INVESTIGATING THE EFFECT OF TAI CHI AND ZUMBA GOLD® ON MARKERS OF PHYSIOLOGICAL AND PSYCHOLOGICAL HEALTH IN OLDER AGE ADULTS

by

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Abstract

As the average life expectancy of populations across the world increases, there is a growing challenge to maintain the health of older adults into older age. Older adults are at greater risk of endothelial dysfunction, reduction in functional fitness and mental ill-health issues such as depression, anxiety and loneliness. Research has suggested that low physical activity (PA) among older age populations contributes to an increase in oxidative stress and inflammation, which contribute to perpetuate further endothelial dysfunction, and growing mental ill-health. Low PA coupled to the natural process of sarcopenia are factors in an older adults' decreased functional fitness, which limits their ability to do things independently. This creates a declining spiral in ageing leading to isolation, disease and eventually death. Therefore, encouraging older adults to increase their PA and adhere to an exercise programme is crucial in offsetting the effects of ageing. However, not all modes of PA are perceived as suitable for an older age population. This thesis presents two studies investigating the potential of Tai Chi and Zumba Gold® (i.e., Zumba® for older adults) to offset some of the effects of ageing on functional fitness, accumulation of oxidative stress and inflammation with age, and their role in endothelial function, and mental ill-health. In the acute Tai Chi study, 60 minutes of Tai Chi was able to produce a transient increase in plasma markers of inflammation (IL-6 and IL-10), and oxidative stress (MDA in old and 8-isoprostane in young) participants. Both age groups also had an improvement in endothelium dependent dilation, as measured using the non-invasive technique; flow-mediated dilation (FMD). Following 12 weeks of exercise training, participants in both the Tai Chi and Zumba Gold® groups showed an improvement in blood pressure, FMD, leg strength and endurance compared to baseline.

Physical and mental fatigue, as well as feelings of loneliness were improved in the Tai Chi group, while sleep quality, and perceptions of mental and physical health were improved in the Zumba Gold® group. Both groups also were found to have relatively high autonomous motivation for exercise and high self-efficacy to overcome exercise barriers. However, autonomous motivation and self-efficacy were not associated with changes in physiological or psychological outcome measures. In sum, the data presented in this thesis provide information that both Tai Chi and Zumba Gold are suitable exercise modes for older adults, which can improve markers of both physical and psychological health.

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My daughters

Fatihah Auna Samsuddin and her baby sister Kauthar Aynaz Samsuddin

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INTRODUCTION

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1.1 INTRODUCTION

1.1.1 Ageing and incidence of cardiovascular disease, reduction in functional fitness and mental-ill health.

According to Office of National Statistics United Kingdom 2012-2014, the life expectancy for men aged 64 has reached 18.4 years and 20.9 years for women, which means that men are expected to live until aged 83 and women at aged 86. As age increases, the incidence of health problems, for example cardiovascular diseases (CVD), has also increased, as age is the biggest single risk factor for CVD. Based on the report from General Lifestyle Survey of Great Britain (1988-2011), the prevalence of CVD in the United Kingdom is higher in older adults.

In the year 2011 for example, (figure 1.1), people aged 65 and above had a 28% and 24% (men and women respectively) prevalence of CVD, as compared to middle aged people (45-64 years old), with 14% and 10% prevalence (men and women respectively). Statistics also shown that there was a rise in CVD associated hospital treatment and admissions in UK, with more than 80000 procedures for coronary artery bypass operations and percutaneous coronary interventions in 2011, despite a fall in mortality rates. This causes a substantial burden to health services providers like the National Health Service NHS (Bhatnagar, Wickramasinghe, Wilkins, & Townsend, 2016). It is therefore important to seek disease prevention strategies to reduce CVD, especially in older age.

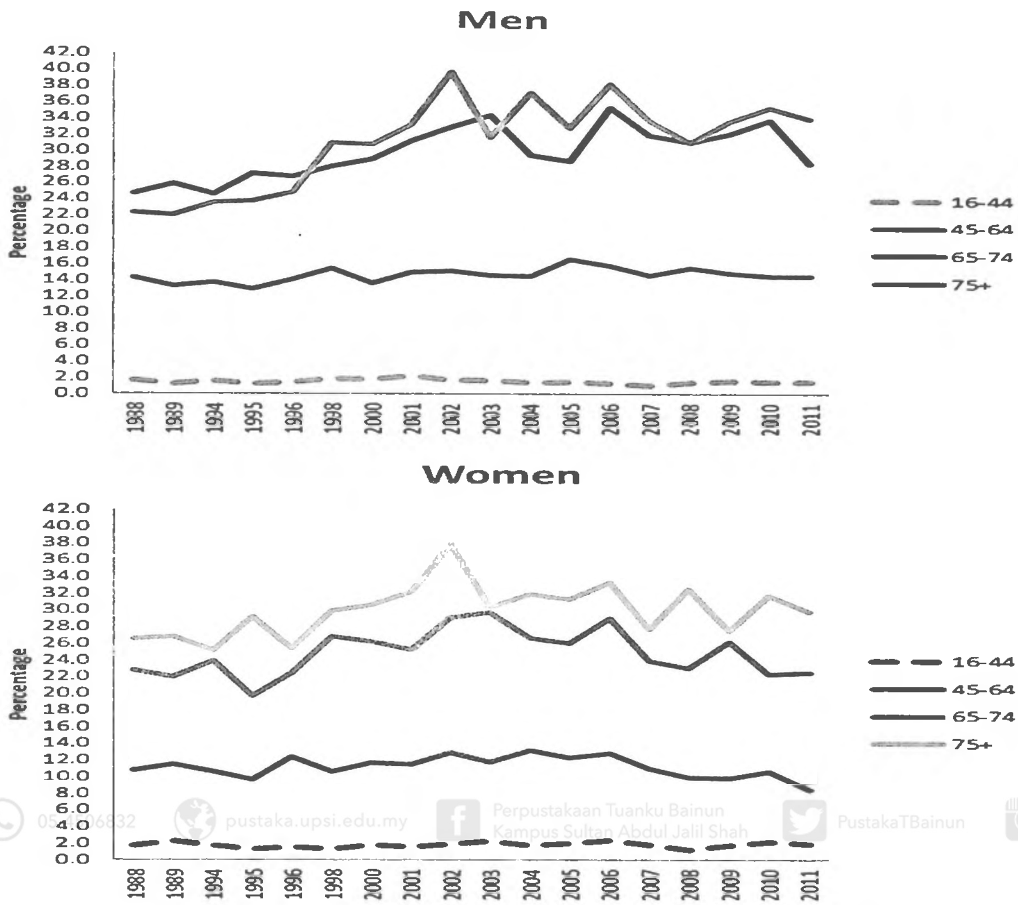

Figure 1. 1: Prevalence of cardiovascular diseases in men and women by age

(Bhatnagar et al., 2016)

Research also suggests that, as chronological aged increases it will not only increase the incidence of CVD but is also accompanied by a reduction in quality of life (QoL) (Neto & de Castro, 2012). According to Farquhar (1995), the term QoL has been commonly used since the end of World War II and was defined differently according to political, social economic or health perspectives. Based on World Health Organization (WHO), QoL is defined as "one's perception of their physical function and mental health" (Fortuño-Godes, Guerra-Balic, & Cabedo-Sanromà, 2013).

Radmila, Slavoljub, Saša, and Ratomir (2011) defined functional fitness as the optimum ability that is needed to perform daily activities independently without the early onset of fatigue. According to Jones, J and Rikli, (2002), there are several components that distinct functional fitness which are muscular strength, agility/balance, cardiorespiratory fitness, and flexibility. Muscular strength is defined as the ability of muscle group to develop maximal contraction on an external resistance or object (Suchomel, Nimphius, & Stone, 2016), while agility/balanced was defined as the ability to induced whole body change of direction rapidly and able to maintained postural stability (M. Rogers & Page, 2013; Sheppard & Young, 2006). Cardiorespiratory fitness was defined as the ability of circulatory and respiratory systems to provide enough fuel during certain task or physical activity, which can be measured using estimated VO_{2max} under a submaximal exercise testing (Caspersen, Powell, & Christenson, 1985). Flexibility on the other hand, was defined as the intrinsic property of body tissue which includes connective tissue and muscle that determined the range of motion without experiencing any injury at joint (Holt, Holt, & Pelham, 1996). Reduction in strength, agility/balance, flexibility and cardiorespiratory fitness can therefore result in difficulties in managing activity of daily living (ADLs) such as dressing and grooming, carrying shopping, rising, climbing stairs and walking (Tuna, Edeer, Malkoc, & Aksakoglu, 2009), which will affect the QoL of an individual (Pernambuco, Gao, & Li, 2012). Individual ability to perform physical activity of daily living is known as physical function which reflect motor function and control, functional fitness and is an independence predictor of morbidity, mortality and disability (Brill, Macera, Davis, Blair, & Gordon, 1999; Garber et al., 2011).

Most gerontologists agree that a reduction in functional fitness is associated with ageing (Manini & Pahor, 2009; Radmila et al., 2011). In agreement with this, Milanović et al. (2013), found poorer physical function and physical fitness among old (70-80 years) compared to younger counterparts (60-69 years) especially in muscle strength, agility, endurance, and flexibility. The authors of this study also reported that reduction in muscle mass and strength began at the age of 30 and the loss is 12 to 14% more at the age of 50 and above.

Decreases in physical function, as mentioned above, are considered part of the development of frailty among the elderly population. According to Fried et al.(2001), the frailty phenotype and criteria can be characterized by weakness, slowing down, exhaustion with poor endurance and energy. While Studenski et al.(2004) treat the frailty criteria as having a poor upper and lower body strength, loss of balance and flexibility, and having difficulties in mobility, which includes walking, transferring or moving from place to place and walking up and down the stairs. As the population continues to age yearly, it has been noted that the prevalence of frailty has also increased. In the Unites States for example, approximately 10% of its older adults are frail, and the prevalence has increased to 30% in those who are aged 80 and above (Collard, Boter, Schoevers, & Oude Voshaar, 2012). In addition to that, the increasing in the percentage of frail individual will also resulted in increasing risk of other adverse health outcomes such as falls, which often result in hospitalisation (Siu, Padilla, & Rajaram, 2017).

Evidence has demonstrated that a reduction in physical functional will not only cause immobility but also could lead to depression and loneliness (Salguero, Martínez-García, Molinero, & Márquez, 2011). This is in line with Jones and Rikli (2002) that suggested that older adults that have good physical function and fitness, are able to maintain their independence in doing daily activities, which can facilitate a better mental health. Hacihasanoĝlu, Yildirim and Karakurt (2012) reported that loneliness scores were significantly higher in older adults that had difficulty performing their ADL as compared to older adults that are independent in doing their daily activities. Further examination showed ADL related to being widowed or divorced, and individuals found ADL more challenging when they had low social support from family and society. Moreover, Launaigh and Lawlor (2008) also reported that older adults that suffer from loneliness had lower sleep quality, and this was likely to affect other health outcomes such as increasing in systolic and diastolic blood pressure, reduction in cardiac output and lower heart rate variability (Hackett, Hamer, Endrighi, Brydon, & Steptoe, 2012). The majority of studies report that increasing age is associated with increased feelings of loneliness (Hacihasanoğlu et al., 2012; Yang & Victor, 2011). Therefore, older aged populations, not only have higher risk in CVD, but are also likely to have lower QoL impacted by both physiological (physical function and fitness) and psychological (loneliness, anxiety and depression) changes.

1.1.2 Physical inactivity and activity guidelines

Recent research suggests that a high prevalence of cardiovascular disease, reduction in functional fitness and mental health as described above is related to low PA or physical inactivity (Chodzko-Zajko et al., 2009). PA can be defined as any body movement that involves muscle contraction which results in energy consumption more than resting expenditure (Caspersen et al., 1985) and can be further categorized into leisure time PA, transport PA and house hold PA (Sun, Norman, & While, 2013). PA also can be categorized according to intensity which are low, moderate and vigorous (González, Fuentes, & Márquez, 2017).

According to the American College of Sport Medicine (ACSM) and American Heart Association (AHA), older adults are recommended to perform a minimum of 30 minutes moderate-intensity aerobic PA on five days each week. Moderate intensity can be classified as at scale 5 or 6, if 0 represents sitting, and 10 is all-out effort. An individual undertaking moderate exercise should be able to speak in sentences whilst exercising but need to take a breath after each sentence, they should be able to talk but not sing! By comparison vigorous exercise would be considered an intensity of 7-8 on the 0-10 scale, and an individual would be able to answer questions with single word answers but not whole sentences (Nelson et al., 2007).

It should be noted that the recommendation from the ACSM of 20 mins x 5 days is a minimum recommendation, which can be further tailored to an individual based on their health condition. Older adults with one or more medical conditions should perform exercise according to their ability and health condition which could include a gradual increase physical activities over time. However, Lachman et al. (2018) also emphasized that any amount of PA can be beneficial to promote health benefits to elderly population. Most people consider exercise to be physical activity of a moderate or high intensity. However, exercise also includes physical activity of low intensity. Low intensity exercise is considered to be above 1.5 METS and below 3.0 METS. METS are defined as metabolic equivalent units, and are used as a unit of measurement in exercise. Similarly, researchers will use the percentage of maximal heart rate, or oxygen consumption, in order to characterise how intense or energy demanding physical activity is (Norton, Norton, & Sadgrove, 2010). Typically, low intensity exercise consists of stretching, light walking and push ups against the wall (Tse, Wong, & Lee, 2015). The classification of intensity category based on percentage of HR_{max}, oxygen uptake reserve, VO_2R, METs and perceived exertion measure is represent in table 1.1. However, it is possible that an individual that ongoing high or fulfil the recommendation of weekly physical activity, can also be consider as sedentary. According to Van der Ploeg and Hillsdon, (2017), an individual who spent most of their days sitting in the office, on a transport and spending time watching television in the evening, but at the same time, went for running after work, as recommended by WHO, can be categorised as highly sedentary and physically active on the same day.

Individuals who do not meet the recommended weekly activity levels are categorized as physically inactive (Ramalho, Petrica, & Rosado, 2018). Based on the report from Centres for Disease Control and Prevention (CDC) only 16% of older adults aged 65 or older in the USA, met the required national recommendation of undertaking 150 min of PA per week (Centers for Disease Control and Prevention, 2018). and this age group was reported to have the highest prevalence of physical inactivity thorough out the world as compared to their younger counterparts (Zhao, Ford, Li, & Balluz, 2011). Several factors have been identified to explain the reduction in PA in older age adults. Namely; retirement, declining health, environmental factors, a lack of interest in the exercise modes available and socio-economic factors (Gobbi et al., 2012).

Table 1. 1: The classification of intensity category based on percentage of maximum heart rate (HRmax) , oxygen uptake reserve (VO2R), METs and perceived exertion measure.

Intensity category (Blumchent, 1990)	$\%HR_{max}$ (Norton et al., 2010)	$\%VO_2R$ (Committee, 2008)	MET (I. Lee & Paffenbarger, 2000)	Perceive exertion measures (Nelson et al., 2007)
Low Activity that resulted in only minimal perspiration and only slight increase in breathing above normal. Example: bowling, light walking, cooking.	40-55	20-39	1.5 – 3.0	1-4
Moderate Activity that resulted in definite perspiration and above normal breathing. Example: carpentry, digging, Tennis double, brisk walk (4mph)	55-70	40-59	3.0 – 6.0	5-6
Vigorous Activity that resulted in heavy perspiration and heavy breathing. Example: wood cutting, marathon, squash, tennis single	70-90	60-84	> 6.0	7-10

1.1.3 Physical inactivity; cardiovascular diseases and reduction in quality of life

There is no doubt that physical inactivity is related to the prevalence of CVD. In the Women's Health Initiative Observational Study, low physical activity among 50-79 year old women was associated with an elevated risk of getting CVD (Lu et al., 2013) and many clinical trials have significantly proven that adhering to exercise training or PA can slow down the progression of CVD itself (Cheng et al., 2013; Palmefors, DuttaRoy, Rundqvist, & Börjesson, 2014; Seals, 2014). According to Lillo, Palomo-Vélez, Fuentes, and Palomo (2015), PA helps in reducing CVD by lowering the risk markers of CVD (endothelial dysfunction, dyslipidaemia, and atherosclerosis) and CVD risk factors of diabetes, hypertension and obesity. The proposed mechanism on effect of exercise/PA on endothelial function will be further explained in section 1.1.7 below.

Physical inactivity is the main cause of loss of functional fitness (Brill, 2004). Buchner et al. (2017) reported that older women that engaged in more than 69.3 minutes of moderate to high PA per week had higher functional fitness and one or fewer falls compared to those who had a lower level of PA. Similar findings were reported by Milanović et al.(2013), where physically inactive older adults aged 70 to 80 years old had lower physical function and an increased risk of falling compared their younger elderly (60-69 years old) that undertook more PA. The authors also suggested that any continuous sedentary behaviour further resulted in a reduction in muscle mass and strength at an average of 3.4% annually but this could be slowed down by engaging in PA. Sedentary behaviour is defined as all activities with low level of metabolic energy expenditure <1.5 METs or too much sitting or reclining posture (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008). To classify one individual for being sedentary of inactive has been controversial, and an accurate classification according to their daily activities is essential. According to Pate, O'Neill, & Lobelo (2008) if a person who engaged in low intensity PA of 75% of his day with 25% of his day being sedentary, he is classified as more active as compared to individual B who met recommendation level of PA, but spent 70% of the day being sedentary.

This is supported by other researchers that have shown community-dwelling older adults that undertook an exercise training programme improved their functional fitness (Giné-Garriga, Roqué-Fíguls, Coll-Planas, Sitjà-Rabert, & Salvà, 2014; Hill, Hunter, Batchelor, Cavalheri, & Burton, 2015). A 12 week multi-component exercise program among nonagenarians for example, showed body agility, endurance and balance performance significantly improved (Cadore et al., 2014). Similar findings were reported by Sousa, Mendes, Abrantes, Sampaio, and Oliveira (2014), where older men that underwent 9 months aerobic and combined aerobic/resistance training significantly improved their functional fitness compared to the control group.

The urgency to promote PA in older age not only exists because of a need to improve physical function and physiological health, but also to improve mental health and QoL. The benefits of exercise in improving QoL have been seen in many studies. This includes the effect of exercise on reduction of depression in older adults, both in those with recently diagnosed depression (Kvam, Kleppe, Nordhus, & Hovland, 2016) and in those that suffer from Major Depressive Disorder (Patten, Williams, Lavorato, & Bulloch, 2013) and in frail older adults that live in care institutions (Weening-Dijksterhuis, Greef MH Scherder, Slaets, & van der Schans, 2011). One of the mechanisms by which exercise might affect depression is via a reduction in inflammation. Studies have shown that inflammatory markers, such as CRP and TNF are linked to depression in major depressive disorder and psychosis (Felger et al., 2018; Goldsmith et al., 2019), and thus the ability of exercise to reduce these proteins associated with inflammation may be one way that exercise could act on depression. Indeed there is speculation that there are bi-directional links between depression and inflammation that may be targeted by exercise (Kiecolt-Glaser, Derry, & Fagundes, 2015).

Besides having poor physical function and mental health issues, another factor that may contribute to low quality of life among elderly population is a reduction in sleep quality. According to Crowley (2011), more than 50% of older adults complain about their sleep quality, including difficulty in initiating and maintaining their sleep and early day waking. Sleep disturbance may further resulted in fatigue, daytime dysfunction, increase in daytime napping and difficulties in memory and concentration (Ancoli-Israel, Ayalon, & Salzman, 2008). Although there are numerous pharmacological approaches to help improve sleep quality, researchers have found that engaging in physical activity or exercise can be an effective non-pharmacological approach to cater for this problem. Research has suggested that mild to moderate intensity exercise (Brandão et al., 2018; Lima et al., 2015; Reid et al., 2010) and mind-body meditation exercise like Tai Chi and Yoga (Chen et al., 2010; Chen, Liu, Huang, & Chiou, 2012; Irwin, Olmstead, & Motivala, 2008; Ma et al., 2016) can improve sleep quality.

1.1.4 Oxidative stress and inflammation in ageing.

According to American College of Sport Medicine (ACSM), older adults should be doing 150 minutes of moderate intensity for example brisk walk, plus muscle strengthening activities for at least 2 days in order to achieved a health benefits. Research has reported that older adults that fulfil this recommendation guidelines have better health outcomes when compared to their counterparts that undertake a lower level of physical activity (PA), or who are physically inactive. PA can reduce oxidative stress and inflammation, two conditions that occur as humans age. These concepts are described in the free radical theory of ageing (Flynn, Markofski, & Carrillo, 2018; Harman, 1981). The free radical theory of ageing was first proposed by Harman in 1956 (Harman, 1956). In this theory, Harman proposed that as humans age there is an accumulation of biomolecules carrying adducts, which have been formed during the metabolic interaction of biomolecules and reactive radicals. The

accumulation of these adducts over the life span can lead to mitochondrial dysfunction and perpetuate further production of free radicals. Oxidative stress is status that is described as an imbalance between free radical reactive species and antioxidants. Free radicals can be defined as molecules that have unpaired electrons in their molecular orbital and examples include superoxide ($O2\cdot-$), and the hydroxyl radical (HO.). Reactive oxygen species (ROS) and reactive nitrogen species (RNS) also have the ability to oxidise biomolecules, and are important in the oxidative balance that contributes to oxidative stress. ROS and RNS are produced in our daily life during cell respiration and have an essential role in cell signalling. The uncontrolled production of ROS can be harmful to the cell, and can lead to interaction with biomolecules such as DNA, lipids and proteins resulting in adduct formation and damage. Hence, the presence of antioxidants are important to balance ROS and maintain cellular homeostasis. There are two types of antioxidant; endogenous antioxidant, which is produced in the body, and exogenous antioxidant, derived from food. Endogenous antioxidants or enzymatic antioxidants include superoxide dismutase (SOD), glutathione peroxidase (GPx), calatase (CAT), while examples of non-enzymatic antioxidants are vitamin E (α-tocopherol), Vitamin C (ascorbic acid) and some flavonoids (Deaton & Marlin, 2003).

In addition to oxidative stress, researchers have observed an increase in chronic low-grade inflammation in ageing. An acute inflammatory response is a normal bodily response towards tissue damage or infection. It will initiate recovery by up regulating cytokines and leukocytes to the site of infection. However, lifelong activation of the immune response may also stimulate the chronic production of the pro-inflammatory mediators Tumor necrosis factor-α (TNF-α), IL-1β, and IL-6, which can be related to poor health. This process is known as inflamm-ageing and has been well described by Franceschi (Franceschi et al., 2000) also in the context of age-related disease (Franceschi & Campisi, 2014). The mechanisms underlying this effect are still unclear. However, some researchers have suggested that sex hormones are the possible antecedents of the increasing inflammatory markers in an ageing population (Chung et al., 2009; Singh & Newman, 2011). The relationship between pro-inflammatory cytokines and sex hormones can also being observed in an in vitro study by Keller, Chang, and William (1996) and Ray, Ghosh, Zhang, and Ray (1997). In this study, the presence of oestrogen suppressed IL-6 secretion. A similar effect was observed by Maggio, Guralnik, Longo, and Ferrucci (2006) where declining levels of testosterone caused elevated pro-inflammatory cytokines. Thus sex hormones appear to down-regulate or supress inflammatory proteins, and as such a reduction in sex hormone availability will have an effect on inflammation, which can be observed after the onset of the menopause (Isabel, Nuria, Lorena, Jesús, & Mónica, 2011).

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1.1.5 Oxidative stress, inflammation and its link to cardiovascular diseases

Evidence strongly supports that an accumulation of free radicals (Harman, 1981; Herrera, Mingorance, Rodríguez-Rodríguez, & Alvarez de Sotomayor, 2010; Selman, Blount, Nussey, & Speakman, 2012) and a decrease in circulating antioxidants (Kumawat et al., 2012; Wickens, 2001) coupled with the presence of low-grade systemic inflammation among an ageing population will increase the risk of CVD (McCrohon et al., 2000; Moens, Goovaerts, & Claeys, 2005) by decreasing Nitric Oxide (NO) which will lead to endothelial dysfunction (Carbone & Montecucco, 2015; Huige & Förstermann, 2013; Yang & Ming, 2013).

In a healthy vasculature, NO acts as a signalling molecule and has a dominant role in regulating vascular homeostasis, not only as vasodilator, but also in aiding permeability and as an antithrombotic agent (Jin & Loscalzo, 2010; Tousoulis, Kampoli, Tentolouris, Papageorgiou, & Stefanadis, 2012). However, the accumulation of oxidative stress and inflammation in an ageing population can decrease the bioavailability of NO via scavenging NO and uncoupling the enzyme responsible for NO production, nitric oxide synthase (NOS), thus disturbing NO synthesis from endothelial NOS. In addition, increased superoxide radicals can cause upregulation of inducible NOS, which can increase superoxide production still further, creating a perpetuating scenario of reduced NO bioavailability.

Due to its multidimensional role in aiding the function of the vasculature, it is crucial to maintain the normal regulation of NO synthesis. (Huige & Förstermann, 2013; Sitia et al., 2010; Tousoulis et al., 2012). The production of NO is facilitated by calcium-calmodulin-dependent enzyme nitric oxide synthase (NOS) which exists in several isoforms: endothelial (eNOS), inducible (iNOS) and neuronal (nNOS) (Michel & Feron, 1997; Tousoulis et al., 2012). iNOS is upregulated during the inflammatory response and is often unregulated. It is expressed in macrophages, neutrophils and platelets and acts to combat microorganisms and infection (Aktan, 2004). nNOS is expressed in neurons which responsible in regulating blood pressure, and synaptic function in central nervous system (CNS) while eNOS is located in endothelial cells, and is responsible for secretion of NO to promote vascular vasodilation (Singh & Gollen, 2015).

In the vasculature, eNOS, in the presence of oxygen converts the substrate L-arginine and cofactor tetrahydrobiopterin (BH_4) to form NO and L-citruline (Figure 1.2) (Förstermann & Sessa, 2012; Northcott, Czubryt, & Wigle, 2017). However, in certain conditions, eNOS may be uncoupled by a reduction in substrate or cofactor that will cause a reduction in bioavailability of NO (Osto & Cosentino, 2010). Results from research studies demonstrate that there is a strong and consistent association between oxidative stress, low-grade inflammation and the bioavailability of L-arginine and BH_4 (Huige & Förstermann, 2013; Yang, Huang, Kaley, & Sun, 2009).

BH_4 is an essential co-factor to L-arginine and eNOS coupling to produce NO (Osto & Cosentino, 2010). However, BH_4 availability can be decreased due to an elevated oxidative stress level and increased inflammation (Channon, 2012; Kietadisorn, Juni, & Moens, 2012; U. Singh, Devaraj, Vasquez-Vivar, & Jialal, 2007). C-reactive protein (CRP), a marker of inflammation, is known to decrease intracellular BH_4 levels via down regulating GTPCH1, an enzyme responsible for BH_4 synthesis. CRP may also impair the bioavailability of NO by directly reducing the expression of eNOS (Chen et al., 2012). The dual role of reducing NO bioavailability, either via uncoupling and inhibition of eNOS has made CRP one of the most measured markers for cardiovascular disease (Grad & Danenberg, 2013). When BH_4 is depleted, this will cause uncoupling of the oxygen molecules with L-arginine, and can cause NOS to produce superoxide. This formation of NOS-derived superoxide will react with available NO to produce peroxynitrite ($ONOO^-$), and the subsequent rapid oxidation of BH_4

will contribute to prolonged eNOS uncoupling and decreased NO synthesis (Schmidt & Alp, 2007).

Iyamu, Perdew, and Woods (2012) reported that increasing oxidative stress in endothelial cells resulted in increased arginase I and arginase II, which are L-arginine degraders, and a resultant suppression of L-arginine activity. Arginase directly metabolizes L-arginine to urea and L-ornithine, and thus results in uncoupling of eNOS with L-arginine (Wu et al., 2015; Yang & Ming, 2013). Oxidative stress also results in oxidation of low-density lipoprotein (Ox-LDL) which reduces the L-arginine coupling via suppressing the endothelial L-arginine uptake (Parthasarathy, Raghavamenon, Garelnabi, & Santanam, 2010; Ryoo et al., 2006; Vergnani et al., 2000). In addition to that, the inflammatory marker TNF-α is also responsible for the degradation of arginine in the endothelial cell by inhibiting arginine-succinate-synthase, and up-regulating arginase expression (Goodwin, Pendleton, Levy, Solomonson, & Eichler, 2007).

TNF-α also has the ability to inhibit the expression of eNOS (Neumann, Gertzberg, & Johnson, 2004). During a low-grade inflammation, TNF-α is responsible for facilitating endothelial dysfunction via activation of endothelin-1, a vasoconstrictor factor (Marsden & Brenner, 1992; Zhao, Chen, Yao, & Chen, 2005). A number of studies have suggested that TNF-α is the principal precursor of the inflammatory response and can alter the redox status of the cell, to promote oxidative stress (Herrera et al., 2010; Zhang et al., 2009) thus promoting endothelial dysfunction, atherosclerosis and arterial stiffness. Atherosclerosis is also one of the common risk factor for CVD, which characterised by thickening of the intimal layer of arteries and accumulation of fat (Mahmoud, Mahbubeh, Monir, Azar, & Hamid, 2014) . It starts with a deposition of small cholesterol in the intima and smooth muscle layer which then resulted in hardening of arteries and obstruction of blood flow. Research suggest that, both inflammation and oxidative stress play a major role in the development in endothelial dysfunction and atherosclerosis (Sitia et al., 2010; Spagnoli, Bonanno, Sangiorgi, & Mauriello, 2007).

There are many factors that may relate oxidative stress and inflammation, which interact to affect vascular function. Figure 1.2 here below depicts the possible factors that could be involved in the mechanisms of endothelial dysfunction.

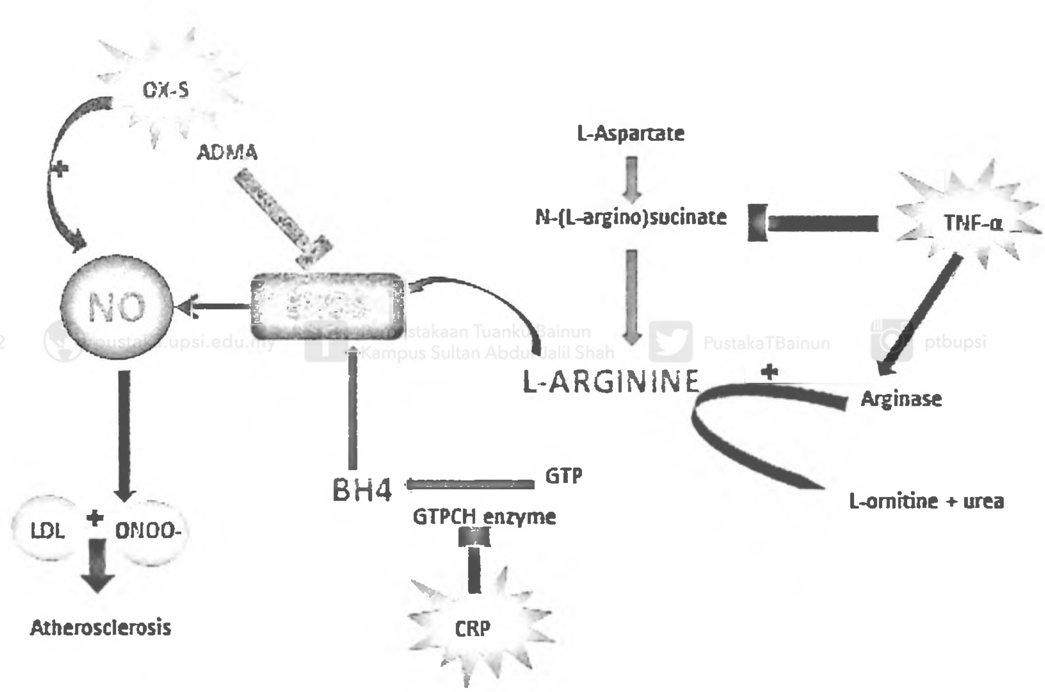

Figure 1. 2: Role of oxidative stress and inflammation in reducing NO bioavailability

Figure 1.2 describes the production of NO in the human vasculature. eNOS with the present of oxygen together with L-arginine and co-factor BH_4 will form NO and L-citruline. However, this pathway will be impaired in the present of oxidative stress and inflammation, thus causing an impairment in NO synthesis. Oxidative stress and inflammation in vasculature can cause an increasing level of NOS inhibitor, ADMA; supressing the GTPCH enzyme that is essential for BH4 synthesis; and reduction in L-arginine substrate by L-arginine degrader, arginase.

1.1.6 Oxidative stress, inflammation and its link to reduction in quality of life

Oxidative stress and inflammation are not considered as criteria for frailty by Fried et al. (2001) but have been proposed as factors associated with frailty (McArdle & Jackson, 2000). During ageing, the reduction in both sex and growth hormones is associated with increased low grade inflammatory proteins and oxidative stress, and recent evidence suggests that there is a positive relationship between inflammatory cytokines and ROS with poor physical performance, muscle weakness and functional fitness (Mulero & Zafrilla, 2011). The accumulation of low grade systemic inflammation couple with physical inactivity among elderly worsen the functional fitness which causes frailty (Beltran Valls et al., 2014; Landi et al., 2010). Research showed that, elderly that that engaged in exercise training shown an improvement in frailty symptoms which includes increasing in anabolism, muscle protein synthesis and reduction in marker of inflammation (Aguirre & Villareal, 2015; Nascimento et al., 2014).

Loss of functional fitness is mainly due to muscle breakdown and loss of muscle mass. Research suggested that this is due to the activation of 11βHSD1 protein and cortisol generation by the high circulating levels of IL-6, CRP and TNF-α caused by muscle breakdown in an ageing population (Wilson, Jackson, Sapey, & Lord, 2017). Studies suggest that ROS, especially H_2O_2 are responsible for the impairment of protein synthesis, and increases in somatic mutation and cell death in the muscle (Giorgio & Trinei, 2007). According to Viña et al. (2016), activation of P38 MAPK protein in the mitochondriogenic cell signal pathway results in loss of muscle mass.

Due to the importance of recognising the risk of losing functional ability in older adults, Rikli, Roberta E, Jones, (1998) have designed an assessment tool called The Senior Fitness Test (SFT). This validated assessment consists of 30 seconds chair stand, arm curl test, chair sit-and reach, back scratch test and 8 foot-up and go test which measures lower body strength, upper body strength, lower body flexibility, upper body flexibility and balance respectively (Jones & Rikli, 2002; Purath, Buchholz, & Kark, 2009).

1.1.7 Effect of exercise on oxidative stress and inflammation in older age adults

Research has suggested that adhering to exercise can help reduce oxidative stress and inflammation thus improve endothelial function and QoL in older adults (Bouzid, Filaire, McCall, & Fabre, 2015; Carvalho et al., 2010; Gomes, Silva, & Oliveira, 2012). Studies report that, free radical and pro-inflammatory cytokines that increase during an exercise session may act as a physical stress to the body, thus stimulating the secretion of antioxidant capacity and anti-inflammatory cytokines as has been proposed in the hormesis theory that will be further explained in chapter 2.

There is no doubt that exercise is beneficial for health. Evidence strongly suggests exercise is beneficial for vascular function, as well as overall QoL, but there are other factors to consider when 'prescribing' exercise to older age adults. Studies have reported inconsistent findings when assessing effect of exercise in older age adults. Some inconsistencies can perhaps be explained by the varying intensity, duration, and type or mode of exercise that have been studied in older age adults. In order to see an improvement in functional fitness for example, the type or mode of exercise undertaken, related to the intensity may be key. There is uncertainty about which mode of exercise may maximize the changes in elderly functional fitness. Leirós-rodríguez, Soto-rodríguez, Pérez-ribao, & García-soidán (2018) for example, suggested that aerobic exercise may beneficial more in promoting functional fitness as compared to strength training. While Silva & Pinto (2018) reported both water based training (aerobic and aerobic and resistance) are equally effective in improving functional fitness among elderly. In addition, the frequency of exercise sessions also may be an important factor. Nakamura, Tanaka, Yabushita, Sakai, and Shigematsu (2007) showed that older women that were involved in exercise session 3 times per week, resulted in better functional fitness as compared to those that exercised less frequently.

1.1.8 Barriers to exercise in older age

Previous studies have highlighted the barriers that might prevent older adults from exercising or that may reduce their motivation to do exercise. The most common factors are poor physical health and physical impairment. Older adults may choose not to be involved in any PA because of their inability to stand for long periods of time, or because they have limited mobility (Kosteli et al., 2017). In an interview with older age participants of a study by Chen (2010), the participants stated: 'For a person who is sitting in a wheelchair like me, it is impossible to perform any physical activities. I cannot move freely' (Male, 79) 'my functional ability does not allow me to be physically active any more' (Male, 72), and 'My health is very poor, how can I perform PA? It is just a dream' (Female 71). In addition to that, other barriers identified relate to the fear of getting injured or falling (Gobbi et al., 2012; Lee, Jackson, & Richardson, 2017; Schmidt, Rempel, Murray, McHugh, & Vallance, 2016; Sjors, Bonn, Trolle Lagerros, Sjolander, & Balter, 2014), that participants had no interest in doing exercise or didn't enjoy any exercise programme earlier in life (Justine, Azizan, Hassan, Salleh, & Manaf, 2013; Kosteli et al., 2017; Lee et al., 2017) and that participants didn't have time do exercise or they find PA too time consuming (Gobbi et al., 2012; Huang, Lin, Lee, & Chen, 2016; Justine et al., 2013).

Therefore, to encourage older adults to exercise, and integrate exercise into their lifestyle it is important to tailor an exercise intervention. It is therefore imperative that the recommended exercise is both effective and appropriate for this age group in order for them to engage with the programme and experience the subsequent health benefits of undertaking PA.

1.1.9 Tai Chi and Zumba Gold®: Are they suitable for elderly population?

Clearly there are many factors to consider before constructing any exercise programme for this age group, not least; the type of exercise, safety aspects, and nature of the exercise itself (Is it perceived as enjoyable? Can it be undertaken when seated? The studies presented in this thesis will assess two types of exercise that are considered to be safe for older age adults; Tai Chi and Zumba Gold®.

Tai Chi and Zumba Gold® are known to be practised among elderly and classified as aerobic exercise. This is based on the classification by American College of Sport Medicine (ACSM), which defined aerobic exercise aa any activities that involved large muscle group, and maintained continuously and is rhythmic in nature. This activities rely on aerobic metabolism which get the energy in form of adenosine triphosphate (ATP) from amino acids, carbohydrate and fatty acids (Patel et al., 2017).

1.1.9.1 Tai Chi: benefits and its safety issue

Tai Chi, Tai Ji Quan, Taiji or Taiji Chuan is an ancient Chinese exercise that has been practiced for hundreds of years in China (Yang et al., 2015). Literally, Tai Chi means the 'The Supreme Ultimate Boxing System' which originally emerged from a form of martial arts and self-defence (Kuramoto, 2006). The full history of Tai Chi is unclear; however, it is believed to have originated from the Henan province in China in the late dynasty of Ming (Guo, Qiu, & Liu, 2014). The first written source on Tai Chi is by the martial artist Chen Wangting

(1600-1680), who suggested Tai Chi as a new form of Kung Fu (Chang, Nien, Tsai, & Etnier, 2010; Wayne & Kaptchuk, 2008b). He is also believed to be the person who created and first practiced Tai Chi (Group of the State Sports General Administration of Martial Arts Research Institute, 2009).

Over the last 300 years, Tai Chi has evolved into five main styles, which include: Wu, Sun, Chen, Yang and Hao (Wang, Collet, & Lau, 2004; Yang et al., 2015). Chen is known as the oldest style while Yang is the most well-known style, and is practised in most Western countries (Lan, Lai, & Chen, 2002). The differences between styles concern the posture, pacing and order of movement, but all styles practice the similar fundamental movements that emphasise relaxation and mindfulness (Fetherston & Wei, 2011).

To perform Tai Chi, the practitioner will start by standing with feet shoulder-width apart, and slightly bending their knees (Wall, 2005). Some practitioners believe that this position relates to enhanced body strength and balance by distributing the body weight on both feet to let the 'qi' or vital energy flow from centre of the earth (gravity) into the body. The philosophy is to let the body be part of gravity. The practitioner will then make a circular arm movement and use imagery and visualisation, for example use your hand to part the cloud, and as a crane would spread its wings (Wayne & Kaptchuk, 2008a). Those movements combined with deep diaphragmatic breathing will produce a slow and graceful movement (Thomas et al., 2005). The concept of shifting weight from one leg to another leg during the slow movements trains the practitioner to become more mindful and aware.

These movements stimulate a three way combination of musculoskeletal strength, breathing and mindfulness, and this has provoked some scholars to identify Tai Chi as mind-body exercise or moving meditation (C. E. Rogers, Larkey, & Keller, 2009). This is therefore not only beneficial to physical, but also to mental health (Adler & Roberts, 2006; Zheng et al., 2018; Zheng, Lal, Meier, Sibbritt, & Zaslawski, 2014). Musculoskeletal strength improves by increasing the neuromuscular response to the lower extremities during the slow movements (Hass et al., 2004; Wu, Liu, Hitt, & Millon, 2004). In addition, deep breathing can have a significant impact on blood pressure, heart rate and cardiorespiratory physiology (Lu & Kuo, 2012; Zheng et al., 2015), and the final component of awareness has a significant effect on the neurophysiology of the brain by improving immune function, pain and mood (Frye, 2015; Jin, 1988; Y. Li et al., 2014).

Nowadays, Tai Chi is not only practised in China. It has recently become popular in Western countries as part of exercise and leisure activities (Lan et al., 2002). In the United States for example, 2.5 million Americans practised Tai Chi in 2007 and the numbers continue to increase (Barnes, Bloom, & Nahin, 2008). This may be due to the growing evidence on the beneficial effects of Tai Chi on wide range of medical conditions including CVD (Lan, Chen, Wong, & Lai, 2013; Park & Park, 2010; Robins, Elswick, Sturgill, & McCain, 2016), rheumatoid arthritis (RA) (Chenchen Wang, 2011; Han et al., 2010; Lee, Pittler, & Ernst, 2007) and respiratory function (Chan, Lee, Suen, & Tam, 2011).

1.1.9.2 Tai Chi: Exercise that is suitable and beneficial for an older age population

There are a few factors which make Tai Chi a suitable exercise form for an older age adult or elderly population. The nature of Tai Chi itself, as a mix of strength (Lan, Chen, Lai, & Wong, 2013; Wang et al., 2004), flexibility (Carbonell-Baeza et al., 2011; Liu, Li, & Shnider, 2010) and cardiorespiratory exercise, offers a form of complete exercise as recommended by the ACSM (Chodzko-Zajko et al., 2009). In addition to that, research has proven that Tai Chi is a moderate intensity exercise, which equal to 60-70% maximum heart rate, that is tolerated among older aged adults (Li, Hong, Chan, & Max, 2001; Xu et al., 2015). Further, Tai Chi is also considered to be suitable for older adults due to the slow movements that make it low impact, low velocity and low risk for orthopaedic injury (Lan, Lai, Chen & Wong, 1998). In addition, as a form of exercise with low risk for injury (Lo, Yeh, Chang, Sung, & Smith, 2012), Tai Chi is safe to be practised, not only by older adults but also by people with mobility problems or frailty (Wayne & Kaptchuk, 2008a).

Several review papers on PA in older age have highlighted the benefits and safety of Tai Chi (Chiang, Cebula, & Lankford, 2012; Taylor et al., 2004) and most of the studies agreed that Tai Chi is beneficial in reducing the fall rate in this population. Statistics show that most people aged 65 and above experience a fall each year, and 20-30% of cases result in hip fracture and immobility (Hornbrook et al., 1994). The higher fall rate is potentially due to reduced muscle strength, poor balance and less flexibility (Nguyen & Kruse, 2012) and for this reason, Tai Chi has been recommended as a suitable exercise regime to reduce the fall rate in this population (Hwang et al., 2016; Taylor-Piliae et al., 2014; Xiao & Zhuang, 2015).

Tai Chi has no adverse effect on patients that suffer in chronic heart failure (Caminiti et al., 2011; Lan, Chen, Wong, et al., 2013), obstructive pulmonary disease (Chan et al., 2011; Fu, Min, Yu, McDonald, & Mao, 2016; Leung, McKeough, & Alison, 2013), or cancer (Campo et al., 2014; Sprod et al., 2012) and appears to be safe among RA patients (Kirsteins, Dietz, & Hwang, 1991).

1.1.9.3 Zumba Gold®: benefits and its safety issue

Zumba® was first created in Colombia in the 1990s, by a Latin dance instructor, Alberto Perez. The exercise programme was a blend of various dance types including salsa, merengue, cumbia, and samba. Over the last 30 years, Zumba® has been performed by over

12 million people in over 150 countries (Inouye, Nichols, Maskarinec, & Tseng, 2013) and has been voted in the top 20 of fitness trends worldwide in ACSM Health and Fitness Journal (Thompson, 2012). Zumba® has evolved to include different types of Zumba®: for example Zumba® for elderly and those who has physical limitation (Zumba Gold®), Zumba® using light weight which targeted to tone targeted body part including arms, core and lower body (Zumba toning®), Zumba® for kids (Zumbatomic®), higher intensity of Zumba® which includes strength and resistance training using chair and focusing on building muscle, calories burns and improving cardiovascular health (Zumba sentao®), and low impact of Aqua Zumba® that is perform with combination of aqua fitness and danced moved from Zumba® (Benham, Hall, & Barney, 2013). The research undertaken in this thesis uses Zumba Gold® due to its suitability for use by older adults and those with limited physical ability (Bennett, Corradini, Ockerby, & Cossich, 2012). Despite the popularity of Zumba® across the World, there are only 27 research studies published in Medline, PubMed and Scopus, of which 4 were specifically undertaken using Zumba Gold®.

Based on previous research, Zumba® has been categorized as moderate to high intensity exercise based on the mean heart rate reserve that can be achieved in an average session (Domene, Moir, Pummell, Knox, & Easton, 2016): An average of 65.5% to 92.5% heart rate reserve (HRR) (Sanders & Prouty, 2012) or 135± 19 beats/min (bpm) which is the equivalent to 73% ± 8 of HR max. However, Zumba Gold® has been modified to achieve a lower intensity compared to Zumba® corresponding to 50.1 ±10.1% HRR or 114 ± 14 bpm (Dalleck, Roos, Byrd, & Weatherwax, 2015). However the modification of Zumba Gold® still fulfils the ACSM requirements of moderate intensity exercise which can improved cardiorespiratory fitness. In the study by Dalleck et al.(2015), the total energy expenditure was 197.9 ± 38 kcal/session, and participants were encouraged to follow their own pace and rhythm. In Zumba Gold® participants are encouraged to move according to their ability, low or half tempo, and can undertake the exercise in a chair if needs be.

1.1.9.4 Zumba Gold®: Exercise that is suitable and beneficial for older age population

At present, there is limited evidence on the safety of Zumba Gold® however Delextrat et al.(2016) investigated Zumba Gold® in eleven people with mild-to-moderate Parkinson's disease and assessed the incidence of falls, dizziness and pain during each session and measured the rating perceived exertion (RPE) immediately after session. This study found that Zumba Gold® was a safe form of exercise for people with Parkinson's Disease, with no adverse events reported. In addition Zumba Gold® was also undertaken by renal disease patients that underwent haemodialysis (Bennett et al., 2012). Patients were guided to do a modified form of Zumba Gold® while undertaking 30 minutes of haemodialysis. The authors concluded that the modified version of Zumba Gold® was safe and feasible during haemodialysis treatment. It is possible to undertake Zumba Gold® in a chair which further reduces the risk of fall and injury, and makes it safe to perform by frail elderly and those who have a physical limitation to stand.

1.2 AIM AND OBJECTIVES OF THESIS

The aims of this thesis were to examine the effect of 2 different types of exercise; Tai Chi and Zumba Gold® in improving physiological (vascular function, oxidative stress and inflammation, physical function and fitness) and psychological (anxiety, depression, loneliness, QoL) factors. As Tai Chi is largely uncharacterised by research studies, an acute study was conducted in chapter 2. The effect of 60 minutes Tai Chi was investigated to measure the response of this slow and moderate intensity exercise in increasing blood marker of lipid oxidation, inflammation, and total antioxidant capacity (TAC). Research has shown that by increasing both oxidative stress and inflammation from an acute bout of exercise, the exercise is capable of increasing antioxidants, which may improve endothelial function. The information from this study will therefore aid in understanding how Tai Chi may stimulate benefits during a training study (undertaken in chapter 3).

The study in chapter 4, aimed to investigate the effect of Tai Chi and Zumba Gold® in reversing the effect of ageing; endothelial dysfunction, reduction in physical function (upper and lower body flexibility, leg strength and body endurance) and mental health problem (depression, anxiety, loneliness and low sleep quality). A further aim was to investigate the barriers of this aged group in adhering to an exercise programme. The information gained from this study may facilitate future training programmes that may not only be beneficial in improving physical and mental health, but may also motivate individuals in continuing to exercise.

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