in the dash line

Figure 4.102 Association among cognitive plasticity, motor plasticity, and HRV of elderly fallers

4.18.2 Discussion

4.18.2.1 Overall association of elderly fallers

The most frequent significant correlations with HRV were found in the time spent obtaining correct answers in the Stroop test at thirteen correlations. The total time spent with juggling at nine correlations. The total time spent taking the Stroop test at eight correlations. The number of correct answers and incorrect answers in the Stroop test at seven correlations. And the time spent obtaining incorrect answers in the Stroop test at one correlation.

Similarly, the most frequent significant correlations with the Stroop were found in the time domain and the nonlinear domain of HRV at twenty six and fourteen correlations respectively. Also, the most frequent significant correlations with the total time spent juggling was found in the time domain and the nonlinear domain of HRV at six and three correlations respectively.

Interestingly, pNN50 and RR triangular index in the sitting positions were significantly correlated with four indices of the Stroop test as follows: the total time spent taking the test, the number of correct answers in the test, the time spent obtaining correct answers in the test, and the number of incorrect answers in the test. Six indices of HRV were found significantly correlated in all positions as follows: Mean RR, Mean HR, RR triangular index, TINN, SD2, and DET.

4.18.2.2 Association of D2 between HRV and Stroop of elderly fallers

The result from the elderly fallers group in the present study found that D2 of HRV in the sitting position was positively associated with the number of incorrect answers, and negatively associated with the number of correct answers of the Stroop test (Figure 4.102). This evidence suggested that as the complexity of HRV increases with age, the greater where the number of incorrect answers in the Stroop test in the same position the sitting and vice versa.

This result of the elderly fallers group was linked to that the combined elderly participants group with the same condition as the correlation.

4.18.2.3 Association of SD2 between HRV and juggling of elderly fallers

The standard descriptor 2 (SD2) reflects the sympathetic and parasympathetic contributions to the heart (86). SD2 measures short- and long-term HRV and correlated with LF power and BRS (229). The results from the elderly fallers group in the present study found that SD2 of HRV in the standing position was positively associated with the total time spent juggling 3 balls (Figure 4.101). This evidence suggested that a high activity of the sympathetic and parasympathetic contributions, at an increasing age, in the standing position was linked to the increase of the total time spent juggling the 3 balls. This related to a previous study of HRV and effect of endurance training, indicated that SD2 is influenced by both parasympathetic and sympathetic tone. The results showed that the SD2, SD2n, and LF increased during standing and decreased during exercise compared to the supine rest condition, confirming that these indexes are influenced by both parasympathetic and sympathetic modulations and thus they are not specific indexes (219).

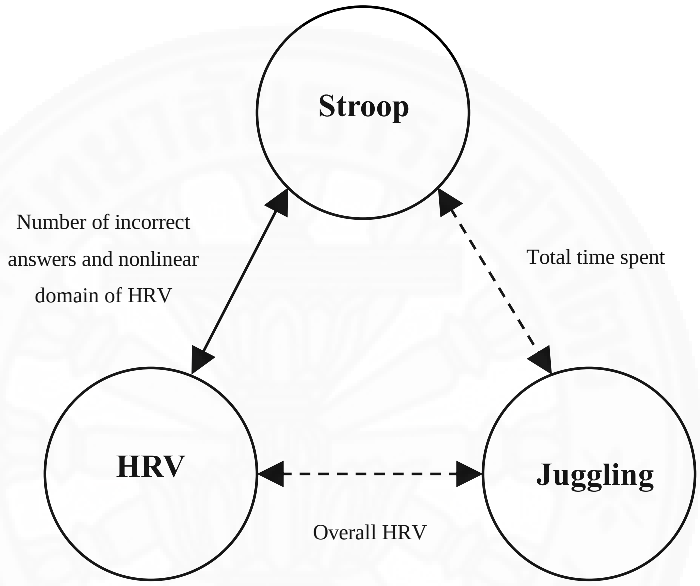
Previous study concluded that age and health status were important factors when considering the relationship between exercise and HRV response to postural change. There is an alteration in physiological response to postural change with aging, notably a shift from autonomic cardiac control, predominately vagal withdrawal, towards increasing peripheral resistance (272). In contrast, another previous study indicated that autonomic modulation of heart rate during exercise was not dependent of age and sex. The results suggested that submaximal exercise did not elicit excessive sympathetic activity with aging (273).

A previous study found that participants with greater physical fitness showed increased responsiveness (indicated by increased sympathetic activity and vagal withdrawal) to the orthostatic challenge. It may be explained by the fact that the maintenance of blood pressure in standing up from the supine position is dependent on increased sympathetic activity and vagal withdrawal, while the supine position is marked by vagal activation with sympathetic withdrawal (274).

However, a previous study of a short-term parasympathetic modulation of HRV indicated that higher volumes of physical activity had significantly higher levels of parasympathetic HRV than less active participants while supine, but also demonstrated a much greater change in parasympathetic HRV in response to standing (272).

4.19 Overview of association among cognitive plasticity, motor plasticity, and HRV in all elderly groups

Based on the association among the Stroop test, the juggling, and the HRV of the all participants, the non-fallers, and the fallers, the present study suggested that the number of incorrect answers in the Stroop test had a positively strong relationship with the nonlinear domain of the HRV in the sitting to the standing positions. The juggling task had a positively moderate relationship with an overall index of the HRV in the standing position. Also, the total time spent taking the Stroop test had a positively moderate relationship with the total time spent with the juggling task (Figure 4.103).



Strong relationship in continuous line, moderate relationship in dash line

Figure 4.103 Association among cognitive plasticity, motor plasticity, and HRV in all elderly groups

It has been clearly seen that all associations with the Stroop test of the combined participants, the non-fallers, and the fallers groups were found in the number of incorrect answers. Two indices of the HRV were found in D2 of the combined participants and the fallers groups, and DFA $\alpha 1$of the non-fallers group. These were categorized as the nonlinear domain of the HRV. In a similar way, the 2 positions were found in the associations. The sitting position was found in the combined participants and the fallers groups, while the standing position was found in the non-fallers group. Thus, this correlation was found from the sitting position to the standing position. Interestingly, the association between the Stroop test and the HRV of the all participants had the same pattern as the faller groups. This may be explained by the influence of the correlation coefficient value (r) of the fallers group that is higher than in the non-fallers group. Thus, it affected the result of the combined participants.

This strong evidence suggested that relationship between the Stroop test and the nonlinear domain of the HRV in the sitting to the standing positions was indicated by the number of incorrect answers. The nonlinear domain is unpredictable, which results from the complexity of the mechanisms that regulate the HRV (229). Therefore, the nonlinear domain of the HRV in the orthostatic challenge condition could be referring to the complexity of the HRV in the fall situation in the elderly population. The complexity of the HRV, for example, as an intrinsic factor since the OH could generate falls in the elderly population. It could imply that the elderly with OH could have a greater chance of falling by making wrong decisions to avoid the fall situation. On the other hand, the number of incorrect answers was reflected an inaccurateness. The accurateness of making the decision has degenerated with increasing age. An unpredictable and complicated environment for the elderly population could stimulate falls. It could imply that the elderly population has to make the right decisions to avoid falls. The less inaccurate decisions in the fall situation of the elderly may reflect the good EF of cognition.

The RR triangular index, LF, and SD2 of the HRV were found in positive correlation with the juggling task, while HF of the HRV had a negative correlation with the juggling task. LF and SD2 were linked by both the PNS and SNS, while HF was only linked to the PNS. However, the RR triangular index reflected the overall HRV which included both the PNS and SNS. Thus, the overall HRV was used to represent the moderate relationship of the correlation. The standing position was found in all associations between the HRV and juggling.

This evidence suggested that the moderate relationship between the juggling task and the overall index of the HRV was flagged by the total time spent in the standing position. The total time juggling reflected to the speed of movement. In the elderly population, the speed of movement and the HRV had declined (275). The slow speed and/or the restriction of movement were linked to falls. The decreased

HRV has been linked to cardiovascular disorders (276) which falls in the elderly population could be caused by (277). Thus, the increase of cardiovascular risk factors may contribute to reduced physical movement activities (278) which leads to the cause of falls. In the standing position, the less time spent and the faster speed of movement could reduce the chance to fall. The rapid balance movement of the elderly population in the fall situation may reflect the good coordination and gross motor skills of an active aging.

Unsurprisingly, the association between the Stroop and juggling was only found in the combined participants group. It may be a limitation of the low numbers of the participants in the non-fallers and fallers groups. In the meanwhile, the association which was found in the combined participants group could be influenced by the other doubling number of participants from the non-fallers and fallers groups as well. The total time spent taking the Stroop test correlated with the total time spent with the juggling task. It has been clearly seen that the total time spent with the situations was found as a mediator of the correlated.

This evidence suggested that the moderate relationship between the Stroop test and the juggling task was indicated by the total time spent in the situation. The total time reflected the speed. In the elderly population, the speed of cognition and the motor functions has declined. This was one of the main reasons the elderly could fall. In the fall situations, the elderly population has to make a good decision quickly to avoid falls. Quick decisions of the elderly in a fall situation could reflect the positive speed of processing of cognition and good motor reaction as well.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The first purpose of the present study is to determine the fall-related factors in elderly people. The second is to examine and evaluate the cognitive, motor, and sensory plasticity along with HRV during the training of the elderly people in the study. And the third is to describe the associations among the cognitive, motor plasticity, and the HRV in the elderly people. The results of the present study are interpreted in the aspect of how does cognitive plasticity contribute to reducing falls in elderly people, and why does it have an influence on the frequency falls of elderly people.

5.1 Fall-related factors in the elderly people

5.1.1 Demographic and health characteristics

The findings of the elderly participant characteristics suggest that experiences in the past, such as the previous profession, and the number of falls, differ between the two fall-related groups. Likewise, the reflection of medical factors such as the number of medications per day and the THAI-MMSE score are also relevant to the difference between the elderly non-fallers and the elderly fallers.

5.1.2 Physical characteristics

Information of the characteristics to the elderly participants obtained from the present study using the EF training of the cognitive and motor plasticity could show a difference between the elderly non-fallers and the elderly fallers, through the category of weight, BMI, the VA test, and time spent over the incorrect answers in the finger-nose test. The results may be beneficial as an instrument to evaluate the possibility of future falls in the elderly people.

5.1.3 EF characteristics

The present study suggests that time spent with the Stroop test shares characteristics with a range of cognitive functioning measures associated with falls. The total time spent with the test, and additional time spent attaining the correct answers in the incongruent condition can present a significant risk factor for falls. It was rather about making an accurate decision quickly. The results showed that slower cognitive processing and/or accompanied with poor EF can affect falls.

Eight levels of the juggling tasks in the present study could differentiate the elderly non-fallers from the elderly fallers with the total time spent on the task. The falls classification is even clearer from 1 ball to 3 balls juggling respectively, especially in the dual tasks condition.

5.1.4 HRV characteristics

No indices of the HRV could consistently classify the difference between the elderly groups in the present study. However, the present study suggests using all indices of the HRV to predict fall-related factors in the elderly people. The result may indicate that the nonlinear domain is generally suitable to use prior the real training. The time and the frequency domains are moderately suitable to use, in the middle and the posttest respectively.

5.2 Plasticity of the cognitive, motor, and the sensory in the elderly people, and the change of the HRV

5.2.1 Cognitive plasticity

The present study contributes to the growing body of evidence suggesting that the attention improvement of the EF could be achievable among the elderly people via the Stroop. The fall-related issue was associated with the total time spent with the test, and the time spent attaining the correct answers of the Stroop in the incongruent condition of level 4, 7, and 8. These were found in the elderly non-fallers group who had gained better improvement than the elderly non-fallers group.

5.2.2 Motor plasticity

The present study indicated that elderly people were able to activate their remaining capacities to compensate for the motor weakness. The high gross motor skills of the juggling task in the elderly non-fallers group had offered better performance compared to the elderly fallers group. With that, better performance was found among the elderly non-fallers group compared to the elderly fallers group, especially from week 6 to week 8, where the performance was raised from 61.99 to 124.08%.

5.2.3 Sensory plasticity

In all the elderly participants groups, the EF training in the present study not only decreased the total time spent with all answers in the dynamic position sense, and the number of incorrect answers in the joint position sense of the proprioceptive sense test, but also increased foot sensation in all the elderly participants groups. Both the elderly non-fallers and fallers groups decreased the total time spent with all the answers in the finger-nose test as well. In comparison with the elderly non-fallers, the elderly fallers gained improvements from the training more frequently. However, the elderly non-fallers received the training advantages with more ease and at a better acceleration.

5.2.4 Change of the HRV

All the elderly participants had experienced HRV's changes in all positions. The standing position had also been found to effect HRV changes in all the groups. The elderly non-fallers group mostly dominated the frequency domain meanwhile, the elderly fallers group mostly dominated the time domain. However, no indices of the HRV, could consistently intermediate among all the elderly groups and all the positions. The present study suggests using all indices of the HRV to evaluate the HRV's changes in elderly people.

5.3 Associations among cognitive, and motor plasticity, and HRV in elderly people

Overall, the number of incorrect answers made in the Stroop test has a strong positive relationship within the nonlinear domain of the HRV. The juggling task had a moderate positive relationship within the overall scope of the HRV. Additionally, the total time spent for the Stroop test had a positive moderate relationship with the total time spent for the juggling task.

The present study suggests that the wrong decision making in a fall-related situation associates with the complexity of the nonlinear domain in the HRV, and vice versa. The weakness in gross motor skills affects the risk of falls linked with a reduced HRV overall, and vice versa. The slow processing time to react to the unpredictable circumstance, linked with the low-speed coordination of the eye-hand, as well as eye-feet coordination, impacted on falls.

5.4 Strengths and limitations

5.4.1 Strengths

The present study uses standardized, non-invasive equipment measures, such as THAI-MMSE, TPD, BP, and HRV, with high levels of safety and low risk of missing data. The 8-week follow up activity on overall health and fall-related issues of the participants uncovered no effects. It was the first time a combination of a juggling task and the Thai-Stroop test were used for EF training with elderly people. The Thai-Stroop test was designed to be fun and exciting which may help motivate elderly people to stick with the training program. The training was appreciated by the Watsanawet Social Welfare Development Center for Older Persons for its creative activities that supported social relationships among participants and members at the center. The combined training in this present study is not designed for elderly persons only. Such training applications should be universal across different ages. The training is not complicated for researchers to organize and also it is user friendly. The budget costs of instruments also makes it more possible to reach a broader population and perhaps at a country level. These strengths and benefits should enable a new approach of combined training for everyday life to be taken for everyone, especially the elderly population.

5.4.2 Limitations

There are some limitations to the present study, such as its relatively small sample size. The recall bias on self-reported retrospective data especially when participants were asked to remember fall events in the past, within 12 months. Participants who had little interest in physical exercise and low social relationships were slightly reluctant to participate in the juggling training intervention. On the other hand, participants who had never experienced the Stroop test application on the tablet device were very willing to learn to use the technology, which was confirmed by the fact that more Stroop practicing was the most requested.

The time schedule of training and testing had been noticed as a limitation as well. The tests were collected on the day after the repetitive 4 days of training at the end of each week. Participants who had not had enough rest time may have experienced fatigue caused by the frequency of training. The resultant lower motivation to achieve the tasks and being easily distracted may have shown in the test. The quality of performances where affected by participants who may lose their encouragement by rushing to complete the tests.

At this point of the research, the interpretation of HRV has been debated essentially in that of the elderly people. It should be noted that there is no gold standard of HRV characteristics for elderly people yet. This study has gone beyond that by linking the HRV and cognitive functions through the elderly persons brain-heart axis. Thus, the present study mainly considered the evidence that was found in the present results and interpreted as substantial, both qualitative and quantitative, of the contribution to the cognitive plasticity in elderly people.

Also, it should be noted that the deterioration of brain and a cognitive decline are regarded as prevalent characteristics of the elderly. It could not be denied that senescence, no matter how severe it can be, occurred in most people. Each person’s differences in the quality of cognitive brain and functions in advanced age reveals that both deterioration and decay are unexpected characteristics of aging (279) which makes these variables uncontrollable; that limitation might have affected the results of this study.

5.5 Recommendations for future directions

5.5.1 Falls risk assessment tools and other tools

To corroborate the clinical interpretation of results, further study should contain more accurate measurements or tests, in order to define specific diseases and disabilities of participants, such as the number of diseases. Advanced brain mapping devices, including diffusion tensor image (DTI) and functional magnetic resonance imaging (fMRI), need to have a parallel assessment with brain structural plasticity to provide insight into which parts of the brain functioning changes in further study, as many falls risk assessment tools used in community settings have not formally been validated. In order to permit the accurate identification of falls risk factors and to identify interventions, further studies are needed to corroborate a set of simple screens and more comprehensive assessment tools (43).

5.5.2 Expanding the understanding of cognitive and motor plasticity

Additionally, it would be interesting to find out how the Stroop and juggling balls, as a combined training, could potentially alleviate some of the age-related impairments in plasticity, including dementia and mild cognitive impairment. Future studies are probably able to investigate whether or not cognitive training has an ability to constitute both behavioral and neural changes, which could definitely develop the understanding of the mechanisms that underlie the training effects. Future studies can investigate the chronological space during which the transition from the neural plastic changes to behavioral changes can be detected. It is advisable to put an effort into undertaking the research to clarify the mechanisms causing the training-transfer effects. This is to increase the beneficial outcome of cognitive training for elderly people. Future study will effectively measure the important aspect of background, including other factors, as to allow elderly people to be able to take advantage of the cognitive training at the maximum level (37). The present findings pertain to increasing pieces of evidence suggesting that motor and cognitive improvement is possibly achieved among elderly people. In the larger scheme, randomized controlled studies are required to well establish effectiveness and the long-term retention effects of cognitive, motor function and falls risk in elderly people, as well as other groups of people, who also may have an increased possibility of falls (280).

5.5.3 Human centered design and related sensorimotor systems

Another interesting question for future studies concerns the potential benefit of multiple sensory stimulation interventions on the maintenance of cognition in elderly people, such as texture of finishing, lighting, and the sound of space that provides acoustic information on the environment. Next, the Stroop application and interface design in terms of color contrast ratio can help elderly people to detect the color easily. Typography designs for Thai elderly people can also help them to reduce time to define letters or words, such as proportion of a letter, dimension of the gap between letters and vowels. Also, other posited hazardous and safe shoe characteristics still require an evaluation in appropriate experimental and prospective epidemiological studies. In particular, required investigation is for the areas as follows: heel collar height, tread patterns and sole hardness. Furthermore, studies are required to determine whether there is only one optimal shoe type for elderly people in all circumstances or whether there are shoe characteristics that particularly suit certain conditions. For example, it needs to be determined whether a kind of shoe that is appropriate for wearing indoors is also appropriate for wearing outdoors. Studies are also required to identify the shoe characteristics that maximize balance in situations that predispose people to falls, such as wet and slippery floors, as well as uneven and icy surfaces (43).

5.5.4 Intensity and type of exercise intervention programs

Further work is required to identify the most effective exercise interventions for improving physical functioning and preventing falls in elderly people. Further studies have indicated that effective exercise programs consist of a range of challenging and progressive balance exercises performed in weight bearing positions, the purpose of which can reduce the use of the upper limbs for support. However, as the elderly population comprises a diverse group in relation to physical functioning, there will be no single effective exercise prescription. Specific studies are required to identify exercise components that are effective in maintaining balance, strength, coordination and ability to carry out functional activities in both a more vigorous, independent elderly population and in frailer groups (43).

5.5.5 Interventions for maximizing vision

Simple intervention strategies, such as expedited cataract surgery, have currently been represented as being able to decrease the fall rates in elderly people. Optical interventions also have the potential to develop contrast sensitivity, stereo acuity and depth perception along with visual acuity. No studies have examined the benefits of providing optimal glasses for distance vision, in spite of the result that multifocal eyeglasses appear to present a vital risk factor of a chance to fall in elderly people and that this may diminish with improved distance vision in situations that present a postural threat (e.g. walking on stairs or in unfamiliar outdoor settings). Since poor vision in one eye raises the risk of both falls and fracture-related falls, strategies to improve vision in both eyes could mainly help the prevention of falls (43).

5.5.6 Fear of falls

Many investigators have included neuropsychological assessments in studies of balance control and in screening batteries for predicting falls. These have shown that the attentional demands of balance control are varied in accordance with the complexity of the postural task, the nature of the secondary task, the age of the person and their balance capabilities. While poor performance in these tests may indicate a general cognitive decline, it provides interesting insights into the causes of falls. The issue of fear of falls has received considerable attention in the past few years. Balance confidence and falls efficacy measures have appeared to be associated with objectively assessed measures of maintaining balance or falling. Interestingly, there have been no studies stating that fear of falls is considered another independent risk factor for falls after the impaired balance and/or physical functional have been adjusted. This aspect therefore needs attention in further research studies (43).

5.5.7 Gait, balance, and cross-cultural assessments

Future studies are to suggest the underlying pathophysiological mechanisms for the relations of executive functions with gait and balance, as well as the capacity of telling the improvement of gait disorders and risk of falls (281). Further studies are required to enhance the understanding of human balance. In particular, work is needed to clarify whether impairments in vestibular function that lead to a reduced sense of the upright and/or unstable retinal images during head movements are significant causes of falling in elderly people. Contributions from the vestibular system to turning, stepping and gait also needs clarification. There is a clear need for the findings of laboratory studies to be tested in larger community samples where possible. Further research could identify lifestyle factors that account for cross-cultural differences in fall rates (43).

5.5.8 Proposed biopsychosocial models

Future study could be conducted extensively on the present findings by using biopsychosocial models that are proposed within dementia to lead the investigation of which cognitive, psychological and social factors have probable impact on falls. More understanding of these related factors may allow clinicians to modify their rehabilitation approach to the individual, and it could underpin the development of interventions (282).

5.5.9 Juggling as an intervention strategy

Further studies are suggested to evaluate the changing movement strategy in the five- and/or seven-ball cascade juggling, to examine if the maximum number of balls a juggler can handle is firmly related to a specific threshold of motion variability, and will also focus on the effect of expertise on the entire body posture (283) and/or might test this hypothesis by capturing with 3D cameras or with multiple cameras and 3D motion analysis techniques (284).

Having come to this point, the research still shows that the results are unable to state the facts about general motor skill learning and its development thorough the life span, due to the fact that this is a highly specific study and little or no transfer is found in the training from one motor skill to another. A good example of successful aging is the high plasticity in motor skill learning when a juggler is performing. It is found that with the development of patterns of new behavior among elderly people, they can still have a reaction to various situations and adjust to new circumstances. It is advisable to investigate motor performance and motor learning in tasks showing a firmer association to ADL in further studies that will also reveal more understandings of the potentials for elderly people. What is described in the present study is the development of motor plasticity of a gross motor skill pertaining to the coordination between eyes and hands throughout the lifespan. Causal explanations cannot be done with the found data. In order to realize the reasons for age-related differences, more tasks need to be done particularly on such respects as how the changes of neurophysiology will have an impact on motor skill learning performance (39).

Juggling is an example that is complex enough to show its interesting elements and simple enough to constitute the modeling of these elements. The performance has an involvement in both the outstanding use of hands and complex spatial perception, cognitive skills and posture. To study the dynamical elements of human perceptual-motor organization, it makes a provable experimental task. The present study shows posture created around a juggling spatial clock, the facilitation of which can be varied by different jugglers. Juggling can be performed reproducibly with anticipatory postural adjustments of the sacrum. The study of the coupling of posture with reverse cascade juggling would therefore be motivating, as it is known that reverse cascade juggling is a harder task of tossing the balls than a standard one (285).

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APPENDICES

APPENDIX I
DEMOGRAPHIC AND HEALTH QUESTIONNAIRE

Information	**Descriptions**	**Remarks**
Date		
Time		
Code no.		
Personal info		
Name		
Surname		
Sex		
Age (years)		
Education		
Occupation		
Status		
Religion		
No. of diseases		
No. of medications/day		
No. of falls		
Measurements		
Weight (cm)		
Height (cm)		
Rest HR (bpm)		
Rest SBP (mmHg)		
Rest DBP (mmHg)		
THAI-MMSE (score)		
Stroop level 1		
Total time (ms)		
No. of correct		
Time of correct (ms)		
No. of error		
Time of error (ms)		
Note: Juggling performance opinions/ Personal limitations		

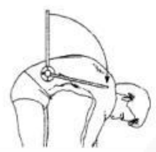
APPENDIX II

RANGE OF MOTION EVALUATION CHART

NAME OF PATIENT	CLIENT IDENTIFICATION NUMBER

INSTRUCTIONS: For each affected joint, please indicate the existing limitation of motion by drawing a line(s) on the figures below, showing the maximum possible range of motion or by notating the chart in degrees. Provide a complete description of all affected joints in your narrative summary. If range of motion was normal for all joints, please comment in your narrative summary. If joints which do not appear on this chart are affected, please indicate the degree of limited motion in your narrative.

1. Back

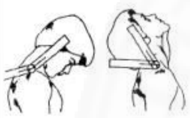


Extension 25°	Flexion 90°
Degrees	Degrees

2. Lateral (flexion)

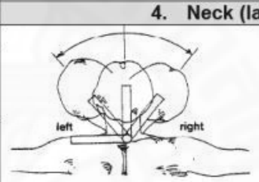
Left 25°	Right 25°
Degrees	Degrees

3. Neck



Extension 60°	Flexion 50°
Degrees	Degrees

4. Neck (lateral bending)

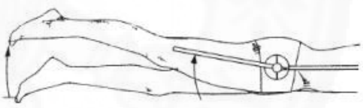


Left 45°	Right 45°
Degrees	Degrees

5. Neck (rotation)

Left 80°	Right 80°
Degrees	Degrees

6. Hip (backward extension)



Left 30°	Right 30°
Degrees	Degrees

7. Hip (flexion)

Left	
Knee Flexed 100°	Knee Extended 100°
Degrees	Degrees
Right	
Knee Flexed 100°	Knee Extended 100°
Degrees	Degrees

8. Hip (adduction)

Left 20°	Right 20°
Degrees	Degrees

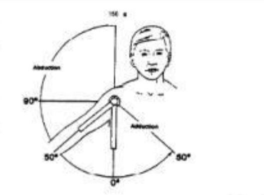
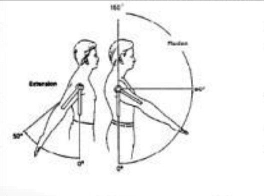
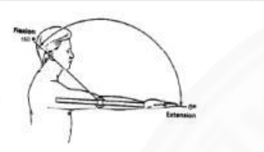
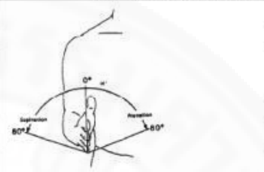
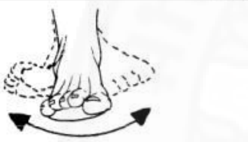
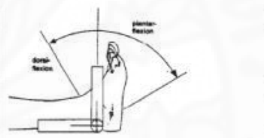
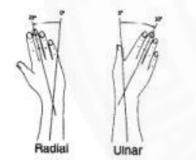
9. Hip (abduction)

Left 40°	Right 40°
Degrees	Degrees

10. Knee (flexion)

Left 150°	Right 150°
Degrees	Degrees

APPENDIX II
RANGE OF MOTION EVALUATION CHART (CONT.)

11. Shoulder (Abduction – Adduction)			12. Shoulder (Flexion – Extension)		
	Left			Left	
	Abduction 150°	Adduction 30°		Extension 50°	Flexion 150°
	Degrees	Degrees		Degrees	Degrees
	Right			Right	
	Abduction 150°	Adduction 30°		Extension 50°	Flexion 150°
	Degrees	Degrees		Degrees	Degrees
13. Elbow			**14. Forearm (Pronation – Supination)**		
	Left			Left	
	Extension 0°	Flexion 150°		Pronation 80°	Supination 80°
	Degrees	Degrees		Degrees	Degrees
	Right			Right	
	Extension 0°	Flexion 150°		Pronation 80°	Supination 80°
	Degrees	Degrees		Degrees	Degrees
15. Ankle			**16. Ankle (Flexion – Extension)**		
	Left			Left	
	Inversion 30°	Eversion 20°		Plantar 40°	Dorsal 20°
	Degrees	Degrees		Degrees	Degrees
	Right			Right	
	Inversion 30°	Eversion 20°		Plantar 40°	Dorsal 20°
	Degrees	Degrees		Degrees	Degrees
17. Wrist (radial, ulnar)			**18. Wrist**		
	Left			Left	
	Radial 20°	Ulnar 30°		Extension 60°	Flexion 60°
	Degrees	Degrees		Degrees	Degrees
	Right			Right	
	Radial 20°	Ulnar 30°		Extension 60°	Flexion 60°
	Degrees	Degrees		Degrees	Degrees
DATE OF EXAMINATION	EXAMINING PHYSICIAN'S SIGNATURE			DATE OF REPORT	

Adapted from the "Range of Joint Motion Evaluation Chart" of Washington State Department of Social and Health Services: DSHS 13-585A (REV. 03/2014)

APPENDIX III

CONTENT VALIDITY INDEX OF STROOP APPLICATION

Stroop items	Professor 1	Professor 2	Number in agreement	Item CVI
1	X	X	2	1.00
2	X	X	2	1.00
3	X	X	2	1.00
4	X	X	2	1.00
5	X	X	2	1.00
6	X	X	2	1.00
7	X	X	2	1.00
8	X	X	2	1.00
Proportion relevant	1.00	1.00	1.00	1.00

Content validity of individual items, proportion of content experts giving item a relevant rating of 3 or 4, I-CVI = 1.00. Proportion of items on a scale that achieves a relevance rating of 3 or 4 by all the experts, S-CVI/UA = 1.00. Average of the I-CVI for all items on the scale, S-CVI/Ave = 1.00.

Professor 1: Medical Engineering, Faculty of Medicine

Professor 2: Environmental Psychology, Faculty of Architecture and planning

APPENDIX IV
DEMOGRAPHIC CHARACTERISTICS OF ALL ELDERLY PARTICIPANTS

All elderly participants	**n (%)**
Sex	
Male	8 (28.6%)
Female	20 (71.4%)
Education	
Primary school (grade 4)	12 (42.9%)
Secondary school (grade 6)	1 (3.6%)
Junior high school	3 (10.7%)
Senior high school	3 (10.7%)
Bachelor degree	8 (28.6%)
Master degree	1 (3.6%)
Occupation in the past	
Government service	10 (35.7%)
Business owner	5 (17.9%)
Housewife	1 (3.6%)
Employee	3 (10.7%)
Farmer	2 (7.1%)
General contractor career	7 (25%)
Status	
Single	17 (60.7%)
Married	2 (7.1%)
Divorce	5 (17.9%)
Widow	4 (14.3%)
Religion	
Buddhism	28 (100%)

APPENDIX V
HEALTH CHARACTERISTICS OF ALL ELDERLY PARTICIPANTS

All elderly participants	**Mean (±SD)**
Age (years)	74.64 (±6.64)
Height (cm)	153.88 (±7.47)
Number of diseases	1.64 (±1.06)
Number of medications per day	1.14 (±1.01)
Number of falls	0.79 (±1.13)
THAI-MMSE (score)	26.71 (±2.55)

APPENDIX VI
DEMOGRAPHIC CHARACTERISTICS BETWEEN THE ELDERLY NON-FALLERS AND FALLERS GROUPS

	Elderly non-fallers n (%)	**Elderly fallers n (%)**	***P* value**
Sex			1.000
Male	4 (14.3%)	4 (14.3%)	
Female	10 (35.7%)	10 (35.7%)	
Education			0.123
Primary school	4 (14.3%)	8 (28.6%)	
Secondary school	1 (3.6%)	0	
Junior high school	2 (7.1%)	1 (3.6%)	
Senior high school	0	3 (10.7%)	
Bachelor degree	6 (21.4%)	2 (7.1%)	
Master degree	1 (3.6%)	0	
Occupation in the past			**0.016***
Government service	8 (28.6%)	2 (7.1%)	
Business owner	0	5 (17.9%)	
Housewife	0	1 (3.6%)	
Employee	3 (10.7%)	0	
Farmer	1 (3.6%)	1 (3.6%)	
General contractor career	2 (7.1%)	5 (17.9%)	
Status			0.630
Single	7 (25.0%)	10 (35.7%)	
Married	1 (3.6%)	1 (3.6%)	
Divorce	3 (10.7%)	2 (7.1%)	
Widow	3 (10.7%)	1 (3.6%)	
Religion			N/A
Buddhism	14 (50%)	14 (50%)	

* Significant at $P < 0.05$, N/A = Not available

APPENDIX VII
HEALTH CHARACTERISTICS BETWEEN THE ELDERLY NON-FALLERS AND FALLERS GROUPS

	Elderly non-fallers Mean (±SD)	**Elderly fallers Mean (±SD)**	***P* value**
Age (years)	74.43 (±6.32)	74.86 (±7.18)	0.868
Number of diseases	1.57 (±0.85)	1.71 (±1.26)	0.729
Number of medications per day	0.71 (±0.73)	1.57 (±1.09)	**0.021***
Number of falls	0	1.57 (±1.16)	**< 0.001***
THAI-MMSE (score)	28.07 (±2.24)	25.36 (±2.13)	**0.003***

* Significant at $P < 0.05$

APPENDIX VIII
PARTICIPANT CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS AT PRETEST

Pretest	**Elderly non-fallers Mean (±SD)**	**Elderly Fallers Mean (±SD)**	***P* value**
Weight (kg)	57.15 (±6.81)	50.19 (±7.12)	**0.014***
BMI (kg/m^2)	23.92 (±2.95)	21.41 (±2.31)	**0.019***
6MWT			
Rest HR (bpm)	75.93 (±6.29)	80.50 (±8.87)	0.128
Rest SBP (mm Hg)	145.71 (±20.25)	147.21 (±14.57)	0.824
Rest DBP (mm Hg)	73.14 (±10.44)	68.79 (±10.29)	0.276
Distance (meters)	379.95 (±91.67)	376.66 (±72.58)	0.917
Velocity (m/min)	63.33 (±15.28)	62.78 (±12.10)	0.917
$VO_{2\ max}$ ($ml/kg^{-1}/min^{-1}$)	29.41 (±2.78)	30.29 (±3.56)	0.473
MET	2.80 (±0.44)	2.79 (±0.35)	0.917
VA (decimal notation)			
Right side	0.28 (±0.17)	0.16 (±0.22)	0.116
Left side	0.31 (±0.20)	0.12 (±0.13)	**0.006***
Right side with glasses	0.33 (±0.17)	0.21 (±0.23)	0.307
Left side with glasses	0.30 (±0.23)	0.17 (±0.22)	0.309
Finger-nose test			
Number of incorrect answers on the right hand	0.14 (±0.36)	0.93 (±0.92)	**0.008***
Time spent with all answers on the right hand (second)	12.30 (±3.11)	15.63 (±4.85)	**0.039***
Number of incorrect answers on the left hand	0.21 (±0.58)	0.43 (±0.65)	0.364
Time spent with all answers on the left hand (second)	12.12 (±3.35)	14.74 (±4.40)	0.088
Toe position sense			
Number of incorrect answers on the right foot	0.43 (±1.09)	0.43 (±1.09)	1.000
Number of incorrect answers on the left foot	0.29 (±0.83)	0.36 (±0.63)	0.799
TPD (mm)			
Metatarsal of the right foot	25.93 (±7.63)	29.79 (±11.68)	0.310
Metatarsal of the left foot	30.43 (±10.90)	31.21 (±14.79)	0.874
Toe of the right foot	21.21 (±5.56)	18.64 (±5.93)	0.247
Toe of the left foot	22.14 (±5.53)	19.93 (±5.72)	0.307

* Significant at $P < 0.05$

APPENDIX IX

PARTICIPANT CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS AT MIDTEST

Midtest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Weight (kg)	56.28 (±7.03)	49.23 (±6.72)	**0.012***
BMI (kg/m^2)	23.56 (±3.12)	21.02 (±2.36)	**0.022***
6MWT			
Rest HR (bpm)	73.36 (±8.32)	80.71 (±10.48)	**0.050***
Rest SBP (mm Hg)	138.29 (±20.57)	149.71 (±14.64)	0.102
Rest DBP (mm Hg)	67.79 (±8.83)	71.79 (±8.97)	0.245
Distance (meters)	384.41 (±77.73)	363.87 (±75.29)	0.484
Velocity (m/min)	64.07 (±12.95)	60.65 (±12.55)	0.484
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	30.25 (±2.21)	30.22 (±3.88)	0.977
MET	2.83 (±0.37)	2.73 (±0.36)	0.484
VA (decimal notation)			
Right side	0.29 (±0.15)	0.18 (±0.26)	0.191
Left side	0.31 (±0.20)	0.12 (±0.16)	**0.008***
Right side with glasses	0.39 (±0.17)	0.23 (±0.21)	0.152
Left side with glasses	0.37 (±0.21)	0.20 (±0.21)	0.154
Finger-nose test			
Number of incorrect answers on the right hand	0.14 (±0.36)	0.29 (±0.61)	0.459
Time spent with all answers on the right hand (second)	8.82 (±2.24)	14.74 (±5.51)	**0.002***
Number of incorrect answers on the left hand	0.71 (±0.83)	0.36 (±0.63)	0.210
Time spent with all answers on the left hand (second)	7.81 (±2.36)	10.17 (±2.12)	**0.010***
Toe position sense			
Number of incorrect answers on the right foot	0.14 (±0.36)	0.21 (±0.42)	0.637
Number of incorrect answers on the left foot	0.21 (±0.43)	0.07 (±0.27)	0.299

* Significant at $P < 0.05$

APPENDIX X

PARTICIPANT CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS AT POSTTEST

Posttest	**Elderly non-fallers** **Mean (±SD)**	**Elderly fallers** **Mean (±SD)**	***P* value**
Weight (kg)	27.19 (±7.19)	49.34 (±6.72)	**0.006***
BMI (kg/m^2)	23.94 (±3.17)	21.06 (±2.27)	**0.010***
6MWT			
Rest HR (bpm)	75.14 (±8.54)	83.07 (±11.21)	**0.045***
Rest SBP (mm Hg)	140.86 (±18.07)	152.93 (±14.34)	0.061
Rest DBP (mm Hg)	72.07 (±12.41)	73.21 (±9.86)	0.789
Distance (meters)	389.08 (±88.60)	390.44 (±57.69)	0.962
Velocity (m/min)	64.85 (±14.77)	65.07 (±9.61)	0.962
$VO_{2\ max}$ ($ml/kg^{-1}/min^{-1}$)	29.76 (±2.60)	30.34 (±3.92)	0.644
MET	2.85 (±0.42)	2.86 (±0.27)	0.962
VA (decimal notation)			
Right side	0.26 (±0.13)	0.20 (±0.24)	0.442
Left side	0.29 (±0.16)	0.12 (±0.13)	**0.005***
Right side with glasses	0.34 (±0.17)	0.24 (±0.25)	0.401
Left side with glasses	0.31 (±0.25)	0.17 (±0.20)	0.256
Finger-nose test			
Number of incorrect answers on the right hand	0.50 (±0.65)	0.43 (±0.76)	0.791
Time spent with all answers on the right hand (second)	8.44 (±2.60)	10.50 (±2.36)	**0.037***
Number of incorrect answers on the left hand	0.29 (±0.61)	0.36 (±0.50)	0.737
Time spent with all answers on the left hand (second)	6.69 (±1.71)	8.22 (±1.82)	**0.030***
Toe position sense			
Number of incorrect answers on the right foot	0	0	N/A
Number of incorrect answers on the left foot	0	0	N/A
TPD (mm)			
Metatarsal of the right foot	24.79 (±4.61)	26.50 (±6.77)	0.441
Metatarsal of the left foot	25.14 (±4.06)	25.14 (±7.32)	1.000
Toe of the right foot	19.86 (±4.07)	21.57 (±7.18)	0.444
Toe of the left foot	20.57 (±3.61)	20.71 (±70)	0.945

* Significant at $P < 0.05$

APPENDIX XI
ALL ELDERLY PARTICIPANTS' CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST

All elderly participants	**Pretest Mean (±SD)**	**Midtest Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Weight (kg)	53.67 (±7.70) a	52.74 (±7.64) a	53.26 (±7.92)	**< 0.001***
BMI (kg/m^2)	22.66 (±2.90) b	22.29 (±3.01) b	22.50 (±3.07)	**< 0.001***
6MWT				
Rest HR (bpm)	78.21 (±7.90)	77.04 (±10.01)	79.11 (±10.58)	0.294
Rest SBP (mm Hg)	146.46 (±17.32)	144.00 (±18.46)	146.89 (±17.15)	0.599
Rest DBP (mm Hg)	70.96 (±10.41)	69.79 (±8.97)	72.64 (±11.01)	0.117
Distance (meters)	378.31 (±81.15)	374.14 (±75.81)	389.76 (±73.37)	0.279
Velocity (m/min)	63.05 (±13.52)	62.36 (±12.64)	64.96 (±12.23)	0.279
$VO_{2\,max}$ (ml/kg^{-1}/min^{-1})	29.85 (±3.17)	30.23 (±3.10)	30.05 (±3.28)	0.515
MET	2.80 (±0.39)	2.78 (±0.36)	2.86 (±0.35)	0.279
VA (decimal notation)				
Right side	0.22 (±0.20)	0.23 (±0.21)	0.23 (±0.19)	0.779
Left side	0.21 (±0.19)	0.22 (±0.20)	0.21 (±0.17)	0.878
Right side with glasses	0.27 (±0.20)	0.31 (±0.20)	0.29 (±0.21)	0.312
Left side with glasses	0.24 (±0.23)	0.29 (±0.22)	0.24 (±0.23)	0.248
Finger-nose test				
Number of incorrect answers on the right hand	0.54 (±0.79)	0.21 (±0.50)	0.46 (±0.69)	0.097
Time spent with all answers on the right hand (second)	13.97 (±4.34) c	11.78 (±5.11) d	9.47 (±2.65) c, d	**< 0.001***
Number of incorrect answers on the left hand	0.32 (±0.61)	0.54 (±0.74)	0.32 (±0.55)	0.509
Time spent with all answers on the left hand (second)	13.43 (±4.06) e, f	8.99 (±2.51) e, g	7.46 (±1.90) g, f	**< 0.001***
Toe position sense				
Number of incorrect answers on the right foot	0.43 (±1.07)	0.18 (±0.39) h	0 h	**0.031***
Number of incorrect answers on the left foot	0.32 (±0.72)	0.14 (±0.36)	0	0.072
TPD (mm)				
Metatarsal of the right foot	27.86 (±9.88)	N/A	25.64 (±5.75)	0.178
Metatarsal of the left foot	30.82 (±12.75)	N/A	25.14 (±5.80)	**0.014***
Toe of the right foot	19.93 (±5.79)	N/A	20.71 (±5.79)	0.568
Toe of the left foot	21.04 (±5.63)	N/A	20.64 (±5.28)	0.747

* Significant at $P < 0.05$, N/A = Not available

APPENDIX XII
ELDERLY NON-FALLERS' CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST

Elderly non-fallers	**Pretest Mean (±SD)**	**Midtest Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Weight (kg)	57.15 (±6.81) a	56.28 (±7.03) a	57.19 (±7.19)	**0.012***
BMI (kg/m^2)	23.92 (±2.95) b	23.56 (±3.12) b	23.94 (±3.17)	**0.013***
6MWT				
Rest HR (bpm)	75.93 (±6.29)	73.36 (±8.32)	75.14 (±8.54)	0.326
Rest SBP (mm Hg)	145.71 (±20.25)	138.29 (±20.57)	140.86 (±18.07)	0.184
Rest DBP (mm Hg)	73.14 (±10.44)	67.79 (±8.83) c	72.07 (±12.41) c	**0.023***
Distance (meters)	379.95 (±91.67)	384.41 (±77.73)	389.08 (±88.60)	0.774
Velocity (m/min)	63.33 (±15.28)	64.07 (±12.95)	64.85 (±14.77)	0.774
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	29.41 (±2.78)	30.25 (±2.21)	29.76 (±2.60)	0.098
MET	2.80 (±0.44)	2.83 (±0.37)	2.85 (±0.42)	0.774
VA (decimal notation)				
Right side	0.28 (±0.17)	0.29 (±0.15)	0.26 (±0.13)	0.615
Left side	0.31 (±0.20)	0.31 (±0.20)	0.29 (±0.16)	0.850
Right side with glasses	0.33 (±0.17)	0.39 (±0.17)	0.34 (±0.17)	0.127
Left side with glasses	0.30 (±0.23)	0.37 (±0.21)	0.31 (±0.25)	0.471
Finger-nose test				
Number of incorrect answers on the right hand	0.14 (±0.36)	0.14 (±0.36)	0.50 (±0.65)	0.254
Time spent with all answers on the right hand (second)	12.30 (±3.11) d, e	8.82 (±2.24) d	8.44 (±2.60) e	**0.002***
Number of incorrect answers on the left hand	0.21 (±0.58)	0.71 (±0.83)	0.29 (±0.61)	0.203
Time spent with all answers on the left hand (second)	12.12 (±3.35) f, g	7.81 (±2.36) f	6.69 (±1.71) g	**< 0.001**
Toe position sense				
Number of incorrect answers on the right foot	0.43 (±1.09)	0.14 (±0.36)	0	0.324
Number of incorrect answers on the left foot	0.29 (±0.83)	0.21 (±0.43)	0	0.235
TPD (mm)				
Metatarsal of the right foot	25.93 (±7.63)	N/A	24.79 (±4.61)	0.554
Metatarsal of the left foot	30.43 (±10.90)	N/A	25.14 (±4.06)	0.074
Toe of the right foot	21.21 (±5.56)	N/A	19.86 (±4.07)	0.536
Toe of the left foot	22.14 (±5.53)	N/A	20.57 (±3.61)	0.449

* Significant at $P < 0.05$, N/A = Not available

APPENDIX XIII
ELDERLY FALLERS' CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST

Elderly fallers	**Pretest Mean (±SD)**	**Midtest Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Weight (kg)	50.19 (±7.12) a, b	49.23 (±6.72) a	49.34 (±6.72) b	**0.022***
BMI (kg/m^2)	21.41 (±2.31) c, d	21.02 (±2.36) c	21.06 (±2.27) d	**0.022***
6MWT				
Rest HR (bpm)	80.50 (±8.87)	80.71 (±10.48)	83.07 (±11.21)	0.636
Rest SBP (mm Hg)	147.21 (±14.57)	149.71 (±14.64)	152.93 (±14.34)	0.220
Rest DBP (mm Hg)	68.79 (±10.29)	71.79 (±8.97)	73.21 (±9.86)	0.205
Distance (meters)	376.66 (±72.58)	363.87 (±75.29)	390.44 (±57.69)	0.332
Velocity (m/min)	62.78 (±12.10)	60.65 (±12.55)	65.07 (±9.61)	0.332
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	30.29 (±3.56)	30.22 (±3.88)	30.34 (±3.92)	0.977
MET	2.79 (±0.35)	2.73 (±0.36)	2.86 (±0.27)	0.332
VA (decimal notation)				
Right side	0.16 (±0.22)	0.18 (±0.26)	0.20 (±0.24)	0.483
Left side	0.12 (±0.13)	0.12 (±0.16)	0.12 (±0.13)	1.000
Right side with glasses	0.21 (±0.23)	0.23 (±0.21)	0.24 (±0.25)	0.649
Left side with glasses	0.17 (±0.22)	0.20 (±0.21)	0.17 (±0.20)	0.625
Finger-nose test				
Number of incorrect answers on the right hand	0.93 (±0.92)	0.29 (±0.61)	0.43 (±0.76)	0.107
Time spent with all answers on the right hand (second)	15.63 (±4.85) e	14.74 (±5.51) f	10.50 (±2.36) e, f	**0.007***
Number of incorrect answers on the left hand	0.43 (±0.65)	0.36 (±0.63)	0.36 (±0.50)	0.915
Time spent with all answers on the left hand (second)	14.74 (±4.40) g, h	10.17 (±2.12) g, i	8.22 (±1.82) h, i	**0.001***
Toe position sense				
Number of incorrect answers on the right foot	0.43 (±1.09)	0.21 (±0.42)	0	0.103
Number of incorrect answers on the left foot	0.36 (±0.63)	0.07 (±0.27)	0	0.133
TPD (mm)				
Metatarsal of the right foot	29.79 (±11.68)	N/A	26.50 (±6.77)	0.234
Metatarsal of the left foot	31.21 (±14.79)	N/A	25.14 (±7.32)	0.102
Toe of the right foot	18.64 (±5.93)	N/A	21.57 (±7.18)	0.082
Toe of the left foot	19.93 (±5.72)	N/A	20.71 (±70)	0.567

* Significant at $P < 0.05$, N/A = Not available

APPENDIX XIV

STROOP TEST OF ALL ELDERLY PARTICIPANTS

Level	**All elderly participants**	**Mean (±SD)**
1	Total time spent taking the test (second)	23.57 (±5.62)
	Number of correct answers (count)	19.96 (±0.14)
	Time spent obtaining correct answers (second)	23.48 (±5.47)
	Number of incorrect answers (count)	0.04 (±0.14)
	Time spent obtaining incorrect answers (second)	0.09 (±0.38)
2	Total time spent taking the test (second)	29.39 (±9.16)
	Number of correct answers (count)	19.61 (±1.15)
	Time spent obtaining correct answers (second)	28.47 (±7.06)
	Number of incorrect answers (count)	0.39 (±1.15)
	Time spent obtaining incorrect answers (second)	0.93 (±3.67)
3	Total time spent taking the test (second)	34.42 (±14.33)
	Number of correct answers (count)	19.48 (±1.38)
	Time spent obtaining correct answers (second)	33.42 (±13.23)
	Number of incorrect answers (count)	0.52 (±1.38)
	Time spent obtaining incorrect answers (second)	1.00 (±2.57)
4	Total time spent taking the test (second)	80.06 (±30.04)
	Number of correct answers (count)	19.07 (±1.82)
	Time spent obtaining correct answers (second)	76.87 (±29.65)
	Number of incorrect answers (count)	0.93 (±1.82)
	Time spent obtaining incorrect answers (second)	3.19 (±3.79)
5	Total time spent taking the test (second)	21.69 (±4.56)
	Number of correct answers (count)	19.98 (±0.13)
	Time spent obtaining correct answers (second)	21.68 (±4.55)
	Number of incorrect answers (count)	0.02 (±0.13)
	Time spent obtaining incorrect answers (second)	0.01 (±0.05)
6	Total time spent taking the test (second)	26.58 (±8.42)
	Number of correct answers (count)	19.96 (±0.10)
	Time spent obtaining correct answers (second)	26.54 (±8.45)
	Number of incorrect answers (count)	0.04 (±0.10)
	Time spent obtaining incorrect answers (second)	0.04 (±0.13)
7	Total time spent taking the test (second)	34.82 (±17.20)
	Number of correct answers (count)	19.56 (±0.91)
	Time spent obtaining correct answers (second)	33.58 (±16.14)
	Number of incorrect answers (count)	0.44 (±0.91)
	Time spent obtaining incorrect answers (second)	1.24 (±3.08)
8	Total time spent taking the test (second)	133.90 (±48.50)
	Number of correct answers (count)	18.94 (±1.26)
	Time spent obtaining correct answers (second)	127.71 (±45.99)
	Number of incorrect answers (count)	1.06 (±1.26)
	Time spent obtaining incorrect answers (second)	6.19 (±6.89)

APPENDIX XV
STROOP TEST BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS

Level		Elderly non-fallers Mean (±SD)	Elderly fallers Mean (±SD)	*P* value
1	Total time spent taking the test (second)	22.07 (±5.80)	25.08 (±5.20)	0.160
	Number of correct answers (count)	20.00 (±0.00)	19.93 (±0.19)	0.189
	Time spent obtaining correct answers (second)	22.07 (±5.80)	24.90 (±4.92)	0.175
	Number of incorrect answers (count)	0	0.07 (±0.19)	0.189
	Time spent obtaining incorrect answers (second)	0	0.18 (±0.54)	0.228
2	Total time spent taking the test (second)	26.64 (±7.10)	32.14 (±10.36)	0.114
	Number of correct answers (count)	19.93 (±0.27)	19.29 (±1.57)	0.144
	Time spent obtaining correct answers (second)	26.59 (±7.06)	30.34 (±6.79)	0.163
	Number of incorrect answers (count)	0.07 (±0.27)	0.71 (±1.57)	0.144
	Time spent obtaining incorrect answers (second)	0.06 (±0.21)	1.80 (±5.12)	0.226
3	Total time spent taking the test (second)	30.58 (±14.20)	38.26 (±13.89)	0.160
	Number of correct answers (count)	19.76 (±0.71)	19.19 (±1.82)	0.288
	Time spent obtaining correct answers (second)	29.98 (±12.73)	36.85 (±13.27)	0.175
	Number of incorrect answers (count)	0.24 (±0.71)	0.81 (±1.82)	0.288
	Time spent obtaining incorrect answers (second)	0.60 (±2.06)	1.41 (±3.03)	0.411
4	Total time spent taking the test (second)	67.13 (±23.57)	92.98 (±30.97)	**0.020***
	Number of correct answers (count)	19.64 (±0.70)	18.50 (±2.38)	0.105
	Time spent obtaining correct answers (second)	65.88 (±22.89)	87.86 (±32.28)	**0.048***
	Number of incorrect answers (count)	0.36 (±0.70)	1.50 (±2.38)	0.105
	Time spent obtaining incorrect answers (second)	1.25 (±2.68)	5.12 (±8.97)	0.143
5	Total time spent taking the test (second)	20.05 (±4.91)	23.34 (±3.64)	0.054
	Number of correct answers (count)	19.95 (±0.18)	20.00 (±0.00)	0.336
	Time spent obtaining correct answers (second)	20.03 (±4.88)	23.34 (±3.64)	0.052
	Number of incorrect answers (count)	0.05 (±0.18)	0	0.336
	Time spent obtaining incorrect answers (second)	0.02 (±0.08)	0	0.336
6	Total time spent taking the test (second)	23.82 (±5.85)	29.34 (±9.83)	0.083
	Number of correct answers (count)	19.93 (±0.14)	20.00 (±0.00)	0.082
	Time spent obtaining correct answers (second)	23.74 (±5.90)	29.34 (±9.83)	0.079
	Number of incorrect answers (count)	0.07 (±0.14)	0	0.082
	Time spent obtaining incorrect answers (second)	0.08 (±0.18)	0	0.107
7	Total time spent taking the test (second)	27.04 (±8.87)	42.60 (±20.13)	**0.016***
	Number of correct answers (count)	19.90 (±00.28)	19.21 (±1.18)	0.051
	Time spent obtaining correct answers (second)	26.87 (±8.68)	40.28 (±19.21)	**0.029***
	Number of incorrect answers (count)	0.10 (±0.28)	0.79 (±1.18)	0.051
	Time spent obtaining incorrect answers (second)	0.17 (±0.43)	2.32 (±4.12)	0.073
8	Total time spent taking the test (second)	112.15 (±49.12)	155.65 (±38.13)	**0.015***
	Number of correct answers (count)	19.19 (±1.04)	18.69 (±1.45)	0.304
	Time spent obtaining correct answers (second)	108.16 (±47.14)	147.26 (±36.71)	**0.021***
	Number of incorrect answers (count)	0.81 (±1.04)	1.31 (±1.45)	0.304
	Time spent obtaining incorrect answers (second)	3.99 (±8.38)	8.38 (±7.30)	0.092

* Significant at $P < 0.05$

APPENDIX XVI
STROOP TEST AMONG 8 LEVELS OF ALL ELDERLY PARTICIPANTS

Mean (±SD)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**	***P* value**
Total time spent taking the test (second)	23.57 (±5.62) a, b, c, d, e	29.39 (±9.17) a, f, g, h	34.42 (±14.33) b, i, j, k	80.06 (±30.04) c, f, i, l, m, n, o	21.69 (±4.56) g, j, l, p, q, r	26.58 (±8.42) m, p, s	34.82 (±17.20) d, n, q, t	133.90 (±48.50) e, h, k, o, r, s, t	**< 0.001***
Number of correct answers (count)	19.96 (±0.14) a	19.06 (±1.15)	19.48 (±1.38)	19.07 (±1.82)	19.97 (±0.13) b	19.96 (±0.10) c	19.56 (±0.91)	18.95 (±1.26) a, b, c	**0.030***
Time spent obtaining correct answers (second)	23.48 (±5.47) a, b, c, d, e	28.47 (±7.06) a, f, g, h	33.42 (±13.23) b, i, j, k	76.87 (±29.65) c, f, i, l, m, n, o	21.68 (±4.55) g, j, l, p, q, r	26.54 (±8.45) m, p, s	33.58 (±16.14) d, n, q, t	127.71 (±45.99) e, h, k, o, r, s, t	**< 0.001***
Number of incorrect answers (count)	0.04 (±0.14) a	0.39 (±1.15)	0.52 (±1.38)	0.93 (±1.82)	0.02 (±0.13) b	0.04 (±0.10) c	0.44 (±0.91)	1.06 (±1.26) a, b, c	**0.030***
Time spent obtaining incorrect answers (second)	0.89 (±0.38) a	0.93 (±3.67)	1.00 (±2.57) b	3.19 (±6.79)	0.01 (±0.05) c	0.04 (±0.13) d	1.24 (±3.08) e	6.19 (±6.89) a, b, c, d, e	**0.014***

* Significant at *P* < 0.05

APPENDIX XVII
STROOP TEST AMONG 8 LEVELS OF ELDERLY NON-FALLERS

Mean (±SD)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**	***P* value**
Total time spent taking the test (second)	22.07 (±5.80) a, b, c	26.64 (±7.10) a, d, e, f, g	30.58 (±14.20) h, i	67.13 (±23.57) b, d, h, j, k, l, m	20.05 (±4.91) e, j, n, o	23.82 (±5.85) f, k, p	27.04 (±8.87) l, n, q	112.15 (±49.12) c, g, i, m, o, p, q	**0.002***
Number of correct answers (count)	20.00	19.93 (±0.27)	19.76 (±0.71)	19.64 (±0.70)	19.95 (±0.18)	19.93 (±0.14)	19.90 (±00.28)	19.19 (±1.04)	0.281
Time spent obtaining correct answers (second)	22.07 (±5.80) a, b, c	26.59 (±7.06) a, d, e, f, g	29.98 (±12.73) h, i, j	65.88 (±22.89) b, d, h, k l, m, n	20.03 (±4.88) e, i, k, o, p	23.74 (±5.90) f, l, q	26.87 (±8.68) m, o, r	108.16 (±47.14) c, g, j, n, p, q, r	**0.002***
Number of incorrect answers (count)	0	0.07 (±0.27)	0.24 (±0.71)	0.36 (±0.70)	0.05 (±0.18)	0.07 (±0.14)	0.10 (±0.28)	0.81 (±1.04)	0.281
Time spent obtaining incorrect answers (second)	0	0.06 (±0.21)	0.60 (±2.06)	1.25 (±2.68)	0.02 (±0.08)	0.08 (±0.18)	0.17 (±0.43)	3.99 (±8.38)	0.331

* Significant at $P < 0.05$

APPENDIX XVIII
STROOP TEST AMONG 8 LEVELS OF ELDERLY FALLERS

Mean (±SD)	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	*P* value
Total time spent taking the test (second)	25.08 (±5.20) a, b	32.14 (±10.36) c, d	38.26 (±13.89) e, f, g	92.98 (±30.97) a, c, e, h, i, j, k	23.34 (±3.64) f, h, l, m	29.34 (±9.83) i, n	42.60 (±20.13) j, l, o	155.65 (±38.13) b, d, g, k m, n, o	**< 0.001***
Number of correct answers (count)	19.93 (±0.19)	19.29 (±1.57)	19.19 (±1.82)	18.50 (±2.38)	20.00	20.00	19.21 (±1.18)	18.69 (±1.45)	0.072
Time spent obtaining correct answers (second)	24.90 (±4.92) a, b, c	30.34 (±6.79) a, d, e, f	36.85 (±13.27) g, h, i	87.86 (±32.28) b, d, g, j, k, l, m	23.34 (±3.64) e, h, j, n	29.34 (±9.83) k, o	40.28 (±19.21) l, p	147.26 (±36.71) c, f, i, m, n, o, p	**< 0.001***
Number of incorrect answers (count)	0.07 (±0.19)	0.71 (±1.57)	0.81 (±1.82)	1.50 (±2.38)	0	0	0.79 (±1.18)	1.31 (±1.45)	0.072
Time spent obtaining incorrect answers (second)	0.18 (±0.54)	1.80 (±5.12)	1.41 (±3.03)	5.12 (±8.97)	0	0	2.32 (±4.12)	8.38 (±7.30)	0.065

* Significant at *P* < 0.05

APPENDIX XIX
JUGGLING PERFORMANCES

JUGGLING PERFORMANCE OF ALL ELDERLY PARTICIPANTS

All elderly participants	**Mean (±SD)**
Week 1 (second)	1.19 (±0.22)
Week 2 (second)	1.20 (±0.24)
Week 3 (second)	1.36 (±0.45)
Week 4 (second)	1.91 (±0.48)
Week 5 (second)	1.14 (±0.42)
Week 6 (second)	2.24 (±0.87)
Week 7 (second)	3.96 (±1.86)
Week 8 (second)	3.09 (±1.66)

JUGGLING PERFORMANCE BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS

Time spent with the task (second)	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Week 1	1.04 (±0.15)	1.33 (±0.19)	**< 0.001***
Week 2	1.06 (±0.08)	1.34 (±0.26)	**0.002***
Week 3	1.09 (±0.13)	1.64 (±0.49)	**0.001***
Week 4	1.69 (±0.38)	2.14 (±0.48)	**0.011***
Week 5	0.95 (±0.08)	1.34 (±0.53)	**0.018***
Week 6	1.71 (±0.54)	2.77 (±0.82)	**< 0.001***
Week 7	2.73 (±1.00)	5.19 (±1.71)	**< 0.001***
Week 8	1.91 (±0.66)	4.28 (±1.50)	**< 0.001***

* Significant at $P < 0.05$

APPENDIX XX
JUGGLING PERFORMANCE AMONG 8 WEEKS

ALL ELDERLY PARTICIPANTS

Mean (±SD)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	*P* value
Total time (second)	1.19 (±0.22) a, b, c, d	1.20 (±0.24) e, f, g, h	1.36 (±0.45) i, j, k, l	1.91 (±0.48) a, e, i, m, n, o	1.14 (±0.42 m, p, q, r	2.24 (±0.87) b, f, j, p, s, t	3.96 (±1.86) c, g, k, n, q, s, u	3.09 (±1.66) d, h, l, o, r, t, u	**< 0.001***

* Significant at $P < 0.05$

ELDERLY NON-FALLERS

Mean (±SD)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	*P* value
Total time (second)	1.04 (±0.15) a, b, c, d	1.06 (±0.08) e, f, g, h	1.09 (±0.13) i, j, k, l, m	1.69 (±0.38) a, e, i, n, o	0.95 (±0.08) j, n, p, q, r	1.71 (±0.54) b, f, k, p, s	2.73 (±1.00) c, g, l, o, q, s, t	1.91 (±0.66) d, h, m, r, t	**0.006***

* Significant at $P < 0.05$

ELDERLY FALLERS

Mean (±SD)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	*P* value
Total time (second)	1.33 (±0.19) a, b, c, d	1.34 (±0.26) e, f, g, h	1.64 (±0.49) i, j, k	2.14 (±0.48) a, e, l, m, n	1.34 (±0.53) l, o, p, q	2.77 (±0.82) b, f, i, o, r	5.19 (±1.71) c, g, j, m, p, r	4.28 (±1.50) d, h, k, n, q	**0.001***

* Significant at $P < 0.05$

APPENDIX XXI
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SITTING POSITION AT PRETEST

Sitting position at pretest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	825.06 (±96.88)	781.90 (±86.89)	0.226
STD RR (ms)	25.74 (±39.07)	17.09 (±6.98)	0.422
Mean HR (1/min)	115.79 (±154.04)	77.62 (±8.26)	0.363
STD HR (1/min)	2.74 (±4.94)	1.66 (±0.60)	0.427
RMSSD (ms)	30.17 (±67.71)	12.62 (±5.67)	0.343
NN50 (count)	13.21 (±43.92)	1.43 (±3.06)	0.326
pNN50 (%)	2.95 (±9.84)	0.36 (±0.77)	0.336
RR triangular index	4.96 (±1.65)	5.17 (±1.75)	0.747
TINN (ms)	108.57 (±129.71)	83.57 (±31.04)	0.489
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	37.10 (±23.24)	53.59 (±21.92)	0.064
HF (0.15-0.4 Hz)	62.90 (±23.24)	46.41 (±21.92)	0.064
LF/HF	0.85 (±0.80)	1.75 (±1.61)	0.074
Nonlinear Results			
Poincare plot			
SD1 (ms)	21.37 (±47.93)	8.94 (±4.01)	0.342
SD2 (ms)	27.33 (±29.65)	22.36 (±9.27)	0.555
SD2/SD1	2.58 (±1.64)	2.68 (±0.69)	0.838
Recurrence plot (beats)			
Lmean	15.54 (±9.78)	11.95 (±2.78)	0.207
Lmax	218.64 (±144.69)	239.79 (±129.14)	0.687
REC (%)	32.87 (±12.61)	34.32 (±6.78)	0.709
DET (%)	97.47 (±1.83)	98.01 (±0.97)	0.347
ShanEn	3.34 (±0.54)	3.24 (±0.21)	0.564
Other			
ApEn	1.05 (±0.20)	1.19 (±0.60)	**0.015***
SampEn	1.46 (±0.43)	1.62 (±0.17)	0.199
DFA α1	0.72 (±0.32)	0.96 (±0.25)	**0.033***
DFA α2	1.10 (±0.27)	1.08 (±0.20)	0.798
D2	0.12 (±0.15)	0.17 (±0.21)	0.515
PTT	0.22 (±0.02)	0.22 (±0.02)	0.921

* Significant at $P < 0.05$

APPENDIX XXII
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SITTING POSITION AT MIDTEST

Sitting position at midtest	**Elderly non-fallers** **Mean (±SD)**	**Elderly fallers** **Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	846.04 (±66.80)	766.74 (±108.64)	**0.028***
STD RR (SDNN) (ms)	34.70 (±50.26)	26.18 (±16.73)	0.552
Mean HR (1/min)	71.71 (±5.71)	79.81 (±10.74)	**0.019***
STD HR (1/min)	3.23 (±4.80)	3.05 (±3.15)	0.904
RMSSD (ms)	46.56 (±90.59)	25.28 (±20.55)	0.399
NN50 (count)	36.50 (±89.77)	21.43 (±26.59)	0.552
pNN50 (%)	9.10 (±21.44)	5.34 (±6.58)	0.539
RR triangular index	5.55 (±2.34)	5.50 (±1.94)	0.945
TINN (ms)	136.79 (±107.98)	132.86 (±97.46)	0.920
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	33.37 (±24.50)	42.79 (±23.70)	0.311
HF (0.15-0.4 Hz)	66.63 (±24.50)	57.21 (±23.70)	0.311
LF/HF	0.75 (±0.78)	1.36 (±1.79)	0.254
Nonlinear Results			
Poincare plot			
SD1 (ms)	32.95 (±64.13)	17.91 (±14.55)	0.400
SD2 (ms)	33.39 (±34.16)	32.07 (±19.29)	0.901
SD2/SD1	2.08 (±1.07)	2.28 (±1.24)	0.650
Recurrence plot (beats)			
Mean line length (Lmean)	29.44 (±52.84)	14.91 (±9.06)	0.320
Max line length (Lmax)	222.00 (±114.14)	167.93 (±115.28)	0.223
Recurrence rate (REC) (%)	38.02 (±17.97)	36.13 (±14.79)	0.763
Determinism (DET) (%)	97.96 (±1.86)	97.87 (±1.58)	0.900
Shannon Entropy (ShanEn)	3.38 (±0.56)	3.26 (±0.52)	0.548
Other			
Approximate entropy (ApEn)	1.03 (±0.29)	1.08 (±0.19)	0.609
Sample entropy (SampEn)	1.36 (±0.46)	1.34 (±0.43)	0.885
Detrended fluctuations (DFA): α1	0.69 (±0.36)	0.87 (±0.28)	0.152
Detrended fluctuations (DFA): α2	0.91 (±0.34)	0.90 (±0.34)	0.914
Correlation dimension (D2)	0.45 (±1.05)	0.59 (±0.65)	0.676
PTT	0.22 (±0.02)	0.22 (±0.02)	0.717

* Significant at $P < 0.05$

APPENDIX XXIII
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SITTING POSITION AT POSTTEST

Sitting position at posttest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	821.06 (±81.65)	770.22 (±112.95)	0.184
STD RR (SDNN) (ms)	32.84 (±33.42)	23.11 (±18.40)	0.349
Mean HR (1/min)	74.11 (±8.49)	79.57 (±11.85)	0.172
STD HR (1/min)	3.21 (±3.56)	2.25 (±1.44)	0.363
RMSSD (ms)	38.22 (±55.31)	24.69 (±33.93)	0.442
NN50 (count)	32.29 (±73.40)	10.57 (±17.59)	0.299
pNN50 (%)	8.16 (±17.96)	2.94 (±4.85)	0.310
RR triangular index	5.28 (±2.26)	5.51 (±2.04)	0.780
TINN (ms)	139.29 (±121.21)	106.07 (±73.04)	0.388
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	36.82 (±27.80)	44.70 (±23.43)	0.425
HF (0.15-0.4 Hz)	63.18 (±27.80)	55.30 (±23.43)	0.425
LF/HF	1.09 (±1.37)	1.26 (±1.29)	0.726
Nonlinear Results			
Poincare plot			
SD1 (ms)	27.06 (±39.16)	17.49 (±24.02)	0.443
SD2 (ms)	35.21 (±30.02)	26.19 (±13.63)	0.315
SD2/SD1	2.36 (±1.31)	2.29 (±0.91)	0.871
Recurrence plot (beats)			
Mean line length (Lmean)	19.59 (±16.17)	13.89 (±7.75)	0.245
Max line length (Lmax)	243.64 (±136.28)	215.71 (±144.04)	0.603
Recurrence rate (REC) (%)	38.79 (±15.43)	35.29 (±13.67)	0.531
Determinism (DET) (%)	98.49 (±1.20)	97.92 (±1.28)	0.243
Shannon Entropy (ShanEn)	3.45 (±0.49)	3.20 (±0.37)	0.136
Other			
Approximate entropy (ApEn)	1.06 (±0.20)	1.16 (±0.14)	0.124
Sample entropy (SampEn)	1.34 (±0.43)	1.56 (±0.31)	0.131
Detrended fluctuations (DFA): α1	0.75 (±0.40)	0.85 (±0.34)	0.515
Detrended fluctuations (DFA): α2	0.97 (±0.28)	0.92 (±0.27)	0.622
Correlation dimension (D2)	0.39 (±0.56)	0.48 (±1.10)	0.794
PTT	0.22 (±0.02)	0.22 (±0.02)	0.612

* Significant at $P < 0.05$

APPENDIX XXIV
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SUPINE POSITION AT PRETEST

Supine position at pretest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	817.05 (±93.67)	817.94 (±91.25)	0.141
STD RR (SDNN) (ms)	26.89 (±20.87)	24.93 (±9.34)	0.751
Mean HR (1/min)	69.77 (±7.82)	74.30 (±8.42)	0.152
STD HR (1/min)	2.26 (±2.02)	2.29 (±0.98)	0.965
RMSSD (ms)	25.16 (±39.28)	17.66 (±9.69)	0.494
NN50 (count)	12.64 (±21.52)	15.43 (±30.50)	0.782
pNN50 (%)	1.92 (±3.24)	2.11 (±3.96)	0.893
RR triangular index	6.26 (±2.16)	6.77 (±2.61)	0.577
TINN (ms)	122.14 (±84.85)	118.57 (±42.22)	0.889
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	40.85 (±25.37)	51.28 (±14.34)	0.195
HF (0.15-0.4 Hz)	59.15 (±25.37)	48.72 (±14.34)	0.195
LF/HF	1.28 (±1.73)	1.22 (±0.63)	0.895
Nonlinear Results			
Poincare plot			
SD1 (ms)	17.81 (±27.80)	12.49 (±6.86)	0.493
SD2 (ms)	31.56 (±15.52)	32.51 (±12.54)	0.861
SD2/SD1	3.08 (±1.83)	3.03 (±1.33)	0.928
Recurrence plot (beats)			
Mean line length (Lmean)	17.84 (±12.52)	18.70 (±8.32)	0.833
Max line length (Lmax)	453.36 (±304.59)	488.43 (±230.68)	0.734
Recurrence rate (REC) (%)	38.84 (±11.29)	40.79 (±8.00)	0.601
Determinism (DET) (%)	98.66 (±1.06)	98.85 (±0.83)	0.601
Shannon Entropy (ShanEn)	3.53 (±0.49)	3.66 (±0.38)	0.463
Other			
Approximate entropy (ApEn)	1.21 (±0.23)	1.26 (±0.12)	0.494
Sample entropy (SampEn)	1.36 (±0.37)	1.38 (±0.24)	0.853
Detrended fluctuations (DFA): α1	0.86 (±0.33)	0.91 (±0.22)	0.610
Detrended fluctuations (DFA): α2	1.00 (±0.24)	1.10 (±0.21)	0.273
Correlation dimension (D2)	0.26 (±0.30)	0.49 (±0.44)	0.120
PTT	0.22 (±0.02)	0.23 (±0.02)	0.530

* Significant at $P < 0.05$

APPENDIX XXV
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SUPINE POSITION AT MIDTEST

Supine position at midtest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	898.09 (±65.35)	810.77 (±116.87)	**0.024***
STD RR (SDNN) (ms)	45.32 (±66.07)	27.76 (±12.92)	0.338
Mean HR (1/min)	67.69 (±4.74)	75.85 (±11.46)	**0.025***
STD HR (1/min)	3.85 (±6.08)	2.81 (±1.65)	0.544
RMSSD (ms)	55.66 (±119.69)	25.77 (±21.66)	0.366
NN50 (count)	41.29 (±113.23)	17.21 (±24.41)	0.444
pNN50 (%)	6.16 (±16.80)	2.43 (±3.49)	0.424
RR triangular index	7.35 (±1.91)	6.65 (±2.38)	0.398
TINN (ms)	147.86 (±115.77)	165.00 (±120.83)	0.705
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	36.84 (±22.99)	42.00 (±15.49)	0.492
HF (0.15-0.4 Hz)	63.16 (±22.99)	58.00 (±15.49)	0.492
LF/HF	0.88 (±0.94)	0.85 (±0.55)	0.944
Nonlinear Results			
Poincare plot			
SD1 (ms)	39.39 (±84.70)	18.24 (±15.34)	0.366
SD2 (ms)	45.87 (±45.10)	33.85 (±12.86)	0.346
SD2/SD1	2.68 (±1.29)	2.50 (±1.27)	0.702
Recurrence plot (beats)			
Mean line length (Lmean)	18.09 (±7.19)	21.13 (±8.38)	0.313
Max line length (Lmax)	409.14 (±230.37)	427.71 (±255.08)	0.841
Recurrence rate (REC) (%)	39.04 (±11.31)	46.18 (±8.96)	0.076
Determinism (DET) (%)	97.97 (±2.71)	99.00 (±0.69)	0.182
Shannon Entropy (ShanEn)	3.50 (±0.45)	3.77 (±0.39)	0.101
Other			
Approximate entropy (ApEn)	1.18 (±0.30)	1.12 (±0.27)	0.582
Sample entropy (SampEn)	1.34 (±0.39)	1.20 (±0.41)	0.359
Detrended fluctuations (DFA): α1	0.77 (±0.34)	0.75 (±0.25)	0.841
Detrended fluctuations (DFA): α2	0.95 (±0.28)	1.04 (±0.20)	0.338
Correlation dimension (D2)	0.39 (±0.25)	0.50 (±0.46)	0.448
PTT	0.22 (±0.02)	0.22 (±0.02)	0.613

* Significant at $P < 0.05$

APPENDIX XXVI
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN SUPINE POSITION AT POSTTEST

Supine position at posttest	**Elderly non-fallers** **Mean (±SD)**	**Elderly fallers** **Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	873.12 (±72.88)	818.01 (±112.21)	0.135
STD RR (SDNN) (ms)	39.48 (±51.56)	28.21 (±13.38)	0.436
Mean HR (1/min)	69.59 (±6.33)	74.77 (±10.41)	0.124
STD HR (1/min)	3.36 (±4.64)	2.62 (±1.32)	0.572
RMSSD (ms)	44.98 (±94.21)	20.30 (±16.84)	0.351
NN50 (count)	40.36 (±118.87)	37.43 (±85.82)	0.941
pNN50 (%)	5.86 (±17.11)	4.92 (±10.74)	0.864
RR triangular index	7.09 (±2.19)	7.34 (±3.20)	0.807
TINN (ms)	138.93 (±98.67)	130.00 (±54.42)	0.769
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	34.46 (±24.27)	53.61 (±20.57)	**0.033***
HF (0.15-0.4 Hz)	65.54 (±24.27)	46.39 (±20.57)	**0.033***
LF/HF	0.82 (±0.91)	1.73 (±1.56)	0.072
Nonlinear Results			
Poincare plot			
SD1 (ms)	31.81 (±66.66)	14.35 (±11.91)	0.351
SD2 (ms)	41.52 (±35.52)	36.56 (±16.28)	0.639
SD2/SD1	3.16 (±1.50)	3.34 (±1.63)	0.760
Recurrence plot (beats)			
Mean line length (Lmean)	19.76 (±8.73)	18.25 (±8.78)	0.652
Max line length (Lmax)	535.00 (±284.24)	467.57 (±301.12)	0.548
Recurrence rate (REC) (%)	40.37 (±10.09)	38.94 (±10.61)	0.719
Determinism (DET) (%)	98.98 (±0.82)	98.11 (±2.39)	0.206
Shannon Entropy (ShanEn)	3.64 (±0.35)	3.58 (±0.51)	0.706
Other			
Approximate entropy (ApEn)	1.16 (±0.23)	1.20 (±0.15)	0.584
Sample entropy (SampEn)	1.26 (±0.31)	1.30 (±0.28)	0.720
Detrended fluctuations (DFA): α1	0.79 (±0.38)	0.95 (±0.28)	0.189
Detrended fluctuations (DFA): α2	1.03 (±0.34)	0.98 (±0.18)	0.622
Correlation dimension (D2)	0.35 (±0.34)	0.89 (±1.06)	0.090
PTT	0.22 (±0.02)	0.22 (±0.02)	0.606

* Significant at $P < 0.05$

APPENDIX XXVII
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN STANDING POSITION AT PRETEST

Standing position at pretest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	806.87 (±86.21)	785.16 (±102.80)	0.550
STD RR (SDNN) (ms)	28.77 (±35.57)	34.40 (±40.01)	0.697
Mean HR (1/min)	75.51 (±8.75)	77.80 (±10.09)	0.527
STD HR (1/min)	3.08 (±4.93)	2.72 (±1.55)	0.795
RMSSD (ms)	28.11 (±61.52)	30.97 (±59.05)	0.901
NN50 (count)	19.36 (±58.29)	8.71 (±16.57)	0.517
pNN50 (%)	6.44 (±19.85)	2.49 (±4.82)	0.476
RR triangular index	5.23 (±1.81)	5.92 (±2.67)	0.427
TINN (ms)	122.50 (±125.98)	114.29 (±55.60)	0.825
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	45.79 (±24.00)	49.87 (±22.22)	0.645
HF (0.15-0.4 Hz)	54.19 (±24.01)	50.13 (±22.22)	0.646
LF/HF	1.36 (±1.38)	1.97 (±2.92)	0.480
Nonlinear Results			
Poincare plot			
SD1 (ms)	19.91 (±43.57)	21.91 (±41.81)	0.902
SD2 (ms)	33.04 (±27.79)	41.57 (±40.38)	0.520
SD2/SD1	3.36 (±1.44)	3.10 (±1.48)	0.631
Recurrence plot (beats)			
Mean line length (Lmean)	21.54 (±6.20)	23.33 (±12.14)	0.628
Max line length (Lmax)	291.71 (±118.41)	320.50 (±105.16)	0.502
Recurrence rate (REC) (%)	45.11 (±11.46)	47.20 (±13.40)	0.660
Determinism (DET) (%)	99.07 (±0.93)	99.11 (±0.79)	0.913
Shannon Entropy (ShanEn)	3.79 (±0.33)	3.68 (±0.42)	0.481
Other			
Approximate entropy (ApEn)	1.02 (±0.15)	1.05 (±0.23)	0.766
Sample entropy (SampEn)	1.23 (±0.29)	1.23 (±0.38)	0.993
Detrended fluctuations (DFA): α1	0.85 (±0.33)	0.92 (±0.32)	0.544
Detrended fluctuations (DFA): α2	1.24 (±0.22)	1.14 (±0.24)	0.278
Correlation dimension (D2)	0.32 (±0.35)	0.44 (±0.66)	0.538
PTT	0.21 (±0.01)	0.21 (±0.02)	0.746

* Significant at $P < 0.05$

APPENDIX XXVIII
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN STANDING POSITION AT MIDTEST

Standing position at midtest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	825.29 (±71.94)	757.94 (±105.61)	0.059
STD RR (SDNN) (ms)	32.97 (±31.88)	26.82 (±11.08)	0.501
Mean HR (1/min)	73.44 (±6.17)	80.77 (±11.68)	0.051
STD HR (1/min)	3.28 (±3.42)	2.94 (±1.29)	0.735
RMSSD (ms)	34.66 (±59.47)	25.77 (±17.22)	0.596
NN50 (count)	25.71 (±66.26)	14.57 (±20.16)	0.552
pNN50 (%)	6.54 (±16.67)	3.49 (±4.19)	0.513
RR triangular index	5.94 (±1.79)	6.11 (±2.64)	0.843
TINN (ms)	139.64 (±107.26)	171.79 (±107.91)	0.436
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	36.78 (±23.01)	37.96 (±14.54)	0.872
HF (0.15-0.4 Hz)	63.51 (±22.75)	62.04 (±14.54)	0.840
LF/HF	0.88 (±1.00)	0.71 (±0.48)	0.588
Nonlinear Results			
Poincare plot			
SD1 (ms)	24.54 (±42.10)	18.24 (±12.19)	0.595
SD2 (ms)	35.94 (±23.58)	32.06 (±13.29)	0.597
SD2/SD1	3.29 (±2.76)	2.26 (±1.24)	0.218
Recurrence plot (beats)			
Mean line length (Lmean)	23.53 (±16.26)	17.56 (±6.80)	0.222
Max line length (Lmax)	237.36 (±139.79)	217.36 (±133.99)	0.702
Recurrence rate (REC) (%)	43.09 (±19.40)	44.65 (±13.87)	0.808
Determinism (DET) (%)	98.42 (±1.70)	98.63 (±1.12)	0.705
Shannon Entropy (ShanEn)	3.63 (±0.63)	3.54 (±0.36)	0.632
Other			
Approximate entropy (ApEn)	0.99 (±0.21)	1.10 (±0.18)	0.120
Sample entropy (SampEn)	1.24 (±0.40)	1.33 (±0.44)	0.588
Detrended fluctuations (DFA): α1	0.77 (±0.35)	0.70 (±0.22)	0.527
Detrended fluctuations (DFA): α2	1.06 (±0.36)	1.05 (±0.30)	0.886
Correlation dimension (D2)	0.31 (±0.26)	0.41 (±0.31)	0.355
PTT	0.22 (±0.02)	0.22 (±0.03)	0.769

* Significant at $P < 0.05$

APPENDIX XXIX
HRV CHARACTERISTICS BETWEEN ELDERLY NON-FALLERS AND FALLERS GROUPS IN STANDING POSITION AT POSTTEST

Standing position at posttest	**Elderly non-fallers Mean (±SD)**	**Elderly fallers Mean (±SD)**	***P* value**
Time Domain Results			
Mean RR (ms)	810.30 (±81.13)	751.86 (±107.21)	0.116
STD RR (SDNN) (ms)	30.94 (±25.92)	25.55 (±19.10)	0.537
Mean HR (1/min)	75.02 (±8.30)	81.46 (±11.67)	0.104
STD HR (1/min)	3.14 (±3.05)	2.56 (±1.55)	0.531
RMSSD (ms)	33.99 (±47.79)	19.08 (±18.04)	0.290
NN50 (count)	25.07 (±58.65)	9.50 (±15.00)	0.345
pNN50 (%)	6.16 (±13.61)	2.54 (±4.04)	0.348
RR triangular index	5.30 (±1.81)	6.39 (±3.63)	0.329
TINN (ms)	145.36 (±118.18)	123.21 (±96.13)	0.591
Frequency Domain Results			
FFT spectrum (Power n.u.)			
LF (0.04-0.15 Hz)	28.82 (±19.21)	60.56 (±15.54)	**< 0.001***
HF (0.15-0.4 Hz)	71.18 (±19.21)	39.44 (±15.54)	**< 0.001***
LF/HF	0.51 (±0.47)	1.95 (±1.30)	**0.001***
Nonlinear Results			
Poincare plot			
SD1 (ms)	24.06 (±33.84)	13.51 (±12.76)	0.285
SD2 (ms)	33.29 (±19.71)	32.89 (±24.58)	0.963
SD2/SD1	2.70 (±2.32)	2.93 (±1.55)	0.765
Recurrence plot (beats)			
Mean line length (Lmean)	22.59 (±16.87)	15.87 (±7.76)	0.187
Max line length (Lmax)	238.57 (±120.62)	238.79 (±149.49)	0.997
Recurrence rate (REC) (%)	42.62 (±15.24)	37.90 (±9.50)	0.335
Determinism (DET) (%)	98.65 (±1.06)	98.39 (±1.23)	0.558
Shannon Entropy (ShanEn)	3.59 (±0.41)	3.43 (±0.45)	0.321
Other			
Approximate entropy (ApEn)	1.01 (±0.23)	1.15 (±0.15)	0.074
Sample entropy (SampEn)	1.20 (±0.39)	1.43 (±0.31)	0.098
Detrended fluctuations (DFA): α1	0.66 (±0.29)	0.97 (±0.22)	**0.003***
Detrended fluctuations (DFA): α2	1.11 (±0.41)	1.04 (±0.29)	0.581
Correlation dimension (D2)	0.45 (±0.78)	0.64 (±1.02)	0.581
PTT	0.21 (±0.01)	0.21 (±0.02)	0.386

* Significant at $P < 0.05$

APPENDIX XXX
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ALL ELDERLY PARTICIPANTS IN SITTING POSITION

All elderly participants in sitting position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	803.48 (±92.94)	806.39 (±97.27)	795.64 (±100.11)	0.755
STD RR (SDNN) (ms)	21.41 (±27.89) a	30.44 (±37.01) a	27.97 (±26.93)	**0.003***
Mean HR (1/min)	96.71 (±108.79)	75.76 (±9.39)	76.84 (±10.19)	0.507
STD HR (1/min)	2.20 (±3.50)	3.14 (±3.99)	2.73 (±2.71)	0.089
RMSSD (ms)	21.40 (±47.99) b	35.92 (±65.36) b	31.46 (±45.55)	**0.004***
NN50 (count)	7.32 (±31.13) c, d	28.96 (±65.42) c	21.43 (±53.53) d	**0.029***
pNN50 (%)	1.66 (±6.97) e, f	7.24 (±15.67) e	5.55 (±13.18) f	**0.029***
RR triangular index	5.07 (±1.67)	5.53 (±2.11)	5.40 (±2.11)	0.408
TINN (ms)	96.07 (±93.42)	134.82 (±100.95)	122.68 (±99.64)	0.095
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	45.35 (±23.70)	38.08 (±24.13)	40.76 (±25.54)	0.191
HF (0.15-0.4 Hz)	54.65 (±23.70)	61.92 (±24.13)	59.24 (±25.54)	0.191
LF/HF	1.30 (±1.33)	1.06 (±1.39)	1.18 (±1.31)	0.725
Nonlinear Results				
Poincare plot				
SD1 (ms)	15.15 (±33.97) g	25.43 (±46.27) g	22.27 (±32.25)	**0.004***
SD2 (ms)	24.84 (±21.71) h	32.73 (±27.23) h	30.70 (±23.34)	**0.008***
SD2/SD1	2.62 (±1.23)	2.18 (±1.14)	2.33 (±1.11)	0.256
Recurrence plot (beats)				
Mean line length (Lmean)	13.75 (±7.29)	22.18 (±37.93)	16.74 (±12.78)	0.307
Max line length (Lmax)	229.21 (±135.00)	194.96 (±115.89)	229.68 (±138.33)	0.442
Recurrence rate (REC) (%)	33.60 (±9.96)	37.07 (±16.18)	37.04 (±14.42)	0.399
Determinism (DET) (%)	97.74 (±1.46)	97.91 (±1.69)	98.21 (±1.25)	0.368
Shannon Entropy (ShanEn)	3.29 (±0.41)	3.32 (±0.53)	3.33 (±0.44)	0.917
Other				
Approximate entropy (ApEn)	1.12 (±0.16)	1.06 (±0.25)	1.11 (±0.18)	0.251
Sample entropy (SampEn)	1.54 (±0.33)	1.35 (±0.44)	1.45 (±0.38)	0.069
Detrended fluctuations (DFA): α1	0.84 (±0.30)	0.78 (±0.33)	0.80 (±0.37)	0.378
Detrended fluctuations (DFA): α2	1.09 (±0.24) i, j	0.91 (±0.34) i	0.95 (±0.27) j	**0.014***
Correlation dimension (D2)	0.14 (±0.18)	0.52 (±0.86)	0.43 (±0.86)	0.077
PTT	0.22 (±0.2)	0.22 (±0.02)	0.22 (±0.02)	0.277

* Significant at $P < 0.05$

APPENDIX XXXI
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ALL ELDERLY PARTICIPANTS IN SUPINE POSITION

All elderly participants in supine position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	844.50 (±94.68)	854.43 (±103.00)	845.57 (±96.99)	0.814
STD RR (SDNN) (ms)	25.91 (±15.90)	36.54 (±47.56)	33.84 (±37.41)	0.260
Mean HR (1/min)	72.03 (±8.30)	71.77 (±9.56)	72.18 (±8.86)	0.964
STD HR (1/min)	2.28 (±1.56)	3.33 (±4.40)	2.99 (±3.37)	0.240
RMSSD (ms)	21.41 (±28.33)	40.72 (±85.76)	32.64 (±67.59)	0.238
NN50 (count)	14.04 (±25.94)	29.25 (±81.30)	38.89 (±101.74)	0.307
pNN50 (%)	2.01 (±3.55)	4.29 (±12.06)	5.39 (±14.03)	0.324
RR triangular index	6.52 (±2.36)	7.00 (±2.15)	7.21 (±2.69)	0.428
TINN (ms)	120.36 (±65.78)	156.43 (±116.44)	134.46 (±78.32)	0.148
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	46.06 (±20.91)	39.42 (±19.41)	44.03 (±24.13)	0.255
HF (0.15-0.4 Hz)	53.94 (±20.91)	60.58 (±19.41)	55.97 (±24.13)	0.255
LF/HF	1.25 (±1.28)	0.86 (±0.76)	1.27 (±1.33)	0.113
Nonlinear Results				
Poincare plot				
SD1 (ms)	15.15 (±20.05)	28.81 (±60.69)	23.08 (±47.82)	0.237
SD2 (ms)	32.04 (±13.85)	39.86 (±33.11)	39.04 (±27.23)	0.222
SD2/SD1	3.05 (±1.57)	2.59 (±1.26) a	3.25 (±1.54) a	**0.036***
Recurrence plot (beats)				
Mean line length (Lmean)	18.27 (±10.44)	19.61 (±7.82)	19.01 (±8.63)	0.844
Max line length (Lmax)	470.89 (±265.72)	418.43 (±238.68)	501.29 (±289.37)	0.120
Recurrence rate (REC) (%)	39.81 (±9.65)	42.61 (±10.65)	39.66 (±10.18)	0.332
Determinism (DET) (%)	98.76 (±0.94)	98.49 (±2.01)	98.55 (±1.81)	0.775
Shannon Entropy (ShanEn)	3.60 (±0.44)	3.64 (±0.44)	3.61 (±0.43)	0.896
Other				
Approximate entropy (ApEn)	1.23 (±0.18)	1.15 (±0.28)	1.18 (±0.19)	0.278
Sample entropy (SampEn)	1.37 (±0.30)	1.27 (±0.40)	1.28 (±0.29)	0.351
Detrended fluctuations (DFA): α1	0.89 (±0.28)	0.76 (±0.29)	0.87 (±0.34)	0.072
Detrended fluctuations (DFA): α2	1.05 (±0.23)	0.99 (±0.24)	1.01 (±0.27)	0.307
Correlation dimension (D2)	0.38 (±0.39)	0.44 (±0.37)	0.62 (±0.82)	0.152
PTT	0.23 (±0.02) b	0.22 (±0.02)	0.22 (±0.02) b	**0.005***

* Significant at $P < 0.05$

APPENDIX XXXII
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ALL ELDERLY PARTICIPANTS IN STANDING POSITION

All elderly participants in standing position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	796.02 (±93.75)	791.61 (±95.07)	781.08 (±97.92)	0.470
STD RR (SDNN) (ms)	31.59 (±37.17)	29.90 (±23.63)	28.24 (±22.51)	0.788
Mean HR (1/min)	76.66 (±9.34)	77.11 (±9.90)	78.24 (±10.46)	0.452
STD HR (1/min)	2.90 (±3.59)	3.11 (±2.54)	2.85 (±2.39)	0.647
RMSSD (ms)	29.54 (±59.19)	30.21 (±43.20)	26.53 (±36.25)	0.735
NN50 (count)	14.04 (±42.40)	20.14 (±48.39)	17.29 (±42.75)	0.324
pNN50 (%)	4.47 (±14.32)	5.01 (±12.03)	4.35 (±10.02)	0.819
RR triangular index	5.58 (±2.27)	6.03 (±2.22)	5.85 (±2.87)	0.216
TINN (ms)	118.39 (±95.64)	155.71 (±106.84)	134.29 (±106.31)	0.107
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	47.83 (±22.79)	37.37 (±18.89)	44.69 (±23.56)	0.096
HF (0.15-0.4 Hz)	52.16 (±22.79)	62.77 (±18.75)	55.31 (±23.56)	0.086
LF/HF	1.67 (±2.26)	0.80 (±0.78)	1.23 (±1.21)	0.156
Nonlinear Results				
Poincare plot				
SD1 (ms)	20.91 (±41.91)	21.39 (±30.59)	18.78 (±25.66)	0.736
SD2 (ms)	3730 (±34.29)	34.00 (±18.88)	33.09 (±21.86)	0.732
SD2/SD1	3.23 (±1.44)	2.78 (±2.16)	2.81 (±1.94)	0.444
Recurrence plot (beats)				
Mean line length (Lmean)	22.44 (±9.50)	20.55 (±12.60)	19.22 (±13.33)	0.499
Max line length (Lmax)	306.11 (±110.86) a, b	227.36 (±134.75) a	238.68 (±133.29) b	**0.006***
Recurrence rate (REC) (%)	46.15 (±12.28)	43.87 (±16.57)	40.26 (±12.69)	0.127
Determinism (DET) (%)	99.09 (±0.84)	98.52 (±1.42)	98.52 (±1.14)	**0.030***
Shannon Entropy (ShanEn)	3.73 (±0.37) c	3.58 (±0.51)	3.51 (±0.43) c	**0.022***
Other				
Approximate entropy (ApEn)	1.03 (±0.19)	1.04 (±0.20)	1.08 (±0.20)	0.454
Sample entropy (SampEn)	1.23 (±0.33)	1.29 (±0.41)	1.31 (±0.37)	0.593
Detrended fluctuations (DFA): α1	0.89 (±0.32)	0.74 (±0.29)	0.82 (±0.30)	0.095
Detrended fluctuations (DFA): α2	1.19 (±0.23) d	1.06 (±0.32) d	1.08 (±0.35)	**0.022***
Correlation dimension (D2)	0.38 (±0.52)	0.36 (±0.29)	0.54 (±0.90)	0.524
PTT	0.21 (±0.02)	0.22 (±0.03)	0.21 (±0.02)	**0.022***

* Significant at $P < 0.05$

APPENDIX XXXIII
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY NON-FALLERS IN SITTING POSITION

Non-fallers in sitting position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	825.06 (±96.88)	846.04 (±66.80)	821.06 (±81.65)	0.336
STD RR (SDNN) (ms)	25.74 (±39.07)	34.70 (±50.26)	32.84 (±33.42)	0.067
Mean HR (1/min)	115.79 (±154.04)	71.71 (±5.71)	74.11 (±8.49)	0.170
STD HR (1/min)	2.74 (±4.94)	3.23 (±4.80)	3.21 (±3.56)	0.261
RMSSD (ms)	30.17 (±67.71)	46.56 (±90.59)	38.22 (±55.31)	0.099
NN50 (count)	13.21 (±43.92)	36.50 (±89.77)	32.28 (±73.40)	0.180
pNN50 (%)	2.95 (±9.83)	9.10 (±21.43)	8.16 (±17.96)	0.175
RR triangular index	4.96 (±1.65)	5.55 (±2.34)	5.28 (±2.26)	0.566
TINN (ms)	108.57 (±129.71)	136.78 (±107.98)	139.28 (±121.21)	0.560
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	0.85 (±0.80)	0.75 (±0.78)	1.08 (±1.37)	0.648
HF (0.15-0.4 Hz)	37.10 (±23.24)	33.37 (±24.50)	36.82 (±27.80)	0.793
LF/HF	62.90 (±23.24)	66.23 (±24.50)	63.18 (±27.80)	0.793
Nonlinear Results				
Poincare plot				
SD1 (ms)	21.37 (±47.93)	32.95 (±64.13)	27.06 (±39.16)	0.100
SD2 (ms)	27.33 (±29.65)	33.39 (±34.16)	35.21 (±30.02)	0.066
SD2/SD1	2.58 (±1.64)	2.08 (±1.07)	2.36 (±1.31)	0.419
Recurrence plot (beats)				
Mean line length (Lmean)	15.53 (±9.79)	29.44 (±52.83)	19.60 (±16.17)	0.504
Max line length (Lmax)	218.64 (±144.69)	222.00 (±114.14)	243.64 (±136.28)	0.840
Recurrence rate (REC) (%)	32.87 (±12.61)	38.02 (±17.97)	38.79 (±15.43)	0.420
Determinism (DET) (%)	97.47 (±1.83)	97.95 (±1.85)	98.48 (±1.20)	0.148
Shannon Entropy (ShanEn)	3.34 (±0.54)	3.38 (±0.56)	3.45 (±0.49)	0.758
Other				
Approximate entropy (ApEn)	1.05 (±0.19)	1.03 (±0.29)	1.06 (±0.20)	0.907
Sample entropy (SampEn)	1.46 (±0.43)	1.36 (±0.46)	1.34 (±0.43)	0.631
Detrended fluctuations (DFA): α1	0.72 (±0.31)	0.69 (±0.36)	0.75 (±0.40)	0.427
Detrended fluctuations (DFA): α2	1.10 (±0.27)	0.91 (±0.34)	0.97 (±0.28)	0.144
Correlation dimension (D2)	0.12 (±0.15)	0.45 (±1.05)	0.39 (±0.56)	0.244
PTT	0.22 (±0.01)	0.22 (±0.02)	0.22 (±0.02)	0.228

* Significant at $P < 0.05$

APPENDIX XXXIV
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY NON-FALLERS IN SUPINE POSITION

Non-fallers in supine position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	871.05 (±93.67)	898.08 (±65.35)	873.12 (±72.88)	0.330
STD RR (SDNN) (ms)	26.88 (±20.87)	45.32 (±66.07)	39.48 (±51.56)	0.396
Mean HR (1/min)	69.77 (±7.82)	67.69 (±4.74)	69.59 (±6.33)	0.382
STD HR (1/min)	2.26 (±2.02)	3.85 (±6.08)	3.36 (±4.63)	0.436
RMSSD (ms)	25.16 (±39.27)	55.66 (±119.69)	44.98 (±94.21)	0.401
NN50 (count)	12.64 (±21.52)	41.28 (±113.23)	40.36 (±118.87)	0.500
pNN50 (%)	1.92 (±3.24)	6.16 (±16.80)	5.86 (±17.11)	0.508
RR triangular index	6.26 (±2.15)	7.35 (±1.91)	7.08 (±2.19)	0.392
TINN (ms)	122.14 (±84.85)	147.86 (±115.77)	138.93 (±98.67)	0.478
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	40.85 (±25.37)	36.84 (±22.99)	34.46 (±24.27)	0.274
HF (0.15-0.4 Hz)	59.15 (±25.37)	63.16 (±22.99)	65.54 (±24.27)	0.274
LF/HF	1.28 (±1.73)	0.87 (±0.94)	0.82 (±0.91)	**0.044***
Nonlinear Results				
Poincare plot				
SD1 (ms)	17.81 (±27.80)	39.39 (±84.69)	31.81 (±66.66)	0.400
SD2 (ms)	31.56 (±15.52)	45.87 (±45.10)	41.52 (±35.52)	0.348
SD2/SD1	3.08 (±1.83)	2.68 (±1.29)	3.16 (±1.50)	0.128
Recurrence plot (beats)				
Mean line length (Lmean)	17.84 (±12.52)	18.09 (±7.19)	19.76 (±8.73)	0.721
Max line length (Lmax)	453.357 (±304.59)	409.142 (±230.37)	535.00 (±284.24)	0.069
Recurrence rate (REC) (%)	38.83 (±11.29)	39.04 (±11.31)	40.37 (±10.09)	0.815
Determinism (DET) (%)	98.66 (±1.06)	97.97 (±2.71)	98.98 (±0.82)	0.150
Shannon Entropy (ShanEn)	3.53 (±0.49)	3.50 (±0.45)	3.64 (±0.35)	0.253
Other				
Approximate entropy (ApEn)	1.21 (±0.23)	1.18 (±0.30)	1.16 (±0.23)	0.483
Sample entropy (SampEn)	1.36 (±0.37)	1.34 (±0.39)	1.26 (±0.31)	0.173
Detrended fluctuations (DFA): α1	0.86 (±0.33)	0.77 (±0.34)	0.79 (±0.38)	0.532
Detrended fluctuations (DFA): α2	1.00 (±0.24)	0.95 (±0.28)	1.03 (±0.34)	0.238
Correlation dimension (D2)	0.26 (±0.30)	0.39 (±0.25)	0.35 (±0.34)	0.522
PTT	0.22 (±0.02) a	0.22 (±0.02)	0.22 (±0.02) a	**0.036***

* Significant at $P < 0.05$

APPENDIX XXXV
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY NON-FALLERS IN STANDING POSITION

Non-fallers in standing position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	806.87 (±86.21)	825.28 (±71.94)	810.30 (±81.13)	0.626
STD RR (SDNN) (ms)	28.77 (±35.37)	32.97 (±31.88)	30.93 (±25.92)	0.383
Mean HR (1/min)	75.51 (±8.75)	73.44 (±6.17)	75.02 (±8.30)	0.504
STD HR (1/min)	3.08 (±4.93)	3.27 (±3.42)	3.14 (±3.05)	0.897
RMSSD (ms)	28.11 (±61.52)	34.66 (±59.47)	33.98 (±47.79)	0.167
NN50 (count)	19.36 (±58.28)	25.71 (±66.26)	25.07 (±58.65)	0.408
pNN50 (%)	6.44 (±19.85)	6.53 (±16.67)	6.16 (±13.60)	0.986
RR triangular index	5.23 (±1.81)	5.94 (±1.79)	5.30 (±1.81)	0.280
TINN (ms)	122.50 (±125.98)	139.64 (±107.26)	145.36 (±118.18)	0.434
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	45.79 (±24.00) a	36.78 (±23.01)	28.82 (±19.21) a	**0.026***
HF (0.15-0.4 Hz)	54.19 (±24.00) b	63.51 (±22.75)	71.18 (±19.21) b	**0.028***
LF/HF	1.35 (±1.38)	0.88 (±1.00)	0.51 (±0.47)	0.057
Nonlinear Results				
Poincare plot				
SD1 (ms)	19.91 (±43.57)	24.53 (±42.10)	24.06 (±33.84)	0.169
SD2 (ms)	33.03 (±27.79)	35.93 (±23.58)	33.28 (±19.71)	0.792
SD2/SD1	3.36 (±1.44)	3.29 (±2.76)	2.70 (±2.32)	0.564
Recurrence plot (beats)				
Mean line length (Lmean)	21.54 (±6.20)	23.53 (±16.26)	22.59 (±16.87)	0.854
Max line length (Lmax)	291.71 (±118.41)	237.36 (±139.79)	238.57 (±120.62)	0.210
Recurrence rate (REC) (%)	45.11 (±11.46)	43.08 (±19.40)	42.62 (±15.24)	0.701
Determinism (DET) (%)	99.07 (±0.93)	98.42 (±1.70)	98.65 (±1.06)	0.273
Shannon Entropy (ShanEn)	3.78 (±0.33)	3.63 (±0.63)	3.59 (±0.40)	0.125
Other				
Approximate entropy (ApEn)	1.02 (±0.15)	0.98 (±0.21)	1.01 (±0.23)	0.752
Sample entropy (SampEn)	1.23 (±0.29)	1.24 (±0.39)	1.20 (±0.39)	0.877
Detrended fluctuations (DFA): α1	0.85 (±0.33)	0.77 (±0.35)	0.66 (±0.28)	0.093
Detrended fluctuations (DFA): α2	1.24 (±0.22)	1.06 (±0.35)	1.11 (±0.40)	0.057
Correlation dimension (D2)	0.32 (±0.35)	0.31 (±0.26)	0.45 (±0.78)	0.826
PTT	0.21 (±0.01)	0.22 (±0.02)	0.21 (±0.01)	0.185

* Significant at $P < 0.05$

APPENDIX XXXVI

HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY FALLERS IN SITTING POSITION

Fallers in sitting position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	781.90 (±86.89)	766.74 (±108.64)	770.22 (±112.95)	0.698
STD RR (SDNN) (ms)	17.08 (±6.98)	26.18 (±16.72)	23.11 (±18.40)	0.060
Mean HR (1/min)	77.62 (±8.25)	79.81 (±10.74)	79.57 (±11.85)	0.431
STD HR (1/min)	1.66 (±0.60)	3.05 (±3.15)	2.25 (±1.43)	0.072
RMSSD (ms)	12.62 (±5.67)	25.28 (±20.55)	24.69 (±33.93)	0.057
NN50 (count)	1.43 (±3.06) a	21.43 (±26.58) a	10.57 (±17.59)	**0.042***
pNN50 (%)	0.36 (±0.77) b	5.37 (±6.58) b	2.94 (±4.85)	**0.043***
RR triangular index	5.17 (±1.74)	5.50 (±1.94)	5.51 (±2.04)	0.744
TINN (ms)	83.57 (±31.03)	132.86 (±97.46)	106.07 (±73.04)	0.089
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	53.59 (±21.92)	42.79 (±23.70)	44.70 (±23.42)	0.132
HF (0.15-0.4 Hz)	46.41 (±21.92)	57.21 (±23.70)	55.30 (±23.42)	0.132
LF/HF	1.75 (±1.61)	1.36 (±1.79)	1.26 (±1.29)	0.423
Nonlinear Results				
Poincare plot				
SD1 (ms)	8.93 (±4.01)	17.91 (±14.55)	17.48 (±24.02)	0.057
SD2 (ms)	22.36 (±9.27)	32.07 (±19.29)	26.18 (±13.63)	0.090
SD2/SD1	2.67 (±0.69)	2.28 (±1.24)	2.29 (±0.91)	0.297
Recurrence plot (beats)				
Mean line length (Lmean)	11.95 (±2.78)	14.91 (±9.06)	13.89 (±7.75)	0.335
Max line length (Lmax)	239.78 (±129.17)	167.93 (±115.28)	215.71 (±144.04)	0.266
Recurrence rate (REC) (%)	34.32 (±6.78)	36.12 (±14.78)	35.29 (±13.67)	0.842
Determinism (DET) (%)	98.01 (±0.97)	97.87 (±1.58)	97.92 (±1.28)	0.928
Shannon Entropy (ShanEn)	3.24 (±0.21)	3.26 (±0.52)	3.20 (±0.37)	0.812
Other				
Approximate entropy (ApEn)	1.19 (±0.06)	1.08 (±0.19)	1.16 (±0.14)	0.191
Sample entropy (SampEn)	1.62 (±0.17)	1.34 (±0.42)	1.56 (±0.31)	0.091
Detrended fluctuations (DFA): α1	0.96 (±0.25)	0.87 (±0.28)	0.85 (±0.34)	0.382
Detrended fluctuations (DFA): α2	1.08 (±0.20)	0.90 (±0.34)	0.92 (±0.27)	0.134
Correlation dimension (D2)	0.17 (±0.21)	0.58 (±0.65)	0.48 (±1.09)	0.135
PTT	0.22 (±0.02)	0.22 (±0.02)	0.22 (±0.02)	0.692

* Significant at $P < 0.05$

APPENDIX XXXVII
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY FALLERS IN SUPINE POSITION

Fallers in supine position	**Pretest** **Mean (±SD)**	**Mid-test** **Mean (±SD)**	**Posttest** **Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	817.94 (±91.25)	810.77 (±116.87)	818.01 (±112.21)	0.959
STD RR (SDNN) (ms)	24.93 (±9.34)	27.76 (±12.92)	28.21 (±13.38)	0.507
Mean HR (1/min)	74.30 (±8.41)	75.85 (±11.46)	74.77 (±10.41)	0.791
STD HR (1/min)	2.29 (±0.98)	2.81 (±1.65)	2.62 (±1.32)	0.347
RMSSD (ms)	17.66 (±9.70)	25.77 (±21.66)	20.30 (±16.84)	0.316
NN50 (count)	15.43 (±30.50)	17.21 (±24.41)	37.43 (±85.82)	0.273
pNN50 (%)	2.11 (±3.95)	2.43 (±3.48)	4.92 (±10.74)	0.309
RR triangular index	6.78 (±2.61)	6.65 (±2.38)	7.34 (±3.20)	0.739
TINN (ms)	118.57 (±42.22)	165.00 (±120.83)	130.00 (±54.42)	0.338
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	51.28 (±14.34)	42.00 (±15.49)	53.61 (±20.57)	0.207
HF (0.15-0.4 Hz)	48.72 (±14.34)	58.00 (±15.49)	46.39 (±20.57)	0.207
LF/HF	1.22 (±0.63)	0.85 (±0.55)	1.72 (±1.56)	0.081
Nonlinear Results				
Poincare plot				
SD1 (ms)	12.49 (±6.85)	18.23 (±15.33)	14.35 (±11.91)	0.316
SD2 (ms)	32.51 (±12.54)	33.85 (±12.86)	36.56 (±16.28)	0.671
SD2/SD1	3.02 (±1.33)	2.50 (±1.27)	3.34 (±1.63)	0.154
Recurrence plot (beats)				
Mean line length (Lmean)	18.70 (±8.32)	21.12 (±8.38)	18.25 (±8.78)	0.464
Max line length (Lmax)	488.43 (±230.67)	427.71 (±255.08)	467.57 (±301.12)	0.616
Recurrence rate (REC) (%)	40.79 (±8.00)	46.18 (±8.96)	38.94 (±10.60)	0.106
Determinism (DET) (%)	98.85 (±0.83)	99.00 (±0.69)	98.11 (±2.39)	0.398
Shannon Entropy (ShanEn)	3.66 (±0.38)	3.77 (±0.39)	3.58 (±0.51)	0.335
Other				
Approximate entropy (ApEn)	1.25 (±0.12)	1.12 (±0.27)	1.20 (±0.15)	0.196
Sample entropy (SampEn)	1.38 (±0.23)	1.20 (±0.40)	1.30 (±0.28)	0.308
Detrended fluctuations (DFA): α1	0.91 (±0.22)	0.75 (±0.25)	0.95 (±0.28)	0.112
Detrended fluctuations (DFA): α2	1.10 (±0.21)	1.03 (±0.19)	0.98 (±0.18)	0.150
Correlation dimension (D2)	0.49 (±0.44)	0.49 (±0.46)	0.89 (±1.06)	0.241
PTT	0.23 (±0.02)	0.22 (±0.02)	0.22 (±0.2)	0.092

* Significant at $P < 0.05$

APPENDIX XXXVIII
HRV CHARACTERISTICS AMONG PRETEST, MIDTEST, AND POSTTEST OF ELDERLY FALLERS IN STANDING POSITION

Fallers in standing position	**Pretest Mean (±SD)**	**Mid-test Mean (±SD)**	**Posttest Mean (±SD)**	***P* value**
Time Domain Results				
Mean RR (ms)	785.16 (±102.80) a	757.93 (±105.61)	751.86 (±107.21) a	**0.040***
STD RR (SDNN) (ms)	34.40 (±40.01)	26.82 (±11.08)	25.55 (±19.10)	0.664
Mean HR (1/min)	77.80 (±10.09)	80.77 (±11.68)	81.46 (±11.67)	**0.041***
STD HR (1/min)	2.72 (±1.55)	2.94 (±1.28)	2.56 (±1.55)	0.659
RMSSD (ms)	30.97 (±59.05)	25.77 (±17.22)	19.08 (±18.04)	0.551
NN50 (count)	8.71 (±16.57)	14.57 (±20.16)	9.50 (±15.00)	0.643
pNN50 (%)	2.50 (±4.82)	3.49 (±4.19)	2.54 (±4.03)	0.709
RR triangular index	5.92 (±2.67)	6.11 (±2.64)	6.39 (±3.63)	0.561
TINN (ms)	114.28 (±55.60)	171.78 (±107.91)	123.21 (±96.13)	0.201
Frequency Domain Results				
FFT spectrum (Power n.u.)				
LF (0.04-0.15 Hz)	49.87 (±22.22)	37.96 (±14.54) b	60.56 (±15.54) b	**0.006***
HF (0.15-0.4 Hz)	50.13 (±22.22)	62.03 (±14.54) c	39.43 (±15.54) c	**0.006***
LF/HF	1.97 (±2.92)	0.71 (±0.48) d	1.95 (±1.30) d	**0.009***
Nonlinear Results				
Poincare plot				
SD1 (ms)	21.91 (±41.81)	18.23 (±12.19)	13.51 (±12.76)	0.552
SD2 (ms)	41.57 (±40.38)	32.06 (±13.29)	32.89 (±24.57)	0.638
SD2/SD1	3.10 (±1.48)	2.26 (±1.24)	2.92 (±1.55)	0.058
Recurrence plot (beats)				
Mean line length (Lmean)	23.33 (±12.14)	17.56 (±6.80)	15.86 (±7.76)	0.175
Max line length (Lmax)	320.50 (±105.16) e	217.36 (±133.99) e	238.78 (±149.49)	**0.032***
Recurrence rate (REC) (%)	47.20 (±13.40)	44.65 (±13.87)	37.90 (±9.50)	0.138
Determinism (DET) (%)	99.11 (±0.78)	98.63 (±1.12)	98.39 (±1.23)	0.125
Shannon Entropy (ShanEn)	3.68 (±0.42)	3.54 (±0.36)	3.43 (±0.45)	0.168
Other				
Approximate entropy (ApEn)	1.04 (±0.23)	1.10 (±0.18)	1.15 (±0.15)	0.257
Sample entropy (SampEn)	1.23 (±0.38)	1.33 (±0.44)	1.43 (±0.31)	0.306
Detrended fluctuations (DFA): α1	0.92 (±0.32)	0.70 (±0.22) f	0.97 (±0.22) f	**0.028***
Detrended fluctuations (DFA): α2	1.14 (±0.24)	1.05 (±0.30)	1.04 (±0.29)	0.290
Correlation dimension (D2)	0.44 (±0.66)	0.41 (±0.31)	0.64 (±1.02)	0.656
PTT	0.21 (±0.02)	0.22 (±0.03)	0.20 (±0.02)	0.107

* Significant at $P < 0.05$

APPENDIX XXXIX
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ALL ELDERLY PARTICIPANTS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Total time spent with juggling	0.527* **(0.004)**	-0.251 (0.198)	0.493* **(0.008)**	0.251 (0.198)	0.418* **(0.027)**	1
Time Domain Results						
Mean RR (ms) in the sitting position	-0.569* **(0.002)**	-0.340 (0.077)	-0.602* **(0.001)**	0.340 (0.077)	0.009 (0.965)	-0.040 (0.839)
Mean RR (ms) in the supine position	-0.452* **(0.016)**	-0.374* **(0.050)**	-0.490* **(0.008)**	0.374* **(0.050)**	0.088 (0.656)	0.011 (0.955)
Mean RR (ms) in the standing position	-0.550* **(0.002)**	-0.379* **(0.047)**	-0.594* **(0.001)**	0.379* **(0.047)**	0.090 (0.647)	-0.018 (0.927)
STD RR (ms) in the sitting position	-0.317 (0.100)	-0.025 (0.898)	-0.326 (0.090)	0.025 (0.898)	-0.056 (0.777)	-0.081 (0.681)
STD RR (ms) in the supine position	-0.159 (0.419)	0.124 (0.530)	-0.147 (0.454)	-0.124 (0.530)	-0.136 (0.489)	-0.086 (0.664)
STD RR (ms) in the standing position	-0.218 (0.264)	0.008 (0.968)	-0.223 (0.254)	-0.008 (0.968)	-0.050 (0.802)	0.144 (0.464)
Mean HR (1/min) in the sitting position	0.590* **(0.001)**	0.275 (0.156)	0.613* **(0.001)**	-0.275 (0.156)	0.059 (0.767)	0.052 (0.792)
Mean HR (1/min) in the supine position	0.455* **(0.015)**	0.329 (0.088)	0.486* **(0.009)**	-0.329 (0.088)	-0.044 (0.825)	-0.025 (0.898)
Mean HR (1/min) in the standing position	0.556* **(0.002)**	0.329 (0.087)	0.593* **(0.001)**	-0.329 (0.087)	-0.047 (0.811)	0.015 (0.941)
STD HR (1/min) in the sitting position	-0.271 (0.163)	0.082 (0.678)	-0.270 (0.165)	-0.082 (0.678)	-0.107 (0.587)	-0.108 (0.586)
STD HR (1/min) in the supine position	-0.091 (0.646)	0.191 (0.331)	-0.072 (0.715)	-0.191 (0.331)	-0.156 (0.429)	-0.093 (0.639)
STD HR (1/min) in the standing position	-0.159 (0.418)	0.136 (0.489)	-0.149 (0.449)	-0.136 (0.489)	-0.126 (0.523)	0.069 (0.726)
RMSSD (ms) in the sitting position	-0.208 (0.289)	-0.041 (0.834)	-0.217 (0.268)	0.041 (0.834)	-0.017 (0.932)	-0.059 (0.766)
RMSSD (ms) in the supine position	-0.171 (0.385)	0.161 (0.413)	-0.155 (0.432)	-0.161 (0.413)	-0.170 (0.388)	-0.169 (0.389)
RMSSD (ms) in the standing position	-0.259 (0.184)	0.078 (0.691)	-0.256 (0.189)	-0.078 (0.691)	-0.113 (0.567)	-0.095 (0.629)
NN50 (count) in the sitting position	-0.194 (0.322)	-0.023 (0.906)	-0.198 (0.313)	0.023 (0.906)	-0.046 (0.815)	-0.204 (0.298)
NN50 (count) in the supine position	0.051 (0.798)	0.075 (0.703)	0.059 (0.764)	-0.075 (0.703)	-0.039 (0.846)	-0.005 (0.980)
NN50 (count) in the standing position	-0.214 (0.274)	0.089 (0.652)	-0.208 (0.288)	-0.089 (0.652)	-0.119 (0.548)	-0.135 (0.494)

APPENDIX XXXIX (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ALL ELDERLY PARTICIPANTS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
pNN50 (%) in the sitting position	-0.198 (0.313)	-0.071 (0.720)	-0.207 (0.290)	0.071 (0.720)	-0.009 (0.964)	-0.191 (0.331)
pNN50 (%) in the supine position	0.016 (0.937)	0.068 (0.732)	0.023 (0.906)	-0.068 (0.732)	-0.045 (0.821)	-0.024 (0.902)
pNN50 (%) in the standing position	-0.220 (0.260)	0.062 (0.753)	-0.217 (0.267)	-0.062 (0.753)	-0.100 (0.612)	-0.118 (0.550)
RR triangular index in the sitting position	-0.439* **(0.019)**	-0.225 (0.251)	-0.473* **(0.011)**	0.225 (0.251)	0.063 (0.752)	0.124 (0.528)
RR triangular index in the supine position	-0.077 (0.698)	<0.001 (0.998)	-0.078 (0.692)	<0.001 (0.998)	-0.017 (0.932)	0.350 (0.068)
RR triangular index in the standing position	-0.094 (0.635)	-0.063 (0.752)	-0.101 (0.611)	0.063 (0.752)	0.011 (0.956)	0.538* **(0.003)**
TINN (ms) in the sitting position	-0.301 (0.119)	-0.035 (0.858)	-0.310 (0.109)	0.035 (0.858)	-0.053 (0.789)	-0.025 (0.898)
TINN (ms) in the supine position	-0.098 (0.620)	0.219 (0.262)	-0.076 (0.702)	-0.219 (0.262)	-0.184 (0.349)	0.107 (0.590)
TINN (ms) in the standing position	-0.235 (0.229)	0.015 (0.940)	-0.243 (0.213)	-0.015 (0.940)	-0.030 (0.878)	0.151 (0.443)
Frequency Domain Results						
FFT spectrum (Power n.u.)						
LF (0.04-0.15 Hz) in the sitting position	0.038 (0.848)	-0.033 (0.868)	0.047 (0.813)	0.033 (0.868)	-0.047 (0.814)	0.109 (0.581)
LF (0.04-0.15 Hz) in the supine position	0.165 (0.402)	-0.285 (0.142)	0.138 (0.483)	0.285 (0.142)	0.237 (0.224)	0.329 (0.087)
LF (0.04-0.15 Hz) in the standing position	0.308 (0.111)	-0.220 (0.260)	0.298 (0.124)	0.220 (0.260)	0.182 (0.353)	0.487* **(0.009)**
HF (0.15-0.4 Hz) in the sitting position	-0.038 (0.848)	0.033 (0.868)	-0.047 (0.813)	-0.033 (0.868)	0.047 (0.814)	-0.109 (0.581)
HF (0.15-0.4 Hz) in the supine position	-0.165 (0.402)	0.285 (0.142)	-0.138 (0.483)	-0.285 (0.142)	-0.237 (0.224)	-0.329 (0.087)
HF (0.15-0.4 Hz) in the standing position	-0.308 (0.111)	0.220 (0.260)	-0.298 (0.124)	-0.220 (0.260)	-0.182 (0.353)	-0.487* **(0.009)**
LF/HF in the sitting position	0.182 (0.355)	-0.008 (0.966)	0.191 (0.329)	0.008 (0.966)	0.002 (0.990)	0.041 (0.838)
LF/HF in the supine position	0.128 (0.516)	-0.172 (0.382)	0.116 (0.557)	0.172 (0.382)	0.129 (0.514)	0.206 (0.293)
LF/HF in the standing position	0.258 (0.185)	-0.246 (0.207)	0.244 (0.210)	0.246 (0.207)	0.186 (0.342)	0.446* **(0.017)**

APPENDIX XXXIX (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ALL ELDERLY PARTICIPANTS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Nonlinear Results						
Poincare plot						
SD1 (ms) in the sitting position	-0.208 (0.289)	-0.041 (0.835)	-0.217 (0.268)	0.041 (0.835)	-0.017 (0.931)	-0.059 (0.766)
SD1 (ms) in the supine position	-0.171 (0.386)	0.161 (0.414)	-0.154 (0.433)	-0.161 (0.414)	-0.170 (0.388)	-0.170 (0.388)
SD1 (ms) in the standing position	-0.259 (0.184)	0.078 (0.691)	-0.256 (0.189)	-0.078 (0.691)	-0.113 (0.568)	-0.095 (0.629)
SD2 (ms) in the sitting position	-0.399* **(0.035)**	-0.017 (0.930)	-0.408* **(0.031)**	0.017 (0.930)	-0.085 (0.669)	-0.091 (0.644)
SD2 (ms) in the supine position	-0.131 (0.506)	0.062 (0.756)	-0.126 (0.522)	-0.062 (0.756)	-0.080 (0.685)	0.040 (0.839)
SD2 (ms) in the standing position	-0.151 (0.444)	-0.085 (0.666)	-0.165 (0.401)	0.085 (0.666)	0.040 (0.838)	0.333 (0.084)
SD2/SD1 in the sitting position	-0.044 (0.824)	0.188 (0.338)	-0.023 (0.906)	-0.188 (0.338)	-0.154 (0.433)	-0.176 (0.370)
SD2/SD1 in the supine position	0.188 (0.339)	-0.025 (0.900)	0.178 (0.366)	0.025 (0.900)	0.136 (0.489)	0.016 (0.934)
SD2/SD1 in the standing position	0.174 (0.376)	0.029 (0.882)	0.185 (0.346)	-0.029 (0.882)	-0.012 (0.951)	0.142 (0.470)
Recurrence plot (beats)						
Lmean in the sitting position	-0.076 (0.700)	0.142 (0.470)	-0.054 (0.786)	-0.142 (0.470)	-0.177 (0.369)	-0.161 (0.412)
Lmean in the supine position	0.002 (0.992)	0.153 (0.436)	0.003 (0.988)	-0.153 (0.436)	-0.005 (0.978)	-0.168 (0.392)
Lmean in the standing position	-0.040 (0.841)	0.139 (0.481)	-0.026 (0.897)	-0.139 (0.481)	-0.108 (0.585)	-0.017 (0.932)
Lmax in the sitting position	0.074 (0.709)	0.293 (0.130)	0.091 (0.643)	-0.293 (0.130)	-0.091 (0.643)	-0.122 (0.535)
Lmax in the supine position	0.077 (0.698)	0.287 (0.138)	0.105 (0.595)	-0.287 (0.138)	-0.162 (0.409)	-0.174 (0.377)
Lmax in the standing position	-0.122 (0.537)	0.332 (0.084)	-0.079 (0.689)	-0.332 (0.084)	-0.329 (0.087)	-0.161 (0.414)
REC (%) in the sitting position	-0.044 (0.825)	0.171 (0.385)	-0.028 (0.888)	-0.171 (0.385)	-0.121 (0.539)	-0.058 (0.769)
REC (%) in the supine position	-0.027 (0.892)	0.100 (0.613)	-0.026 (0.895)	-0.100 (0.613)	-0.014 (0.945)	-0.093 (0.638)
REC (%) in the standing position	-0.182 (0.355)	0.146 (0.458)	-0.171 (0.385)	-0.146 (0.458)	-0.138 (0.483)	-0.044 (0.825)

APPENDIX XXXIX (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ALL ELDERLY PARTICIPANTS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
DET (%) in the sitting position	-0.034 (0.862)	0.351 (0.067)	<0.001 (0.998)	-0.351 (0.067)	-0.240 (0.219)	-0.208 (0.288)
DET (%) in the supine position	-0.051 (0.797)	0.544* **(0.003)**	-0.002 (0.993)	-0.544* **(0.003)**	-0.346 (0.071)	-0.226 (0.247)
DET (%) in the standing position	-0.185 (0.346)	0.289 (0.135)	-0.151 (0.442)	-0.289 (0.135)	-0.294 (0.129)	0.004 (0.984)
ShanEn in the sitting position	-0.148 (0.451)	0.221 (0.258)	-0.125 (0.525)	-0.221 (0.258)	-0.207 (0.289)	-0.299 (0.122)
ShanEn in the supine position	0.069 (0.728)	0.154 (0.432)	0.077 (0.697)	-0.154 (0.432)	-0.029 (0.885)	-0.110 (0.577)
ShanEn in the standing position	-0.046 (0.815)	0.263 (0.176)	-0.017 (0.933)	-0.263 (0.176)	-0.214 (0.273)	0.027 (0.893)
Other						
ApEn in the sitting position	0.332 (0.084)	-0.076 (0.699)	0.320 (0.097)	0.076 (0.699)	0.202 (0.302)	0.200 (0.308)
ApEn in the supine position	-0.002 (0.993)	-0.099 (0.617)	-0.013 (0.949)	0.099 (0.617)	0.071 (0.718)	0.151 (0.444)
ApEn in the standing position	0.197 (0.314)	-0.022 (0.913)	0.194 (0.323)	0.022 (0.913)	0.095 (0.631)	0.012 (0.953)
SampEn in the sitting position	0.149 (0.449)	-0.185 (0.347)	0.131 (0.508)	0.185 (0.347)	0.178 (0.364)	0.190 (0.334)
SampEn in the supine position	-0.085 (0.669)	-0.091 (0.647)	-0.094 (0.634)	0.091 (0.647)	0.033 (0.868)	0.147 (0.457)
SampEn in the standing position	0.157 (0.426)	-0.115 (0.560)	0.144 (0.464)	0.115 (0.560)	0.139 (0.481)	0.031 (0.874)
DFA α1 in the sitting position	0.049 (0.806)	0.001 (0.996)	0.066 (0.739)	-0.001 (0.996)	-0.099 (0.618)	0.010 (0.961)
DFA α1 in the supine position	0.159 (0.419)	-0.254 (0.192)	0.134 (0.496)	0.254 (0.192)	0.223 (0.253)	0.266 (0.171)
DFA α1 in the standing position	0.176 (0.370)	-0.271 (0.163)	0.153 (0.436)	0.271 (0.163)	0.217 (0.267)	0.431* **(0.022)**
DFA α2 in the sitting position	-0.033 (0.867)	0.379* **(0.047)**	0.009 (0.964)	-0.379* **(0.047)**	-0.292 (0.131)	-0.231 (0.237)
DFA α2 in the supine position	-0.005 (0.979)	0.011 (0.956)	-0.008 (0.968)	-0.011 (0.956)	0.017 (0.930)	-0.076 (0.702)
DFA α2 in the standing position	0.111 (0.573)	0.228 (0.244)	0.145 (0.461)	-0.228 (0.244)	-0.185 (0.345)	-0.056 (0.777)

APPENDIX XXXIX (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ALL ELDERLY PARTICIPANTS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
D2 in the sitting position	-0.260 (0.182)	-0.662* **(<0.001)**	-0.333 (0.083)	0.662* **(<0.001)**	0.396* **(0.037)**	0.048 (0.809)
D2 in the supine position	0.164 (0.405)	-0.438* **(0.020)**	0.119 (0.546)	0.438* **(0.020)**	0.357 (0.062)	0.320 (0.097)
D2 in the standing position	-0.089 (0.654)	-0.472* **(0.011)**	-0.138 (0.484)	0.472* **(0.011)**	0.298 (0.124)	0.319 (0.098)
PTT in the sitting position	0.059 (0.766)	-0.107 (0.589)	0.055 (0.783)	0.107 (0.589)	0.051 (0.797)	0.064 (0.745)
PTT in the supine position	0.247 (0.206)	-0.191 (0.331)	0.226 (0.247)	0.191 (0.331)	0.226 (0.246)	0.030 (0.879)
PTT in the standing position	-0.117 (0.553)	0.028 (0.887)	-0.107 (0.588)	-0.028 (0.887)	-0.110 (0.577)	-0.139 (0.480)

* Significant at $P < 0.05$

APPENDIX XL
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY NON-FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Total time spent with juggling	0.502 (0.081)	-0.053 (0.863)	0.496 (0.085)	0.053 (0.863)	0.132 (0.667)	1
Time Domain Results						
Mean RR (ms) in the sitting position	-0.570* **(0.042)**	-0.308 (0.305)	-0.595* **(0.032)**	0.308 (0.305)	0.150 (0.624)	-0.029 (0.925)
Mean RR (ms) in the supine position	-0.481 (0.096)	-0.310 (0.302)	-0.513 (0.073)	0.310 (0.302)	0.231 (0.447)	0.017 (0.957)
Mean RR (ms) in the standing position	-0.571* **(0.041)**	-0.238 (0.433)	-0.589* **(0.034)**	0.238 (0.433)	0.081 (0.792)	-0.054 (0.861)
STD RR (ms) in the sitting position	-0.292 (0.332)	0.293 (0.331)	-0.267 (0.378)	-0.293 (0.331)	-0.283 (0.348)	-0.228 (0.454)
STD RR (ms) in the supine position	-0.201 (0.511)	0.339 (0.256)	-0.172 (0.574)	-0.339 (0.256)	-0.300 (0.320)	-0.284 (0.347)
STD RR (ms) in the standing position	-0.128 (0.677)	0.311 (0.301)	-0.104 (0.734)	-0.311 (0.301)	-0.241 (0.429)	-0.123 (0.689)
Mean HR (1/min) in the sitting position	0.534 (0.060)	0.288 (0.340)	0.557* **(0.048)**	-0.288 (0.340)	-0.132 (0.668)	-0.030 (0.923)
Mean HR (1/min) in the supine position	0.456 (0.117)	0.327 (0.275)	0.489 (0.090)	-0.327 (0.275)	-0.231 (0.448)	-0.087 (0.778)
Mean HR (1/min) in the standing position	0.545 (0.054)	0.243 (0.423)	0.563* **(0.045)**	-0.243 (0.423)	-0.084 (0.784)	-0.003 (0.992)
STD HR (1/min) in the sitting position	-0.264 (0.384)	0.360 (0.227)	-0.232 (0.445)	-0.360 (0.227)	-0.334 (0.264)	-0.215 (0.481)
STD HR (1/min) in the supine position	-0.182 (0.552)	0.367 (0.218)	-0.150 (0.624)	-0.367 (0.218)	-0.324 (0.280)	-0.288 (0.340)
STD HR (1/min) in the standing position	-0.085 (0.783)	0.354 (0.235)	-0.057 (0.853)	-0.354 (0.235)	-0.273 (0.367)	-0.154 (0.615)
RMSSD (ms) in the sitting position	-0.209 (0.492)	0.281 (0.353)	-0.183 (0.549)	-0.281 (0.353)	-0.275 (0.362)	-0.183 (0.550)
RMSSD (ms) in the supine position	-0.228 (0.453)	0.376 (0.206)	-0.194 (0.525)	-0.376 (0.206)	-0.355 (0.234)	-0.311 (0.301)
RMSSD (ms) in the standing position	-0.245 (0.421)	0.402 (0.174)	-0.208 (0.495)	-0.402 (0.174)	-0.378 (0.203)	-0.133 (0.666)
NN50 (count) in the sitting position	-0.157 (0.609)	0.222 (0.465)	-0.137 (0.655)	-0.222 (0.465)	-0.207 (0.497)	-0.221 (0.468)
NN50 (count) in the supine position	-0.218 (0.475)	0.358 (0.230)	-0.185 (0.545)	-0.358 (0.230)	-0.337 (0.261)	-0.313 (0.298)
NN50 (count) in the standing position	-0.117 (0.703)	0.314 (0.296)	-0.090 (0.770)	-0.314 (0.296)	-0.273 (0.366)	-0.108 (0.725)

APPENDIX XL (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY NON-FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
pNN50 (%) in the sitting position	-0.166 (0.588)	0.196 (0.522)	-0.150 (0.626)	-0.196 (0.522)	-0.177 (0.563)	-0.205 (0.503)
pNN50 (%) in the supine position	-0.220 (0.471)	0.360 (0.227)	-0.187 (0.540)	-0.360 (0.227)	-0.339 (0.257)	-0.310 (0.302)
pNN50 (%) in the standing position	-0.117 (0.704)	0.319 (0.289)	-0.089 (0.772)	-0.319 (0.289)	-0.275 (0.364)	-0.069 (0.822)
RR triangular index in the sitting position	-0.423 (0.149)	0.143 (0.642)	-0.412 (0.162)	-0.143 (0.642)	-0.174 (0.570)	-0.390 (0.188)
RR triangular index in the supine position	0.052 (0.867)	0.131 (0.670)	0.056 (0.857)	-0.131 (0.670)	-0.030 (0.922)	-0.013 (0.967)
RR triangular index in the standing position	0.284 (0.347)	0.021 (0.946)	0.278 (0.357)	-0.021 (0.946)	0.097 (0.753)	0.381 (0.198)
TINN (ms) in the sitting position	-0.272 (0.369)	0.297 (0.325)	-0.245 (0.421)	-0.297 (0.325)	-0.296 (0.326)	-0.116 (0.707)
TINN (ms) in the supine position	-0.195 (0.522)	0.357 (0.231)	-0.165 (0.590)	-0.357 (0.231)	-0.314 (0.297)	-0.197 (0.518)
TINN (ms) in the standing position	-0.229 (0.453)	0.309 (0.304)	-0.205 (0.501)	-0.309 (0.304)	-0.254 (0.402)	-0.098 (0.750)
Frequency Domain Results						
FFT spectrum (Power n.u.)						
LF (0.04-0.15 Hz) in the sitting position	0.217 (0.476)	-0.181 (0.553)	0.194 (0.526)	0.181 (0.553)	0.255 (0.401)	0.186 (0.542)
LF (0.04-0.15 Hz) in the supine position	0.334 (0.264)	-0.526 (0.065)	0.276 (0.361)	0.526 (0.065)	0.595* **(0.032)**	0.593* **(0.033)**
LF (0.04-0.15 Hz) in the standing position	0.585* **(0.036)**	-0.554* **(0.049)**	0.519 (0.069)	0.554* **(0.049)**	0.703* **(0.007)**	0.246 (0.419)
HF (0.15-0.4 Hz) in the sitting position	-0.217 (0.476)	0.181 (0.553)	-0.194 (0.526)	-0.181 (0.553)	-0.255 (0.401)	-0.186 (0.542)
HF (0.15-0.4 Hz) in the supine position	-0.334 (0.264)	0.526 (0.065)	-0.276 (0.361)	-0.526 (0.065)	-0.595* **(0.032)**	-0.593* **(0.033)**
HF (0.15-0.4 Hz) in the standing position	-0.585* **(0.036)**	0.554* **(0.049)**	-0.519 (0.069)	-0.554* **(0.049)**	-0.703* **(0.007)**	-0.246 (0.419)
LF/HF in the sitting position	0.349 (0.243)	-0.130 (0.671)	0.326 (0.277)	0.130 (0.671)	0.267 (0.378)	0.251 (0.409)
LF/HF in the supine position	0.261 (0.389)	-0.326 (0.276)	0.221 (0.469)	0.326 (0.276)	0.419 (0.154)	0.561* **(0.046)**
LF/HF in the standing position	0.606* **(0.028)**	-0.478 (0.099)	0.546 (0.053)	0.478 (0.099)	0.649* **(0.016)**	0.254 (0.403)

APPENDIX XL (CONT.)

ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY NON-FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Nonlinear Results						
Poincare plot						
SD1 (ms) in the sitting position	-0.209 (0.492)	0.281 (0.353)	-0.183 (0.549)	-0.281 (0.353)	-0.275 (0.363)	-0.183 (0.550)
SD1 (ms) in the supine position	-0.228 (0.453)	0.376 (0.206)	-0.194 (0.525)	-0.376 (0.206)	-0.354 (0.235)	-0.311 (0.301)
SD1 (ms) in the standing position	-0.245 (0.420)	0.402 (0.174)	-0.208 (0.494)	-0.402 (0.174)	-0.378 (0.203)	-0.133 (0.665)
SD2 (ms) in the sitting position	-0.349 (0.243)	0.292 (0.333)	-0.324 (0.280)	-0.292 (0.333)	-0.282 (0.351)	-0.230 (0.450)
SD2 (ms) in the supine position	-0.178 (0.560)	0.306 (0.310)	-0.155 (0.613)	-0.306 (0.310)	-0.244 (0.421)	-0.237 (0.436)
SD2 (ms) in the standing position	0.002 (0.996)	0.159 (0.604)	0.007 (0.981)	-0.159 (0.604)	-0.053 (0.864)	-0.066 (0.829)
SD2/SD1 in the sitting position	0.066 (0.831)	-0.189 (0.537)	0.040 (0.898)	0.189 (0.537)	0.256 (0.398)	-0.254 (0.401)
SD2/SD1 in the supine position	0.330 (0.271)	-0.517 (0.071)	0.272 (0.368)	0.517 (0.071)	0.587* **(0.035)**	0.345 (0.248)
SD2/SD1 in the standing position	0.414 (0.159)	-0.293 (0.332)	0.377 (0.205)	0.293 (0.332)	0.417 (0.156)	0.027 (0.929)
Recurrence plot (beats)						
Lmean in the sitting position	0.079 (0.799)	0.199 (0.514)	0.108 (0.726)	-0.199 (0.514)	-0.260 (0.392)	0.014 (0.965)
Lmean in the supine position	-0.117 (0.703)	-0.212 (0.487)	-0.136 (0.658)	0.212 (0.487)	0.157 (0.609)	-0.130 (0.671)
Lmean in the standing position	0.021 (0.947)	0.063 (0.839)	0.019 (0.951)	-0.063 (0.839)	0.018 (0.954)	0.123 (0.689)
Lmax in the sitting position	0.233 (0.443)	0.192 (0.530)	0.248 (0.413)	-0.192 (0.530)	-0.105 (0.733)	-0.277 (0.359)
Lmax in the supine position	0.412 (0.162)	-0.408 (0.166)	0.368 (0.216)	0.408 (0.166)	0.471 (0.105)	0.063 (0.839)
Lmax in the standing position	-0.083 (0.787)	-0.237 (0.436)	-0.110 (0.720)	0.237 (0.436)	0.240 (0.429)	-0.053 (0.865)
REC (%) in the sitting position	0.070 (0.819)	0.003 (0.992)	0.070 (0.819)	-0.003 (0.992)	0.010 (0.975)	-0.067 (0.828)
REC (%) in the supine position	0.020 (0.949)	-0.564* **(0.045)**	-0.042 (0.892)	0.564* **(0.045)**	0.581* **(0.037)**	0.200 (0.512)
REC (%) in the standing position	-0.332 (0.268)	-0.227 (0.456)	-0.359 (0.228)	0.227 (0.456)	0.205 (0.501)	-0.078 (0.801)

APPENDIX XL (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY NON-FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
DET (%) in the sitting position	0.048 (0.876)	-0.013 (0.967)	0.046 (0.882)	0.013 (0.967)	0.031 (0.920)	-0.165 (0.590)
DET (%) in the supine position	0.132 (0.666)	-0.450 (0.123)	0.079 (0.799)	0.450 (0.123)	0.524 (0.066)	0.262 (0.387)
DET (%) in the standing position	-0.385 (0.193)	-0.246 (0.418)	-0.419 (0.154)	0.246 (0.418)	0.254 (0.402)	-0.122 (0.692)
ShanEn in the sitting position	-0.009 (0.978)	-0.012 (0.969)	-0.007 (0.982)	0.012 (0.969)	-0.016 (0.959)	-0.176 (0.565)
ShanEn in the supine position	0.136 (0.657)	-0.496 (0.085)	0.087 (0.778)	0.496 (0.085)	0.483 (0.094)	0.190 (0.533)
ShanEn in the standing position	-0.164 (0.593)	-0.203 (0.506)	-0.188 (0.538)	0.203 (0.506)	0.201 (0.509)	-0.027 (0.929)
Other						
ApEn in the sitting position	0.309 (0.304)	-0.346 (0.247)	0.278 (0.358)	0.346 (0.247)	0.342 (0.252)	-0.093 (0.761)
ApEn in the supine position	0.253 (0.404)	-0.299 (0.321)	0.228 (0.454)	0.299 (0.321)	0.273 (0.366)	0.176 (0.566)
ApEn in the standing position	0.002 (0.995)	-0.205 (0.502)	-0.007 (0.982)	0.205 (0.502)	0.084 (0.786)	-0.036 (0.907)
SampEn in the sitting position	0.197 (0.518)	-0.226 (0.457)	0.182 (0.551)	0.226 (0.457)	0.169 (0.581)	-0.035 (0.910)
SampEn in the supine position	0.190 (0.533)	-0.197 (0.520)	0.177 (0.564)	0.197 (0.520)	0.158 (0.606)	0.085 (0.782)
SampEn in the standing position	-0.015 (0.961)	-0.154 (0.614)	-0.018 (0.952)	0.154 (0.614)	0.030 (0.923)	0.072 (0.816)
DFA α1 in the sitting position	0.311 (0.301)	-0.195 (0.523)	0.284 (0.346)	0.195 (0.523)	0.298 (0.323)	0.073 (0.814)
DFA α1 in the supine position	0.372 (0.211)	-0.561* **(0.046)**	0.308 (0.305)	0.561* **(0.046)**	0.649* **(0.016)**	0.518* **(0.070)**
DFA α1 in the standing position	0.317 (0.291)	-0.649* **(0.016)**	0.245 (0.421)	0.649* **(0.016)**	0.730* **(0.005)**	0.071 (0.818)
DFA α2 in the sitting position	-0.107 (0.728)	-0.307 (0.308)	-0.134 (0.663)	0.307 (0.308)	0.235 (0.439)	-0.255 (0.401)
DFA α2 in the supine position	0.032 (0.917)	-0.513 (0.073)	-0.020 (0.949)	0.513 (0.073)	0.491 (0.089)	0.194 (0.526)
DFA α2 in the standing position	0.122 (0.691)	-0.282 (0.350)	0.096 (0.755)	0.282 (0.350)	0.262 (0.388)	-0.087 (0.778)

APPENDIX XL (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY NON-FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
D2 in the sitting position	-0.317 (0.292)	-0.028 (0.927)	-0.330 (0.270)	0.028 (0.927)	0.080 (0.795)	-0.187 (0.541)
D2 in the supine position	0.089 (0.772)	0.098 (0.750)	0.086 (0.781)	-0.098 (0.750)	0.048 (0.877)	0.036 (0.907)
D2 in the standing position	0.197 (0.520)	-0.006 (0.985)	0.191 (0.532)	0.006 (0.985)	0.081 (0.793)	0.494 (0.086)
PTT in the sitting position	0.329 (0.272)	-0.036 (0.908)	0.319 (0.287)	0.036 (0.908)	0.144 (0.638)	0.232 (0.446)
PTT in the supine position	0.530 (0.063)	-0.091 (0.767)	0.513 (0.073)	0.091 (0.767)	0.236 (0.438)	0.129 (0.674)
PTT in the standing position	0.344 (0.250)	0.130 (0.673)	0.351 (0.240)	-0.130 (0.673)	-0.012 (0.970)	-0.035 (0.910)

* Significant at $P < 0.05$

APPENDIX XLI
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Total time spent with juggling	0.254 (0.403)	-0.144 (0.640)	0.204 (0.505)	0.144 (0.640)	0.297 (0.324)	1
Time Domain Results						
Mean RR (ms) in the sitting position	-0.649* **(0.016)**	-0.468 (0.107)	-0.674* **(0.012)**	0.468 (0.107)	0.036 (0.906)	0.290 (0.336)
Mean RR (ms) in the supine position	-0.547 (0.053)	-0.456 (0.118)	-0.574* **(0.040)**	0.456 (0.118)	0.063 (0.839)	0.421 (0.152)
Mean RR (ms) in the standing position	-0.627* **(0.022)**	-0.547 (0.053)	-0.681* **(0.010)**	0.547 (0.053)	0.189 (0.537)	0.430 (0.142)
STD RR (ms) in the sitting position	-0.490 (0.089)	-0.344 (0.250)	-0.534 (0.060)	0.344 (0.250)	0.157 (0.609)	0.294 (0.329)
STD RR (ms) in the supine position	0.037 (0.904)	-0.172 (0.575)	0.024 (0.939)	0.172 (0.575)	0.076 (0.805)	0.526 (0.065)
STD RR (ms) in the standing position	-0.406 (0.168)	-0.259 (0.394)	-0.443 (0.130)	0.259 (0.394)	0.128 (0.677)	0.658* **(0.015)**
Mean HR (1/min) in the sitting position	0.691* **(0.009)**	0.398 (0.177)	0.703* **(0.007)**	-0.398 (0.177)	0.041 (0.894)	-0.265 (0.381)
Mean HR (1/min) in the supine position	0.536 (0.059)	0.395 (0.181)	0.555* **(0.049)**	-0.395 (0.181)	-0.018 (0.953)	-0.449 (0.124)
Mean HR (1/min) in the standing position	0.637* **(0.019)**	0.472 (0.103)	0.680* **(0.011)**	-0.472 (0.103)	-0.131 (0.670)	-0.435 (0.137)
STD HR (1/min) in the sitting position	-0.412 (0.162)	-0.206 (0.499)	-0.450 (0.123)	0.206 (0.499)	0.135 (0.659)	0.262 (0.388)
STD HR (1/min) in the supine position	0.320 (0.287)	0.128 (0.676)	0.333 (0.266)	-0.128 (0.676)	-0.022 (0.943)	0.277 (0.360)
STD HR (1/min) in the standing position	-0.329 (0.273)	-0.086 (0.779)	-0.345 (0.248)	0.086 (0.779)	0.036 (0.906)	0.655* **(0.015)**
RMSSD (ms) in the sitting position	-0.359 (0.229)	-0.256 (0.399)	-0.394 (0.183)	0.256 (0.399)	0.129 (0.675)	0.213 (0.485)
RMSSD (ms) in the supine position	0.250 (0.410)	-0.054 (0.861)	0.251 (0.408)	0.054 (0.861)	0.034 (0.913)	0.331 (0.269)
RMSSD (ms) in the standing position	-0.389 (0.189)	-0.305 (0.310)	-0.441 (0.131)	0.305 (0.310)	0.212 (0.487)	0.342 (0.253)
NN50 (count) in the sitting position	-0.582* **(0.037)**	-0.537 (0.058)	-0.634* **(0.020)**	0.537 (0.058)	0.184 (0.548)	-0.165 (0.591)
NN50 (count) in the supine position	0.433 (0.140)	0.016 (0.958)	0.435 (0.137)	-0.016 (0.958)	0.051 (0.868)	0.198 (0.517)
NN50 (count) in the standing position	-0.536 (0.059)	-0.443 (0.129)	-0.612* **(0.026)**	0.443 (0.129)	0.316 (0.293)	0.200 (0.512)

APPENDIX XLI (CONT.)

ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
pNN50 (%) in the sitting position	-0.581* **(0.037)**	-0.616* **(0.025)**	-0.644* **(0.018)**	0.616* **(0.025)**	0.241 (0.428)	-0.129 (0.675)
pNN50 (%) in the supine position	0.403 (0.172)	-0.042 (0.892)	0.398 (0.178)	0.042 (0.892)	0.085 (0.783)	0.205 (0.502)
pNN50 (%) in the standing position	-0.535 (0.060)	-0.504 (0.079)	-0.618* **(0.025)**	0.504 (0.079)	0.349 (0.242)	0.210 (0.491)
RR triangular index in the sitting position	-0.640* **(0.018)**	-0.608* **(0.027)**	-0.723* **(0.005)**	0.608* **(0.027)**	0.333 (0.266)	0.399 (0.177)
RR triangular index in the supine position	-0.236 (0.437)	-0.130 (0.673)	-0.251 (0.408)	0.130 (0.673)	0.042 (0.893)	0.632* **(0.020)**
RR triangular index in the standing position	-0.403 (0.172)	-0.202 (0.507)	-0.428 (0.145)	0.202 (0.507)	0.067 (0.828)	0.700* **(0.008)**
TINN (ms) in the sitting position	-0.512 (0.074)	-0.307 (0.307)	-0.548 (0.052)	0.307 (0.307)	0.113 (0.713)	0.326 (0.277)
TINN (ms) in the supine position	0.037 (0.904)	0.227 (0.456)	0.077 (0.803)	-0.227 (0.456)	-0.200 (0.513)	0.589* **(0.034)**
TINN (ms) in the standing position	-0.351 (0.239)	-0.158 (0.607)	-0.380 (0.200)	0.158 (0.607)	0.099 (0.747)	0.580* **(0.038)**
Frequency Domain Results						
FFT spectrum (Power n.u.)						
LF (0.04-0.15 Hz) in the sitting position	-0.195 (0.523)	-0.086 (0.779)	-0.165 (0.589)	0.086 (0.779)	-0.183 (0.550)	-0.067 (0.828)
LF (0.04-0.15 Hz) in the supine position	-0.323 (0.282)	-0.254 (0.402)	-0.334 (0.264)	0.254 (0.402)	0.012 (0.968)	-0.130 (0.673)
LF (0.04-0.15 Hz) in the standing position	-0.451 (0.122)	-0.105 (0.732)	-0.401 (0.174)	0.105 (0.732)	-0.324 (0.280)	-0.038 (0.902)
HF (0.15-0.4 Hz) in the sitting position	0.195 (0.523)	0.086 (0.779)	0.165 (0.589)	-0.086 (0.779)	0.183 (0.550)	0.067 (0.828)
HF (0.15-0.4 Hz) in the supine position	0.323 (0.282)	0.254 (0.402)	0.334 (0.264)	-0.254 (0.402)	-0.012 (0.968)	0.130 (0.673)
HF (0.15-0.4 Hz) in the standing position	0.451 (0.122)	0.105 (0.732)	0.401 (0.174)	-0.105 (0.732)	0.324 (0.280)	0.038 (0.902)
LF/HF in the sitting position	0.044 (0.887)	0.004 (0.989)	0.071 (0.817)	-0.004 (0.989)	-0.137 (0.655)	-0.140 (0.647)
LF/HF in the supine position	-0.113 (0.714)	-0.153 (0.617)	-0.116 (0.706)	0.153 (0.617)	<0.001 (0.999)	-0.171 (0.577)
LF/HF in the standing position	-0.231 (0.448)	-0.138 (0.653)	-0.212 (0.487)	0.138 (0.653)	-0.133 (0.666)	0.018 (0.953)

APPENDIX XLI (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
Nonlinear Results						
Poincare plot						
SD1 (ms) in the sitting position	-0.359 (0.229)	-0.255 (0.401)	-0.394 (0.183)	0.255 (0.401)	0.128 (0.678)	0.213 (0.485)
SD1 (ms) in the supine position	0.250 (0.409)	-0.054 (0.860)	0.251 (0.408)	0.054 (0.860)	0.034 (0.913)	0.331 (0.269)
SD1 (ms) in the standing position	-0.390 (0.188)	-0.306 (0.310)	-0.442 (0.131)	0.306 (0.310)	0.212 (0.487)	0.342 (0.252)
SD2 (ms) in the sitting position	-0.648* **(0.017)**	-0.476 (0.100)	-0.706* **(0.007)**	0.476 (0.100)	0.206 (0.499)	0.370 (0.213)
SD2 (ms) in the supine position	-0.056 (0.856)	-0.220 (0.469)	-0.075 (0.807)	0.220 (0.469)	0.092 (0.765)	0.570* **(0.042)**
SD2 (ms) in the standing position	-0.391 (0.187)	-0.244 (0.423)	-0.423 (0.150)	0.244 (0.423)	0.111 (0.719)	0.701* **(0.008)**
SD2/SD1 in the sitting position	0.160 (0.602)	0.286 (0.344)	0.209 (0.494)	-0.286 (0.344)	-0.229 (0.451)	-0.194 (0.524)
SD2/SD1 in the supine position	0.284 (0.348)	0.085 (0.784)	0.269 (0.374)	-0.085 (0.784)	0.118 (0.700)	-0.242 (0.426)
SD2/SD1 in the standing position	-0.071 (0.818)	0.194 (0.526)	-0.011 (0.971)	-0.194 (0.526)	-0.320 (0.287)	0.333 (0.267)
Recurrence plot (beats)						
Lmean in the sitting position	-0.145 (0.638)	0.124 (0.688)	-0.135 (0.660)	-0.124 (0.688)	-0.071 (0.818)	0.010 (0.974)
Lmean in the supine position	0.471 (0.104)	0.269 (0.375)	0.456 (0.118)	-0.269 (0.375)	0.149 (0.628)	-0.245 (0.421)
Lmean in the standing position	0.150 (0.625)	0.309 (0.304)	0.205 (0.502)	-0.309 (0.304)	-0.263 (0.385)	0.514 (0.072)
Lmax in the sitting position	0.324 (0.281)	0.168 (0.582)	0.288 (0.339)	-0.168 (0.582)	0.232 (0.446)	0.040 (0.897)
Lmax in the supine position	0.429 (0.143)	0.467 (0.107)	0.464 (0.110)	-0.467 (0.107)	-0.117 (0.702)	-0.237 (0.436)
Lmax in the standing position	0.123 (0.688)	0.400 (0.175)	0.204 (0.505)	-0.400 (0.175)	-0.397 (0.179)	-0.294 (0.330)
REC (%) in the sitting position	-0.036 (0.908)	0.282 (0.351)	-0.004 (0.990)	-0.282 (0.351)	-0.169 (0.580)	0.124 (0.686)
REC (%) in the supine position	0.211 (0.489)	0.359 (0.228)	0.248 (0.414)	-0.359 (0.228)	-0.159 (0.604)	-0.212 (0.488)
REC (%) in the standing position	0.252 (0.406)	0.530 (0.062)	0.351 (0.240)	-0.530 (0.062)	-0.476 (0.100)	0.302 (0.315)

APPENDIX XLI (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY FALLERS

	Total time spent taking the Stroop test	Number of correct answers in the Stroop test	Time spent obtaining correct answers in the Stroop test	Number of incorrect answers in the Stroop test	Time spent obtaining incorrect answers in the Stroop test	Total time spent with juggling
DET (%) in the sitting position	0.148 (0.629)	0.551 (0.051)	0.216 (0.478)	-0.551 (0.051)	-0.330 (0.270)	-0.030 (0.923)
DET (%) in the supine position	0.152 (0.619)	0.751* **(0.003)**	0.245 (0.419)	-0.751* **(0.003)**	-0.459 (0.114)	-0.135 (0.659)
DET (%) in the standing position	0.103 (0.738)	0.563* **(0.045)**	0.221 (0.468)	-0.563* **(0.045)**	-0.596* **(0.032)**	0.226 (0.458)
ShanEn in the sitting position	0.085 (0.782)	0.305 (0.311)	0.119 (0.699)	-0.305 (0.311)	-0.163 (0.595)	-0.100 (0.745)
ShanEn in the supine position	0.297 (0.325)	0.354 (0.235)	0.321 (0.284)	-0.354 (0.235)	-0.084 (0.784)	-0.235 (0.440)
ShanEn in the standing position	0.319 (0.288)	0.489 (0.090)	0.403 (0.172)	-0.489 (0.090)	-0.389 (0.189)	0.367 (0.218)
Other						
ApEn in the sitting position	0.383 (0.196)	0.084 (0.786)	0.356 (0.232)	-0.084 (0.786)	0.198 (0.518)	0.033 (0.916)
ApEn in the supine position	-0.421 (0.152)	-0.062 (0.840)	-0.436 (0.136)	0.062 (0.840)	0.017 (0.957)	0.163 (0.595)
ApEn in the standing position	0.398 (0.178)	0.117 (0.704)	0.387 (0.191)	-0.117 (0.704)	0.115 (0.708)	-0.631* **(0.021)**
SampEn in the sitting position	-0.105 (0.733)	-0.273 (0.366)	-0.158 (0.607)	0.273 (0.366)	0.257 (0.396)	-0.017 (0.956)
SampEn in the supine position	-0.442 (0.131)	-0.109 (0.724)	-0.459 (0.114)	0.109 (0.724)	0.027 (0.930)	0.240 (0.430)
SampEn in the standing position	0.276 (0.361)	-0.154 (0.614)	0.233 (0.443)	0.154 (0.614)	0.263 (0.384)	-0.487 (0.091)
DFA α1 in the sitting position	-0.148 (0.629)	-0.094 (0.760)	-0.111 (0.719)	0.094 (0.760)	-0.218 (0.475)	-0.192 (0.529)
DFA α1 in the supine position	-0.328 (0.274)	-0.174 (0.569)	-0.328 (0.274)	0.174 (0.569)	-0.049 (0.874)	-0.049 (0.873)
DFA α1 in the standing position	-0.414 (0.160)	-0.168 (0.583)	-0.392 (0.185)	0.168 (0.583)	-0.173 (0.571)	0.173 (0.571)
DFA α2 in the sitting position	0.407 (0.168)	0.674* **(0.012)**	0.504 (0.079)	-0.674* **(0.012)**	-0.447 (0.126)	-0.210 (0.492)
DFA α2 in the supine position	0.150 (0.625)	0.516 (0.071)	0.231 (0.448)	-0.516 (0.071)	-0.397 (0.179)	-0.181 (0.554)
DFA α2 in the standing position	0.544 (0.055)	0.561* **(0.046)**	0.641 (0.018)	-0.561* **(0.046)**	-0.423 (0.149)	0.150 (0.624)

APPENDIX XLI (CONT.)
ASSOCIATION AMONG COGNITIVE PLASTICITY, MOTOR PLASTICITY, AND HRV OF ELDERLY FALLERS

	Total time spent taking the Stroop test	**Number of correct answers in the Stroop test**	**Time spent obtaining correct answers in the Stroop test**	**Number of incorrect answers in the Stroop test**	**Time spent obtaining incorrect answers in the Stroop test**	**Total time spent with juggling**
D2 in the sitting position	-0.480 (0.097)	-0.893* **(<0.001)**	-0.591* **(0.033)**	0.893* **(<0.001)**	0.508 (0.076)	0.037 (0.905)
D2 in the supine position	-0.113 (0.712)	-0.470 (0.105)	-0.169 (0.581)	0.470 (0.105)	0.273 (0.367)	0.131 (0.669)
D2 in the standing position	-0.436 (0.137)	-0.802 (0.001)	-0.545 (0.054)	0.802 (0.001)	0.504 (0.079)	0.358 (0.230)
PTT in the sitting position	-0.391 (0.186)	-0.093 (0.762)	-0.380 (0.200)	0.093 (0.762)	-0.115 (0.708)	-0.160 (0.602)
PTT in the supine position	-0.184 (0.546)	-0.125 (0.684)	-0.204 (0.504)	0.125 (0.684)	0.073 (0.812)	-0.217 (0.477)
PTT in the standing position	-0.388 (0.190)	-0.089 (0.773)	-0.385 (0.194)	0.089 (0.773)	-0.072 (0.814)	-0.002 (0.994)

* Significant at $P < 0.05$

BIOGRAPHY

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Publications

Chuangchai W. Association Among Fear of Falling, Stress, and Quality of Life in Adults and Older People. Journal of Architectural/Planning Research and Studies. 2017;Volume 14(2):31-40.

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