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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CHAPTER 1

INTRODUCTION

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.

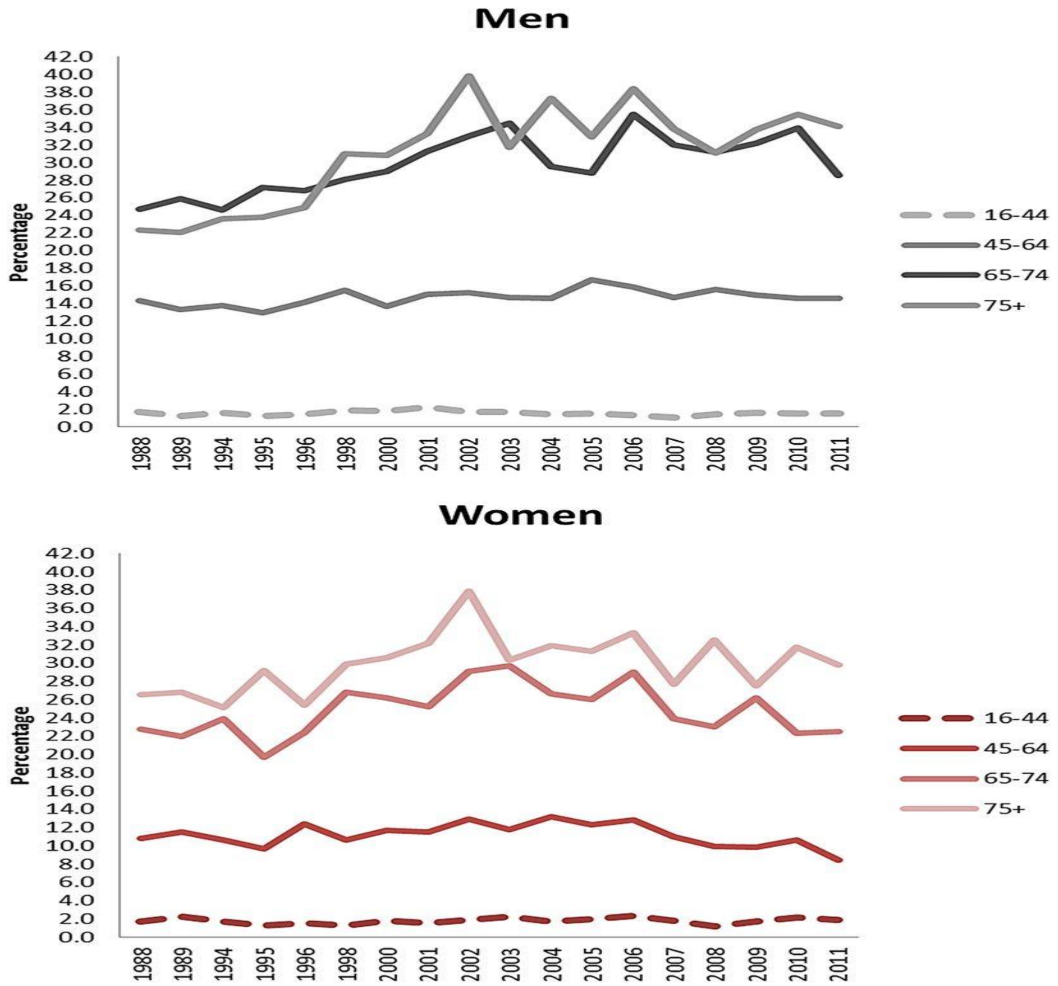

Figure 1. 1: Prevalence of cardiovascular diseases in men and women by age

(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 (Hacihasanoĝlu 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).

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 ($ONOO^{-\cdot}$), 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.

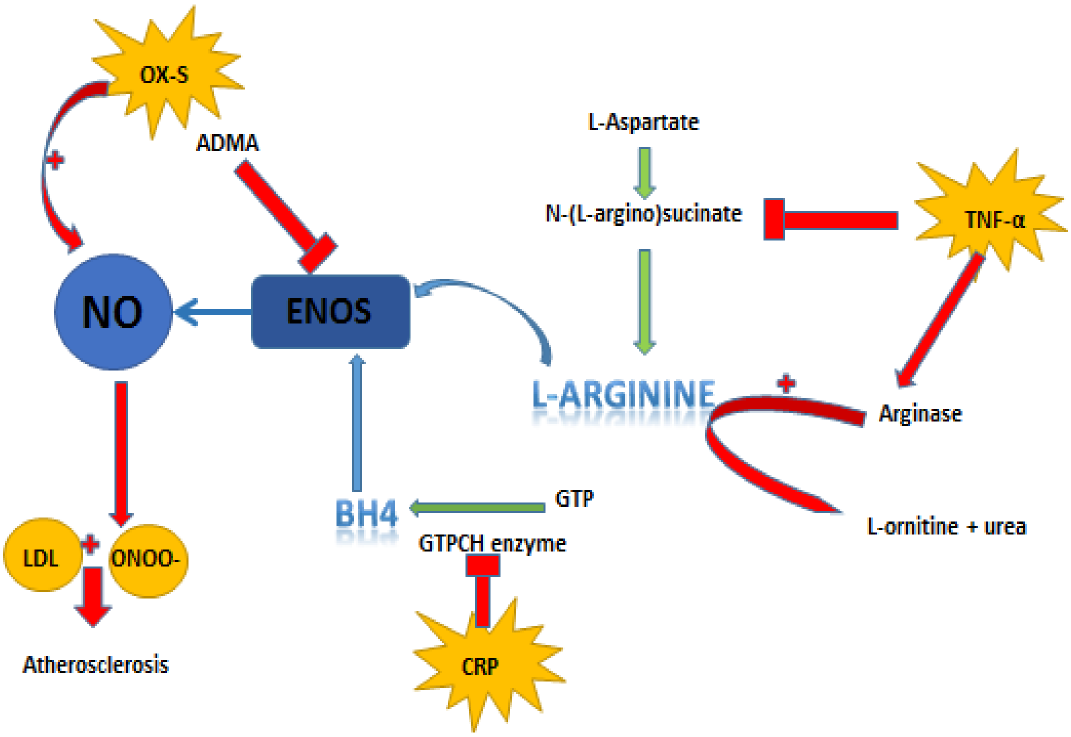

Figure 1. 2: Role of oxidative stress and inflammation in reducing NO bioavailability

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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CHAPTER 2

THE EFFECT OF AN ACUTE BOUT OF TAI CHI ON OXIDATIVE STRESS, INFLAMMATION AND ENDOTHELIAL FUNCTION AMONG OLD AND YOUNG PHYSICALLY INACTIVE PARTICIPANTS

2.1 ABSTRACT

Vigorous exercise is known to have the capability to induce transient increases in oxidative stress, pro- and anti-inflammatory responses, which, if undertaken repeatedly, may lead to adaptations that can improve vascular health. Similarly, moderate intensity exercise undertaken by those unaccustomed to it, can provoke improvements in vascular health. However, less is known about the effects of low to moderate intensity exercise, such as Tai Chi, which includes slow controlled movements, on vascular health. **Aim:** This study investigated the response to a single session of Tai Chi on blood markers of lipid oxidation, IL-6, IL-10, total antioxidant capacity, blood pressure (BP), and flow-mediated dilation (FMD) in sedentary, young (18-25 years old) and older aged participants (65-75 years old). **Method:** Young and old participants were recruited and randomized in a crossover design consisting of (a) one hour Tai Chi visit vs (b) control visit without Tai Chi. Blood withdrawal and FMD assessment were undertaken before the Tai Chi session (8 am), immediately after (9.30 am), post 1h (10.30 am) and post 2h(11.30). Participants were invited to read, or sit quietly during the control visit, and blood withdrawal and FMD were undertaken at time points mimicking the Tai Chi visits. Plasma was assessed for total antioxidant capacity (TAC), Malondialdehyde (MDA), 8-isoprostane, IL-6 and IL-10 **Results:** FMD and IL-6 significantly increased following Tai Chi (IL-6; immediately after Tai Chi in both old and young, FMD; immediately after in young and post 1h in old), while MDA and IL-10 increased only in the older age group following the Tai Chi visit. **Conclusion:** One session of 60 minutes of Tai Chi is able to produce a transient increase plasma markers of inflammation (IL-6 and IL-10) and markers of oxidative stress (MDA in old, isoprostane in young) and to improve FMD in young and older age participants.

2.2 INTRODUCTION

Tai Chi is an ancient form of exercise that has been performed for hundreds of years in China (Guo, Qiu, & Liu, 2014). The slow movements in Tai Chi typically do not stimulate more than 60% of maximum heart rate and oxygen consumption (Aini, Hamid, & Ngah, 2014; Mendoza-Núñez, Hernández-Monjaraz, Santiago-Osorio, Betancourt-Rule, & Ruiz-Ramos, 2014). Despite its low to moderate intensity, there is growing evidence for the beneficial effects of Tai Chi in improving diseases associated with increased oxidative stress and inflammation, for example cardiovascular diseases (Chang, Yeh, Chu, Wu, & Huang, 2013; Hartley, Flowers, Lee, Ernst, & Rees, 2014; Y.-T. T. Huang, Wang, & Wu, 2011; Robins et al., 2016). The capability of Tai Chi to reduce oxidative stress and inflammation is suggested to be due to improvements in NO bioavailability in the vasculature, and thus can promote better vascular health (Wang, Lan, & Wong, 2001). However, the majority of evidence to date is based on long term Tai Chi practise and most research studies have been undertaken in people that have practiced Tai Chi for more than 10 years. Less is known about the acute effects of a single Tai Chi session in untrained old and young healthy participants.

Knowing the effect that a single bout of exercise can have can help predict the capability of that exercise if repeated, in lowering factors such as oxidative stress and inflammation, which are often raised by age and physical inactivity in sedentary or older populations (Fisher-Wellman & Bloomer, 2009; Gomes, Silva, & Oliveira, 2012). After an acute bout of exercise RONS may be increased, especially following a bout of intense or exhaustive exercise (Accattato et al., 2017). This is due to the increase in energy demand and accompanying increase in oxygen uptake which is related to the rise of mitochondrial respiration-induced free-radical production (Bouzid et al., 2015). RONS can cause damage to lipids, proteins and DNA (Berzosa et al., 2011; Radak, Zhao, Koltai, Ohno, & Atalay, 2013).

More specifically, an exercise bout may alter redox homeostasis via increased radical production from the electron transport chain (Accattato et al., 2017), release of ascorbate from the vessel wall (Finaud & Biologie, 2006) , and activation of enzymes such as NADPH oxidase and NOS (Gliemann, Nyberg, & Hellsten, 2014). These processes can cause a transient oxidative stress, dependent on antioxidant capacity and the training status of an individual, by inducing lipid, protein and DNA modification. The rate of oxidation that happens after an acute bout of exercise can be measured by oxidation products such as malondialdehyde (MDA) and F2-isoprotein from lipid peroxidation and formation of protein carbonyl groups from protein modification (Finaud & Biologie, 2006; Suzuki, Carini, & Butterfield, 2010).

Research has shown that this process is part of a well characterised adaptation to exercise which some researchers have characterised as hormesis (Fisher-Wellman & Bloomer, 2009; Radak, Chung, & Goto, 2005, 2008). In the concept of hormesis, a low dose of a potentially harmful substance, which in this case might be RONS from exercise, is actually beneficial. The first work to document this exercise-induced oxidative stress in humans was by Dillard, Litov, Savin, Dumelin, and Tappel (1978), in a study where 60 minutes of cycling exercise resulted in an increased level of expired pentane, a biomarker of lipid peroxidation, which proved that an acute bout of exercise can induce oxidative stress that is beneficial. Research suggested that, the production of RONS during exercise can activate the redox-sensitive transcription factors including NF-κβ, that lead to the expression of some antioxidants that potentially function to scavenge the ROS from damaging lipids, protein and DNA (Berzosa et al., 2011). According to Gleeson, Robertson, and Maughan (1987), a potent hydrophilic antioxidant, vitamin C was found to be increased after an acute bout of intense endurance exercise of 21 km run in plasma and/or lymphocyte, which suggested that adrenal glands may play roles in the source of ascorbic acid efflux in the circulation during exercise. The metabolic function of vitamin C during exercise is well known as it is required for musculoskeletal repair and growth, as well as self-protection of neutrophil from oxidative burst (Michael Gleeson, 2007; Margaritis & Rousseau, 2008)

Research strongly suggests that that the high concentration of cellular RONS is also associated with increasing pro-inflammatory cytokines. IL-6 is the most well characterised cytokine in response to exercise in humans and there is a wealth of evidence showing IL-6 increased in response to exercise in both human and animal models (Mendham, Donges, Liberts, & Duffield, 2011; Pedersen et al., 2004). IL-6 is responsible for the appearance of other cytokines in the circulation (Terra, Silva, Pinto, & Dutra, 2012), and moreover, measuring IL-6 is also interesting due to its capability to act as both a pro- and anti-inflammatory cytokine. Research has shown that an increasing concentration of IL-6 post exercise facilitates the release of the anti-inflammatory cytokines IL-10, IL-1ra, and inhibits TNF-α to protect the human vasculature (Padilla et al., 2011).

One of the known beneficial effects of acute exercise is the improvement of endothelium function in its ability to release Nitric Oxide (NO) via increased blood flow, known as sheer stress (Marti et al., 2012). An acute bout of exercise stimulates sheer stress, and thus can trigger the endothelial cell to produce NO. The production and bioavailability of NO is essential in promoting vascular health as it helps in artery vasodilation and reducing platelet aggregation via its antithrombotic properties (Osto & Cosentino, 2010). Thus, repeated sheer stress during bouts of exercise is proposed as a mechanism in promoting vascular health especially when the exercise is undertaken regularly.

However, due to the ageing related accumulation of free radical among elderly population throughout life span as what has been describes in chapter 1.1.4, the effect of a single bout of exercise may result to be more pronounced in the ageing population, as compared to their young counterparts due the impairment of antioxidant defence among this age group (Bouzid et al., 2014). In order to provide the answer to this question, the effects of a –single session of Tai Chi were investigated on oxidative stress and inflammation in sedentary old and young participants. Bioavailability of NO induced by sheer stress was assessed by flow mediated dilation. This study also aimed to investigate the rate of oxidative stress and inflammation after one Tai Chi session, which will further predict the beneficial effect of this low-moderate type of exercise in inducing adaptation when exercising regularly.

2.3 AIM AND OBJECTIVE

To better understand the potential mechanisms by which Tai Chi training may be beneficial for health, this study aims to assess the response to a single bout of Tai Chi.

This aim will be achieved via the following objectives:

(1) To measure markers of oxidative stress, inflammation and vascular health in response to a single Tai Chi session in untrained participants. Thus measure the effect of Tai Chi.

(2) As baseline levels of oxidative stress and inflammation are often higher in older age, this study aims to compare the response of markers of oxidative stress and inflammation to Tai Chi in old and young. Thus measure the effect of age on the response to Tai Chi.

2.4 RESEARCH DESIGN AND METHODOLOGY

2.4.1 Participants

Participants were recruited via email from a database of older adults who have indicated they wish to be contacted about research studies and from local undergraduate email lists at the University of Birmingham, media (University of Birmingham canvas, local newspaper- Harborne Edgbaston Moseley Life newsletter) and poster advertisements at local community centres, shops, churches, mosques, and house to house flyers. Interested participants were provided with a participant information sheet. Participants were then invited to attend the laboratory for an introductory visit in which written consent for participation in the study was obtained, and screening questionnaires were administered to determine their eligibility. Questionnaire screening consisted of 3 sections; a general health questionnaire, the international physical activity questionnaire (IPAQ) and Marshall sitting questionnaire (Marshall, Miller, Burton, & Brown, 2010; Rosenberg, Bull, Marshall, Sallis, & Bauman, 2008). Participants were excluded if they scored more than 1500 MET-minutes/week with 3 days of vigorous-intense activity or 7 days of any combination of walking, moderate-intensity or vigorous intensity with total physical activity more than 3000 MET-minutes/week. Participants were also excluded if they smoked, had a history of cardiovascular or metabolic disease, or were unable to take part in Tai Chi due to mobility issues. All procedures were conducted at the School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham. This project was approved by the Science, Technology, Engineering and Mathematical Review Committee, University of Birmingham (ERN_15-0554).

2.4.2 Study design

In this study, participants attended the laboratory on 2 separate days for approximately 4 hours each lab visit. Figure 2.1 shows a representation of the study design for both visits

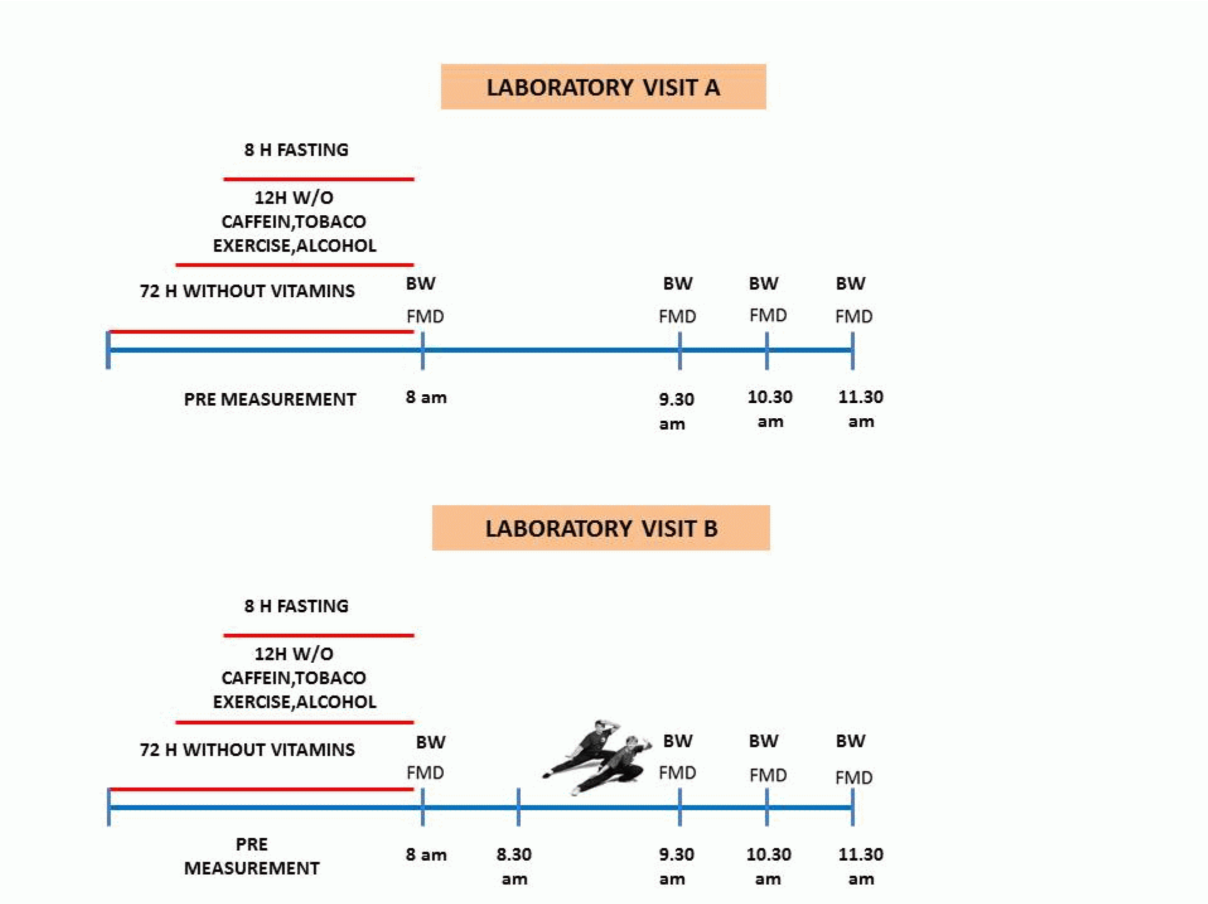

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Figure 2. 1: Research design for acute study laboratory visit (A) Control condition (B) Tai Chi condition

BW: Blood withdrawal
FMD: Flow Mediated Dilation

2.4.2.1 Participant's preparation prior lab visit

Prior to each laboratory visit, participants were asked to consume only water from 10pm the night before the visit. Participants were also required not to refrain from any intense exercise, caffeine, alcohol and tobacco, 12 hours before coming for the laboratory visit. Participants were also reminded not to take any antioxidant vitamins (vitamin C, vitamin E and α-lipoic acid) 72 hours before laboratory visit to eliminate any effect of blood markers and FMD measurement.

2.4.2.2 Study intervention

The order of the control condition vs tai chi condition was counterbalanced and participants were randomized into either control (A) of Tai Chi intervention (B) prior to the first lab visit using research randomizer website at www.randomizer.org (Calé-Benzoor et al., 2017). At each lab visit participants arrived at the laboratory at 7:30am and were asked to rest quietly for 20 minutes. Participants underwent baseline measurements of Flow-Mediated dilation (FMD) and blood pressure, and blood was withdrawn at 8 am (pre), 9.30 am (immediately after Tai Chi; 0), 10.30 am (post 1hour; 1+) and 11.30 am (post 2 hours; 2+). For the Tai Chi condition participants were invited to undertake Tai Chi exercise session for one hour between 8.45am and 9.45 am. During the lab visits, participants remained seated and inactive except during the Tai Chi session. Participants were scheduled for the next session at least one-week after the first visit, and 28 to 30 days after the first visit for young female participants, to standardize the menstrual cycle.

2.4.2.2.1 Resting blood pressure

Brachial blood pressure was taken using an automatic blood pressure machine (Omron M2 Basic, Kyoto, Japan). All measurements, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were made in triplicate, and the mean value was recorded. Measurements were taken at 5 minute intervals while the participant was seated.

2.4.2.2.2. Blood sampling

Blood samples (7ml) were collected by a trained phlebotomist via cannulation (20 gauge cannula) at the antecubital vein while participants remained at a semi-supine position. Blood samples were collected using EDTA tubes, taken at rest (8.00 am), immediately after Tai Chi (9.45am), 1h post Tai Chi (10.30am) and 2 h post-Tai Chi (11.30am). Blood collection for the control intervention was collected at the same time points as the Tai Chi intervention. To obtain plasma, blood was centrifuged at 3000 x g, 10 minutes, 4^{o}C. Plasma samples were aliquoted and stored at -80^{o}C until further analysis.

2.4.2.2.3 Flow mediated dilation (FMD)

FMD were measured according the guideline of Flow Mediated dilation from Harris, Nishiyama, Wray, & Richardson (2010). During the flow-mediated dilation measurement, participants rested in a semi-supine position with their right arm extended and immobilized using a foam arm rest. A standard 3-inch size cuff was positioned around the arm, 2 inches below the antecubital fossa. To assess the FMD response, the image of brachial artery was scanned using B-mode ultrasound (Philip EnVisor, Andover, USA) and a high-frequency linear array transducer (10 MHz). The baseline diameter of the brachial artery was recorded for 2 minutes before the cuff was inflated to 50 mm Hg above the systolic pressure for 5 minutes. Following cuff deflation, images were recorded for a further 3 minutes. The diameter of the brachial artery was captured at 25 images per seconds, using an Online Vascular Imaging Analysis software (VIA), and further offline analysis was conducted using Spike software (CED).

$$\frac{\text{Peak diameter} - \text{baseline diameter}}{\text{Baseline diameter}} \times 100$$

The site of the transducer was marked to ensure standardization between scans.

2.4.2.2.4 Tai Chi session

Participants were invited to undertake a 1 hour session with a trained and certified Tai Chi instructor from the Tai Chi Union of Great Britain (TCUBG). The trainer demonstrated and explained the theory of the movements during the whole session. The 60 minute session involved warm up, Shibashi Qigong set, Tai Chi form (Yang style) and cooling down. The trainer started with 10 minutes of warm up or loosening exercises. Feet were positioned shoulder width apart and small bouncing movements were begun with the arms swinging forward and backward loosely. This was continued with one leg stepped forward. Throughout these movements, participants were reminded to keep bouncing based on the natural elasticity of the leg muscle. The warm-up continued with rotation of the hips, side to side, with arms swinging. The final step in warming up was a loose punching action. The Tai Chi session then continued with Shibashi Qigong which included movements known as 'sunrise', 'opening the chest', 'painting the rainbow' and 'parting the cloud'. The session was closed with 10 minutes cooling down. During all movements, participants were reminded to keep a natural breathing rhythm, soft knees, create harmony between breathing and movement. Heart rate activity was recorded throughout the session using wrist-worn Garmin Vivo Smart HR.

2.4.3 Blood Analysis; Total antioxidant capacity (TAC), TBARS and 8-isoprostane

2.4.3.1 Total antioxidant capacity (TAC)

The total of antioxidant capacity was measured using FRAP assay, the ferric reducing ability of plasma as described by Benzie and Strain (1999). Plasma samples (10µl) or ascorbic acid standards (ranging from 0 to 1000µM) were loaded into the 96-well cell culture plate in triplicate. FRAP reagent (20mM ferric chloride, 300mM sodium acetate buffer and 10mM 2,4,6-Tris (2-pyridyl)-S-Triazine, TTPZ, pH 3.6; 300µl) was added to the plate. Plates were left at room temperature for 8 minutes before the absorbance was read at 650nm. The value of total antioxidant was expressed using the 7 point curve value calculated from the ascorbic acid standard reading.

2.4.3.2 Thiobarbituric acid reacting substance (TBARS)

The thiobarbituric acid reacting substance (TBARS) test is a non-specific test to determine the concentration of malondialdehyde (MDA), a secondary product that is formed following lipid peroxidation. Samples and standards (0 to 50 µM of 1,1,3,3-tetramothoxypropane; 100µl) were loaded into Eppendorf tubes, and mixed with TCA solution (1.23M trichloroacetic acid (TCA), 0.05M H_2SO_4; 100µl) and colour reagent (thiobarbituric acid (TBA), 200µM buthylated hydrotoluene (BHT); 800µl) before being placed in boiling water (100^{o}C) for one hour. The reaction of MDA and thiobarbituric acid forms a fluorescent red adduct and absorbance was read at 540 nm.

2.4.3.3 8-isoprostane

Plasma 8-isoprostane was measured using a commercially available ELISA kit (516351, Caymen Chemical, USA) according to the manufacturer's instructions. Briefly, samples and standards (50µl) were added into wells pre-coated with mouse monoclonal antibody. Samples and standards were then incubated with 8-isoprostane AChE tracer and antiserum for 18 hours at 4^0C. After washing, Ellman's Reagent was added to the wells and the plate was incubated on an orbital shaker for 120 minutes. The plate was read at 420nm and the 8-isoprostane concentration was calculated using the standard curve plotted using log transformation.

2.4.4 Blood analysis; Inflammatory marker of Interleukin-6 (IL-6) and Interleukin-10 (IL-10).

2.4.4.1 Interleukin-6 (IL-6)

Interleukin-6 was measured using a commercially available High Sensitivity Quantikine ELISA kit HS600B according to the manufacturer's instructions, R&D Systems, Minneapolis, USA. Plasma samples were diluted (1:1 dilution using assay diluent) and then added to the microwell plate (100µl). Samples were incubated for 2 hours at room temperature to allow any IL-6 in the sample to bind with the immobilized antibody. After washing, enzyme-linked polyclonal antibody specific for IL-6 was added to the wells, and the plate was incubated for another 2 hours before washing to remove unbound antibody-enzyme reagent. Substrate solution (50µl) and amplifier solution (50µl) were added and colour changes were observed before adding the stop solution. The plate was read at 490 nm and 650nm as corrected wavelength. The concentration of IL-6 was determined from a standard curve of known IL-6 series concentration of 0.156pg/mL to 5pg/mL.

2.4.4.2 Interleukin 10 (IL-10)

The plasma concentration of IL-10 was assessed using a commercially available ELISA kit HS100C, according to manufacturer's instructions (R&D Systems, Minneapolis USA). Briefly, diluted plasma samples and standards (200µl sample/standards with 50µl assay diluent) were added to each well. The plate was incubated for 2 hours at room temperature on a microplate shaker set at 500 rpm. Following incubation, the plate was washed to remove unbound substances and substrate solution (50µl) and amplifier solution (50µl) was added. Colour development was observed before adding stop solution (50µl) to the wells. The plate was read within 30 minutes using micro plate reader set at 490nm. The concentration of IL-10 was determined using a linear standard curve of known IL-10 concentration (0-50 pg/mL).

2.5 DATA ANALYSIS AND REDUCTION

Heart rate was recorded continuously during the 60 minutes Tai Chi session, while SBP, DBP, FMD and blood withdrawal were undertaken at pre Tai Chi (8 am), immediately after Tai Chi (9.30 am), 1h post (10.30am), 2h post (11.30am). Similar measurements were conducted during the control visit, except on the heart rate measurement. Statistical analysis were performed using SPSS (24.0, USA). Data that are not normally distributed (8-isoprostane, IL-6, IL-10) were log transformed to normalize the data before analysis were conducted. Baseline differences between old and young group were analysed using an independent sample t-test or Mann Whitney U test (IPAQ) and chi-square test for categorical data (gender). The effect of different lab visit were analysed using repeated measured ANOVA (time x condition x group). When appropriate, post hoc analysis were conducted using a separate repeated measured ANOVA for young and old group. Significant level were set at 5%, and reported as mean ± SE unless otherwise stated.

2.6 RESULTS

2.6.1 Demographic data

Twenty four participants were recruited to this study; 13 young (18 to 25 years) participants and 11 old (65-75 years) participants. Table 2.1 below presents participant characteristics for both old and young participants. Total IPAQ value was calculated based on the 3 main domains: work, transportation, and leisure. Sitting time was assessed according to the validated Marshall Sitting Questionnaire. The older age group had a significantly higher average BMI (p=.009) than the young group. The young group had a significantly lower IPAQ score of 806.69 ± 424.97 MET-min/week compared to 1781.91 ± 904.11 MET-min/week for the older group. Based on the IPAQ categories, the main difference in physical activity was observed in the transportation domain, where older participants walk more frequently compared to the young group (p=.025). Mean ± SD

Table 2. 1: Demographic characteristics of young and old group

Characteristics		Group		p
		Old (n=11)	Young (n=13)	
Gender	Male, n	6	6	.5
	Female, n	5	7	
Age (years)		72 ± 2.5	22± 1.6	**.000**
BMI (kg/m^2)		28.3 ± 6.6	22.43 ± 3.1	**.009**
IPAQ: Work	Vigorous	0	0	1
	Moderate	54.55 ± 145.6	0	0.244
	Walk	45 ± 120.1	0	0.343
IPAQ Transportation	Cycling	0	0	1
	Walk	1160.9 ± 825.7	640.85 ± 489.8	**0.025**
IPAQ Leisure	Walk	325.01 ± 372.8	38.08 ± 110.9	0.066
	Moderate	120 ± 203.9	25 ± 61.0	0.184
	Vigorous	87.27 ± 221.7	18.46 ± 66.6	0.854
Total IPAQ (MET-minutes/week)		1781.91 ± 904.1	806.69 ± 424.9	**.004**
Total sitting time (hours/week)		52.05 ± 22.6	62.73 ± 27.4	.314

Table 2.2 below shows baseline blood pressure, oxidative stress and inflammatory markers and FMD data of all participants for both visits. A series of 2 Group (young, old) × 2 Condition (Control, Tai Chi) ANOVAs revealed no significant baseline differences between the control and Tai Chi sessions, nor were there any group by condition interaction effects. Significant Group effects were evident for SBP, DBP, 8-Isoprostane, IL-6 and FMD, with blood pressure and IL-6 higher and 8-Isoprostane and FMD lower in older adults compared to the young participants (see Table 3.2). Mean ± SD

Table 2. 2: Baseline characteristics during control and Tai Chi visit for old and young group.

	Old			Young			p-values of 2 group by 2 condition ANOVAs	
	Control	Tai Chi	p	Control	Tai Chi	p	condition	group
SBP (mmHg)	129.8±17.5	128.2±13.9	.619	113.4±11.6	115.9±13.1	.302	.82	**.013**
DBP (mmHg)	82.9±8.4	84.1±8.6	.704	73.0±8.02	72.9±10.2	.972	.77	**.003**
FRAP (μM)	243.8 ± 38.4	246.1 ± 9.8	.788	231.2± 47.3	230.5± 68.6	.957	.39	.52
MDA (μM)	8.2± 2.31	8.17 ± 2.56	.938	8.61 ± 2.11	8.7 ± 2.61	.942	.48	.9
Log_{10} Isoprostane(pg/mL)	1.9 ± 0.26	1.95 ±0.42	.551	2.36 ±0.35	2.3 ± 0.23	.603	.99	**.001**
Log_{10} IL-6 (pg/mL)	0.36 ± 0.25	0.40 ± 0.23	.353	0.11 ± 0.05	0.1 ± 0.06	.918	.43	**.005**
FMD percentage (%)	3.61 ± 2.19	3.41 ± 2.07	.834	4.88 ± 1.94	5.7 ± 2.65	.429	.65	**.023**

2.6.2 Heart Rate

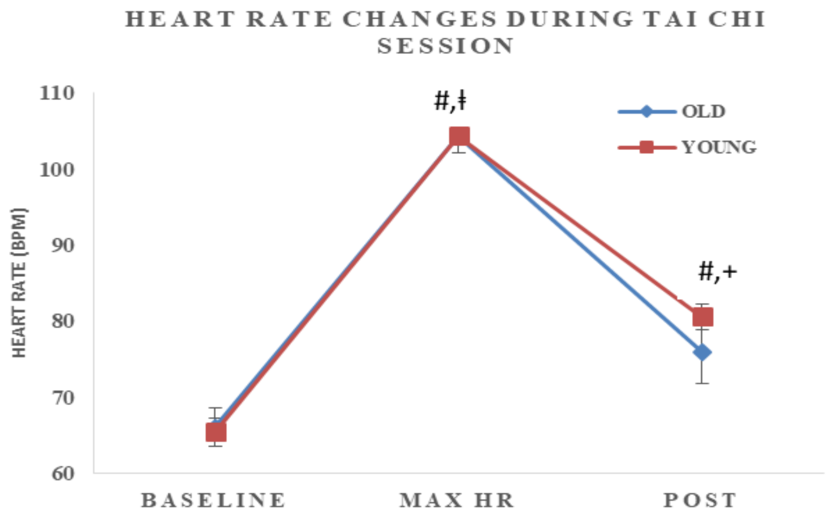

Figure 2. 2: Heart rate changes during a one hour Tai Chi session.

Heart rate changes during a one hour Tai Chi session. # indicates significantly different compared to baseline ($p<.05$), + indicates significantly different compared to maximum Tai Chi heart rate ($p<.05$), ł indicates significantly different compared to post-Tai Chi.

Figure 2.2 displays the heart rate activity at pre-Tai Chi baseline, the maximum achieved during the session (max HR), and immediately after Tai chi for young and old participants. Two Group (young, old) × 3 Time (baseline, max HR, immediately post) ANOVAs revealed a significant time effect, $F_{(2,8,)}= 43.91$, $p<.001$, but no Group × Time interaction effect or Group effect. Post hoc analyses showed that HR was significantly higher during Tai chi compared to baseline, and even though HR was lower post compared to the HR during exercise it remained elevated compared to baseline immediately post tai chi.

Subsequent analyses were conducted to explore differences in age-corrected exercise intensity between old and young participants. Intensity was calculated as the HR reached during the Tai Chi session relative to predicted maximal HR i.e., for young participants: 220-age and for old participants: 208-(0.7xage) (Tanaka, Monahan, & Seals, 2001). One way ANOVA revealed significant differences in intensity between young and old, but not in absolute HR rate (see Table 2.3). Thus, even though absolute HR was similar between the age groups, older adults were exercising at a relatively higher intensity.

Table 2. 3: Absolute and relative Heart Rate during Tai chi in old and young participants

Mean ± SD

	Old	Young	p
Maximum Heart rate	151±1.7	197±1.5	**.0001**
Heart rate reserve	84±29	131±14	**.0001**
Maximum Heart rate changes during Tai Chi (bpm)	104 ± 6.9	104 ± 8.3	.920
Tai Chi intensity based on age-predicted maximum heart rate %	66.4 ±4.1	52.6 ±3.9	**.0001**

2.6.3 Blood pressure response during Tai Chi and control visits

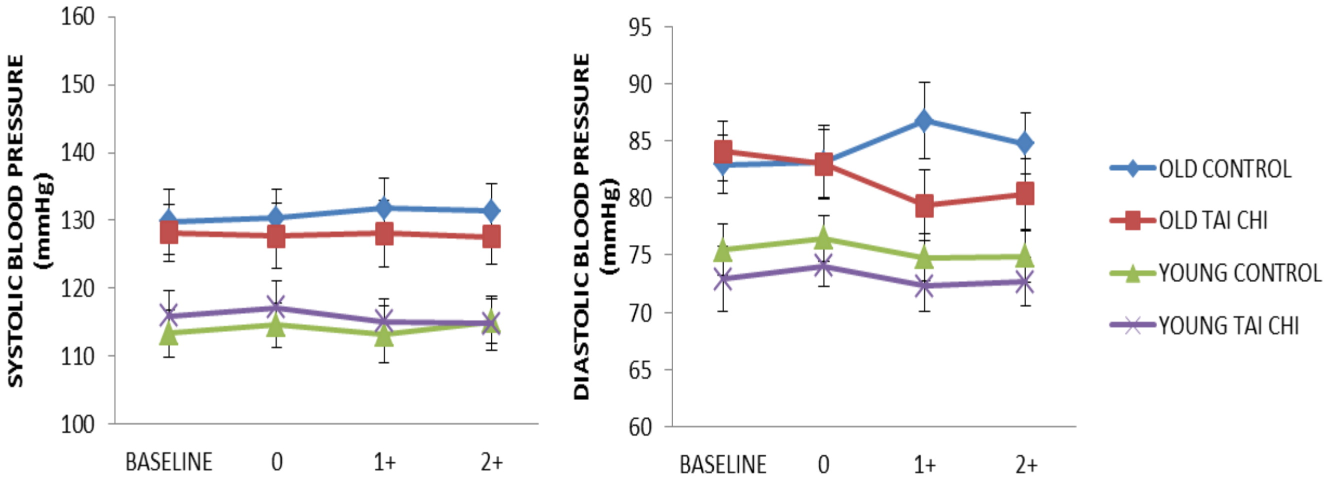

Figure 2. 3: Blood pressure response during Tai Chi and control visits

Systolic and diastolic changes during Tai Chi visit at baseline, immediately after Tai Chi, post 1 hour and post 2 hours in both old and young group.

Figure 2.3 shows the blood pressure during the control and Tai Chi lab visits in both the old and young group. Separate 2 Group × 2 Condition × 4 Time ANOVAs were conducted to explore changes in blood pressure. As expected, there were significant Group effects for both SBP, F $(_{1,22})$=8.04, p=.010 and DBP $(_{1,22})$=11.6, p=.003, with higher blood pressure in older participants. There were no Time, Condition, Condition × Time, Group × Time, or Group × Condition effects. However, for DBP only, there was a significant Group × Condition × Time effect F $(_{2,47})$=3.25, p=0.045. Further examination of this 3-way interaction effect showed a condition × time interaction for older adults ($F_{3,30}$=5.64, p=.003), but not for the young group. DBP was increased one hour post tai chi, whereas a decrease was found at that time in the control condition (see Figure 2.3).

2.6.4 Antioxidant capacity and Oxidative stress markers

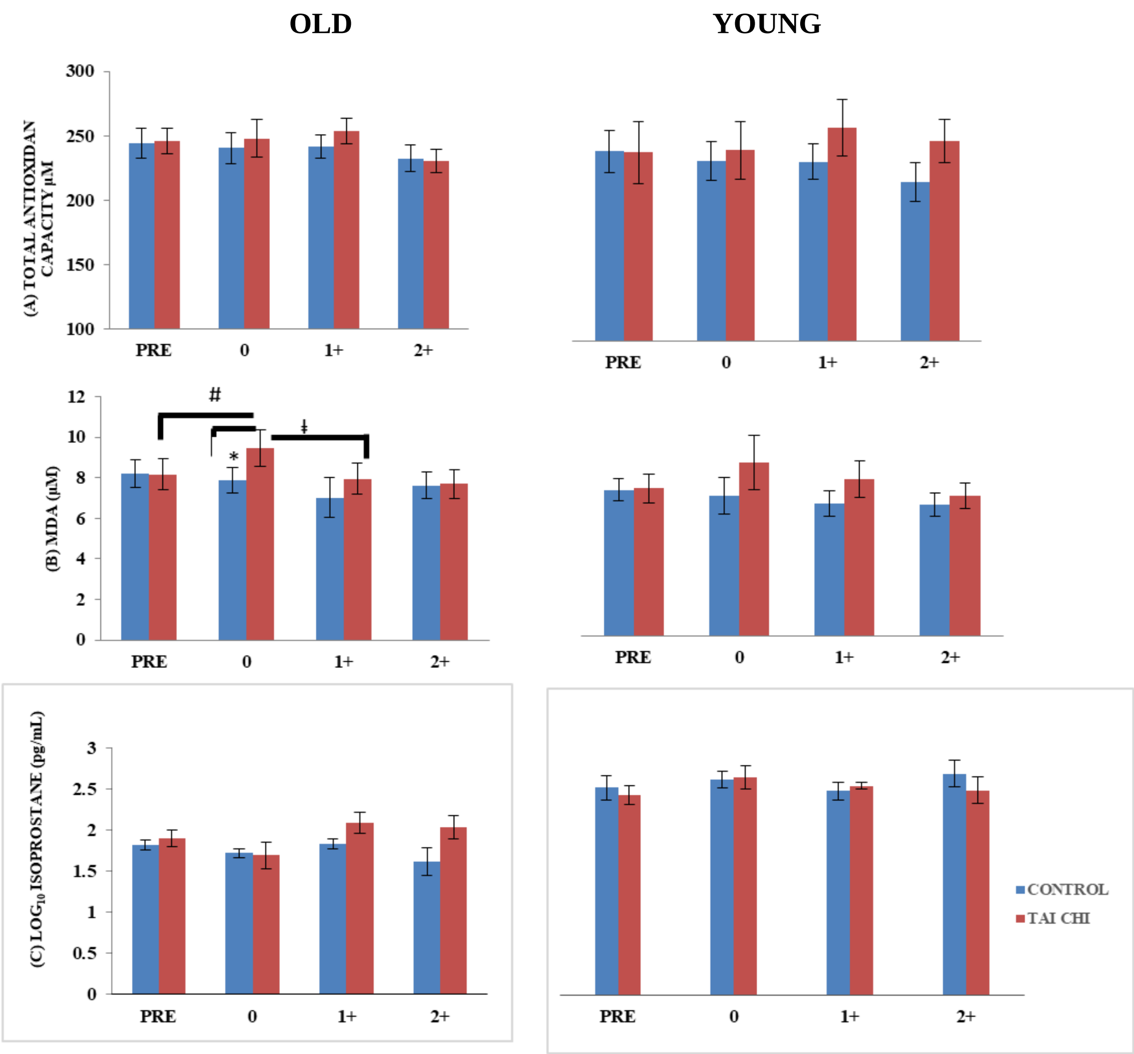

Figure 2. 4: Blood oxidative stress and inflammation markers

Blood oxidative stress and inflammation markers (a) total antioxidant capacity (b) MDA concentration (c) 8-isoprostane at 4 different time points (baseline, 0 hour, 1-hour post, and 2 hours post) in both young and old. Data is expressed as mean ± SE * indicates statistically significant as compared to control group, # indicates significantly different as compared to baseline, + indicates significantly different as compared to 0 hour, ɨ indicates significantly different as compared to 1+, ◊ indicates significantly different as compared to 2+.

(a) **Total antioxidant:**

There were no significant Group, Time, Condition, Condition × Time, Group × Time, or Group × Condition, or Group × Condition × Time effects for total antioxidant capacity. Thus, total antioxidant capacity did not change significantly during the control and Tai Chi visit in either group.

(b) **MDA:**

There was a significant over all time effect, $F_{(2,31)}$ =3.55 p=.044) and Condition × Time interaction effect, $F_{(3,51)}$=3.33 p=0.027 for MDA. There were no Group, Condition, Group × Time, or Group × Condition effects. Post hoc analysis revealed that immediate after tai chi MDA was increased relative to 1 hour and 2 hour post Tai Chi in old group and these differences were not evident in the control condition.

(c) 8-**Isoprostane:**

There were no significant Group, Time, Condition, Condition × Time, Group × Time, or Group × Condition effects for Isoprostane. There was a borderline significant Group × Condition × Time interaction effect $F_{(3,12)}$=3.13, p=.066. Further exploration revealed no significant Time, Condition or Condition × Time effects for either the young or old group.

2.6.5 Inflammatory response to acute Tai Chi

2.6.5.1 IL-6 response to acute Tai Chi

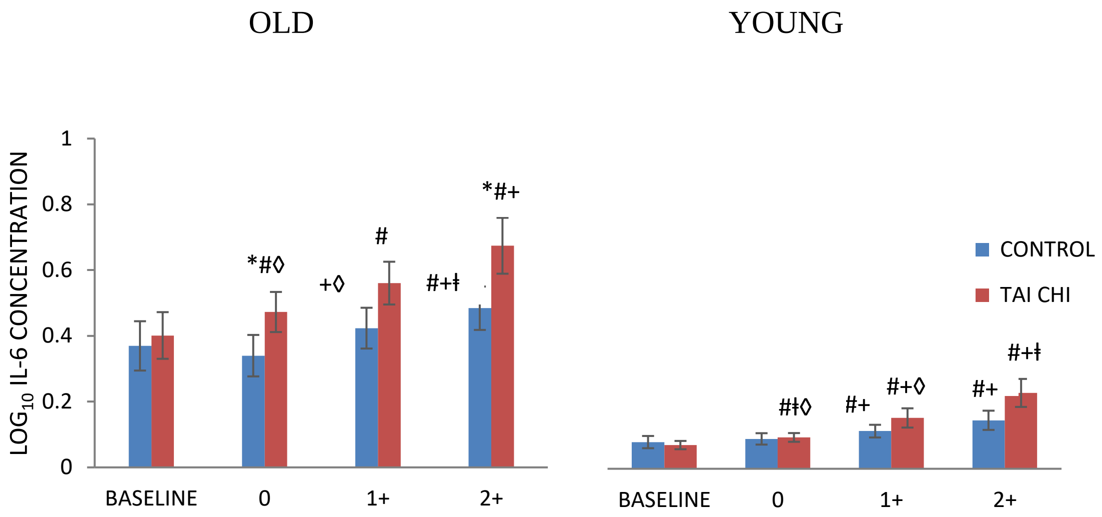

Figure 2. 5: IL-6 concentration at baseline, immediately after Tai Chi (0), post 1hour (1+) and post 2hours (2+) in both intervention and age group.

Data was expressed as mean ± SE * indicates statistically significant as compared to the same time point at control group, # indicates significantly different as compared to baseline, + indicates significantly different as compared to 0 hour, ǂ indicates significantly different as compared to 1+, ◊ indicates significantly different as compared to 2+.

Figure 2.5 represents the IL-6 concentration before and after an acute bout of Tai Chi and during the control visit. There was a significant overall condition, $F_{(1,17)}$ =9.45, p=0.007, time $F_{(1,27)}$ =26.81, p<.001 and condition × Time interaction effect, $F_{(1,27)}$=3.83 p=0.04, for IL-6 but no condition × time × group effect. Higher concentration of IL-6 was found in the old group with a significant group effect of $F_{(1,17)}$=13.81, p=0.002. Further exploration of these main effects revealed that immediate after tai chi IL-6 was increased at 0, 1 hour and 2 hour post Tai Chi.

2.6.5.2 The changes of IL-10 during Tai Chi intervention in old group

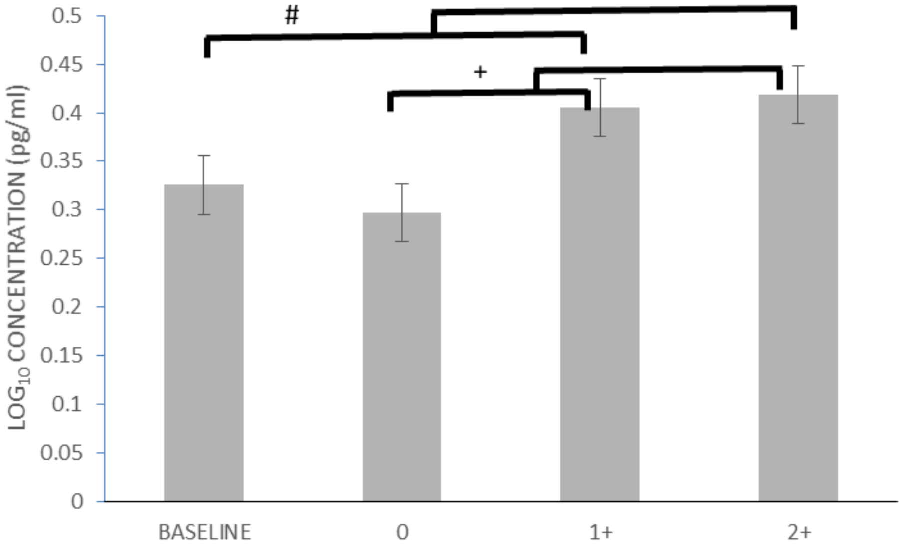

Figure 2. 6: The effect of Tai Chi on IL-10 concentrations at baseline, 0, 1+ and 2+ in the old group.

The effect of Tai Chi on IL-10 concentrations at baseline, 0, 1+ and 2+ in the old group. # indicates significantly different as compared to baseline, + indicates significantly different as compared to 0 hour.

Figure 2.6 shows the changes in IL-10 during Tai Chi intervention in old group. There was a significant increase in IL-10 at 1+ and 2+ post compared to baseline. Repeated measure ANOVA found that there was a significant effect of time with $F_{(3,21)}= 7.79$, $p=0.001$. Further pairwise comparison found an increasing in IL-10 concentration at 1+ and 2+ time points as compared to baseline and immediately after Tai Chi.

2.6.5.3 Correlation between changes in IL-6 and IL-10 during Tai Chi visit in old group

Subsequent analysis of the relationship between the concentration of IL-6 and IL-10 post Tai Chi session were conducted using Pearson correlation in the old group. Data were expressed r_p – Pearson's correlation coefficient, and p – level of 2 tail statistical significance. Data at all time points showed that there is no significant correlation between the changes of IL-6 and IL-10 after Tai Chi exercise among old participants.

Table 2. 4: Represent the Pearson correlation data between IL-6 and IL-10 during Tai Chi visit at immediately after Tai Chi (0), one hour post (1+) and two hours post (2+) in old group.

	0	1+	2+
r_p	-.3	.249	-.192
p	.369	.461	.648

2.6.6 Flow-mediated dilation

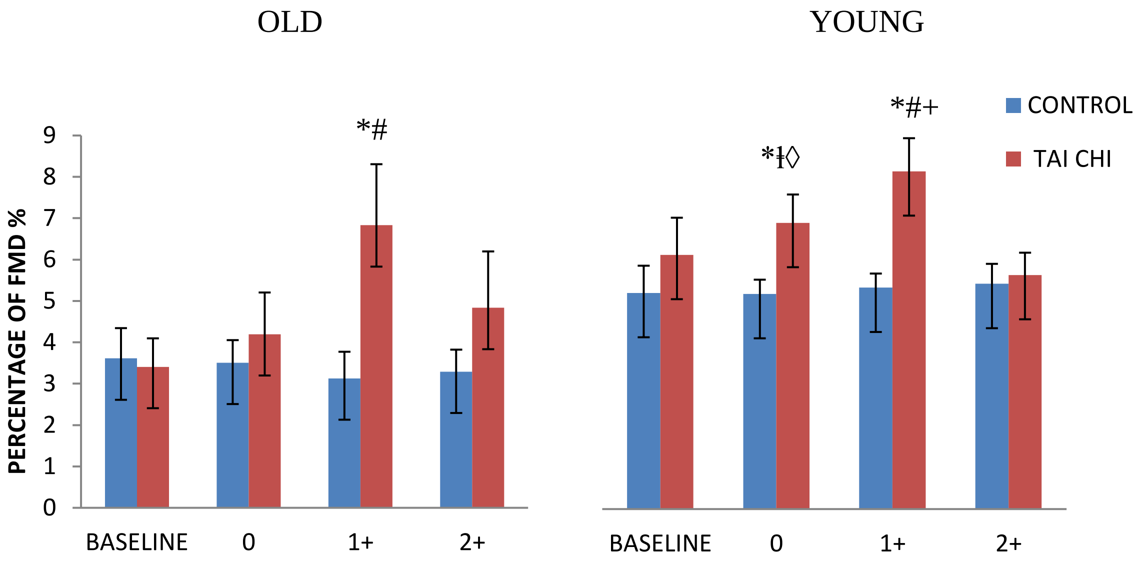

Figure 2. 7: The changes of flow-mediated dilation after an acute bout of Tai chi vs control in both young and old group

The change in flow-mediated dilation after an acute bout of Tai chi vs control in both young and old groups. Data was expressed as mean ± SE. * indicates statistically significant as compare same time point at control group, # indicates significantly different as compared to baseline, + indicates significantly different as compared to 0 hour, ł indicates significantly different as compared to 1+, ◊ indicates significantly different as compared to 2+.

Figure 2.7 shows the FMD percentage during Tai Chi and control lab visit at baseline, immediately post (0), post 1 hour (1+) and post 2hours(2+). There was a significant over all time effect, $F_{(3,51)} = 5.76$, p=0.002, condition $F_{(1,7)}=8.98$,p=0.008 and condition × Time interaction effect, $F_{(3,51)}=7.54$ p=0.001 for FMD, but no Group, Group × Time, or Group × Condition effects. Further exploration of these main effects revealed that FMD was improved at post 1+ after Tai Chi in old group, and at 0 and 1+ in young group.

2.7 DISCUSSION

In this study, the ability of Tai Chi, a unique, slow and low to moderate intensity exercise, to evoke the production of RONS after a single session was investigated. Most studies assessing the effect of an acute bout of exercise report on RONS following higher intensity exercise, but less is known about low to moderate intensity exercise, such as Tai Chi. Due to Tai Chi's long term capability to improve vascular function and cardiovascular health in general (Hartley et al., 2014; Huang et al., 2011), the current study aimed to measure the effect of a single bout of Tai Chi on markers of oxidative stress,inflammation and vascular health in old and young sedentary adults. It is known that the initial increase of ROS post exercise can act as a modulator for future adaptations to physical activity and physical health. However, this modulation is dependent on 2 main factors; exercise (type and duration), and participants characteristics (i.e., health, physical and fitness status). This is the first study to investigate the acute effect of Tai Chi in both age groups.

In total, 24 participants were recruited to this study: 13 young and 11 old. Data presented for the groups show significant group differences in BMI, and weekly physical activity. Data presented at population level on BMI is contradictory, with some studies suggesting that BMI increases in older age, especially in women (Peter, Mayer, Concin, & Nagel, 2015) and other studies suggesting that age is not a factor in BMI change (Hayes, Gearon, Backholer, Bauman, & Peeters, 2015). The data presented herein on habitual physical activity (collected via IPAQ) suggested that the older aged adults were more active with a significantly greater amount of time spent walking than their younger counterparts. There are a small number of studies that have investigated walking for transport in older age adults, and many observations are dependent on region. For example a study conducted in Belgium found increased recreational cycling in older adults following retirement (Van Dyck, Cardon, & De

Bourdeaudhuij, 2016). A study conducted in Australia found walking for recreation, compared to walking for transport, increased in older age, but these changes were dependent on the neighbourhood within one city (Ghani, Rachele, Washington, & Turrell, 2016). The results of the present study, suggesting the older adults walked more than the young, may therefore be specific to this area and cohort. No significant difference in total hours spent sitting was recorded between the groups, however, young participants reported spending significantly more hours on the computer or internet. This may be explained by the demographic of the young participant group as all were undergraduate students from University of Birmingham currently undertaking degree study.

Based on the HR data presented in table 2.3, Tai Chi could be characterised as a form of low to moderate intensity exercise based on the percentage of maximum heart rate achieved being less than 70% of the maximum heart rate during the one-hour session (Norton, Norton, & Sadgrove, 2010). Both groups, young and old, had a maximum heart rate of 104 bpm during the session, which corresponded to 52.6% for young and 66.4% for old, of predicted maximum heart rate, when adjusted according to age-predicted maximum heart rate. As such, 50-60% would usually be classed as low intensity and 60-70% as moderate intensity. These findings are in line with previous studies from Lan et al. (2008), who showed that Tai Chi is a moderate intensity exercise, which was found across different age groups (young: 25-44 years old, middle aged: 45-64 years old and elderly: 65-80 years) and genders. Similar findings were reported by Lan, Chen, and Lai (2004), Liu, Mimura, Wang, and Ikuda (2003).

The magnitude of change in maximum heart rate during the session may be related to experience in practicing Tai Chi. Jin (1988) reported a maximum HR of 108.8 bpm among middle aged Tai Chi practitioners (33.2± 9.0 years old) that had less than 8 months of experience. However, more experienced practitioners had a higher HR max of 124 bpm, which is similar to what has been observed by Brown, Mucci, & Hetzler, 1989; Chen & Zhao, 1984; Lai, Lan, & Wong, 1995; Zhuo, Shephard, & Plyley, 1984. As the current study assessed a single bout of Tai Chi in non-practitioners, the results reported herein fit these observations. Research by Xiong, He, and Ni (2011), suggests that, a high maximum heart rate achieved in experienced Tai Chi practitioners, is due to the ability to perform more energetic movements compared to beginners in Tai Chi. Those who are more experienced tend to perform Tai Chi with lower stance and better technique which requires greater effort and muscle contraction, as compared to a beginner who only concentrates on their movement.

In the current study, the pattern of heart rate change was slightly different from previous studies from Gong et al. (1981a), Liu et al. (2003), Xiong et al. (2011), which found that the maximum heart rate stabilized until the end of the exercise, and started to decrease only once the session ended. However, in this study, an increasing heart rate was observed in the first 20 minutes of Tai Chi, which is similar with other reported data, but towards the end of the session, the heart rate started to decrease towards baseline heart rate (figure 2.2). We predict that the capability to maintain peak heart rate as observed in other studies may be due to experience of their participants in doing Tai Chi and thus the ability to continue the required effort through the whole session, again suggesting that the participants in the current study were inexperienced in Tai Chi practice and this is a factor in the ability of the exercise mode to elicit the most beneficial effects.

In line with a previous study (Gong et al., 1981), no significant change was observed in systolic and diastolic blood pressure when comparing the control and Tai Chi visits as shown in figure 2.3. However, others have reported an increase in SPB and DBP during and post Tai Chi exercise (Chao, Chen, Lan, & Lai, 2002; Gong et al., 1981). These differences may be due to the types of Tai Chi used which are Tai Chi Qui-Gong and Tai Chi Chen that may differ in movement and form.

To investigate the ability of Tai Chi to stimulate an adaptive response, similar to other forms of exercise, two biomarkers of lipid oxidation; malonaldehyde (MDA) and 8-isoprostane were assessed. Figure 2.4b shows a significant time effect and condition×time interaction effect of MDA concentration, with a significant change immediately after Tai Chi in old group only. Such an increase in MDA concentration in older adults after an acute bout of moderate intensity exercise has been well documented (Bouzid, Hammouda, Matran, Robin, & Fabre, 2014; Ozbay & Dülger, 2002). As exercise-induced ROS production is depending on the exercise intensity (Balc et al., 2010; Goto et al., 2007), with higher intensity promoting more lipid oxidation, we postulated that the increase in MDA immediately after Tai Chi among our old but not young group maybe due to the higher relative intensity of Tai Chi exercise of 66.4% in the old group compared to young group, 52.5%, (see Table 2.3). The influence of intensity of exercise has also been shown in young adults, where MDA was increased following 1.5 miles walking at regular speed, but not at slower speed (Balc et al., 2010). Even though lipid oxidation did not change significantly post Tai Chi exercise in our young group, the increase in lipid oxidation after an acute bout of moderate intensity exercise in an untrained young population has been well documented by Falone et al.(2010), and Seifi-Skishahr, Siahkohian, and Nakhostin-Roohi, (2008), which again emphases the need to exercise at a higher intensity to induce changes in lipid oxidation in young healthy participants. The results presented show a significant change in MDA but not isoprostanes. Whilst these adducts are both markers of lipid oxidation, they are formed in very different ways by interaction of radicals with different lipids. For example, isoprostanes are formed from the interaction of radicals with arachidonic acid, whereas MDA is formed from the oxidation of any polyunsaturated fatty acid. The assessment of isoprostanes is therefore more specific. Dependent on the conditions within the cell, and in plasma at the time of sampling, different oxidation events may be taking place. Thus it is optimal to assess a number of markers of oxidative stress in order to gain an understanding of the oxidative load. Where one adduct is formed, or detected, and another is not, this may indicate a threshold oxidation, where the majority of radicals are perhaps kept in check by antioxidants. Under circumstances of severe oxidation, it might be expected that all outcomes assessing oxidation were significant.

An increase in antioxidant capacity, is one of the potential responses toward the adaptation process. However, there were no significant changes observed during Tai Chi visit in either the young or old group (figure 2.4a). The data presented herein assessed total antioxidant capacity of soluble antioxidants. These results therefore represent antioxidants such as vitamin C and uric acid, and as such can be heavily influenced by diet. Whilst transient changes in TAC are commonly seen after an acute bout of moderate exercise, the results are most accurate when diet is controlled.

As described in the introduction, transient changes in inflammatory markers after a single exercise session is also part of adaptation process that links health and physical benefits of exercise. Therefore, in this study, we chose to investigate the changes in two inflammatory markers; IL-6 and IL-10, which are known to be the earliest cytokines secreted following the onset of exercise. As expected, the older group had a higher baseline level of IL-6 compared to the younger group with $p=0.009$ and $p=0.002$ in both control and Tai Chi visits respectively. Our young group had an IL-6 concentration of 0.35 ± 0.32 pg/mL which is indicative of a normal healthy range (Fischer, 2006) but this was not the case for the older group that has higher concentration of 1.75 ± 1.75 pg/mL. Higher IL-6 in older age is not uncommon and has been reported before (Della Gatta, Garnham, Peake, & Cameron-Smith, 2014; Franceschi & Campisi, 2014; Sacheck et al., 2006). It has been suggested that, older adults can experience inflamm-ageing, whereby there is a mildly elevated level of inflammatory markers due to the ageing process (Calçada et al., 2014; Wadley, Veldhuijzen van Zanten, & Aldred, 2013). In addition to that, the higher concentration of IL-6 in the older group might also be partly the result of a higher BMI (Johnson, Justin Milner, & Makowski, 2012; Kanneganti & Dixit, 2012). Studies reported that higher BMI will associated with higher concentration of IL-6 found in the serum as compared to normal BMI which in line with our current data (Khaodhiar, Ling, Blackburn, & Bistrian, 2004). This is might partly due to low-grade inflammation of white adipose tissue, that increased the production of inflammatory molecules including IL-6 (Khan & Haque, 2011).

In this study, the results showed an increase in IL-6 concentration immediately and 1h and 2h after Tai Chi exercise (figure 2.5). An increase in IL-6 immediately after Tai Chi is entirely expected as IL-6 acts as a precursor to other macrophages and inflammatory cytokines, and signals to the body to be ready for possible inflammation or to initiate the recovery process and prevent damage to cells (Scheller, Chalaris, Schmidt-Arras, & Rose-John, 2011). However the magnitude of IL-6 change in this study is potentially not as high as that reported by other researchers employing different modes of exercise, with some studies reporting an increase as much as 100fold as compared to baseline, which is most likely due to the differences in intensity and duration of exercise (Mendham, Donges, Liberts, & Duffield, 2011). In other studies, a higher IL-6 concentration has been observed in response to moderate-vigorous intensity exercise compared to low-moderate intensity exercise.

An acute increase in IL-6 following exercise is associated with a transient increased in anti-inflammatory cytokines for example IL-10, IL-1ra and soluble tumour necrosis factor receptors (Mendham et al., 2011; Padilla et al., 2011). The secretion of IL-10 acts as an anti-inflammatory marker during acute exercise, and is suggested to protect against chronic systemic low-grade inflammation (Petersen & Pedersen, 2006). Figure 2.6 shows that there is a significantly increased level of IL-10 after 1 and 2 hours of Tai Chi. This result supports the theory that IL-6 can act as anti-inflammatory cytokine by regulating the secretion of other anti-inflammatory cytokines including IL-10. However, a Pearson's correlation resulted in a non-significant correlation between IL-6 and IL-10

According to Green, Dawson, Groenewoud, Jones, and Thijssen (2014) meta-analyses, the non-invasive FMD technique is in part mediated by NO. Therefore, any increase in the percentage of FMD post exercise may be due to the increase in NO bioavailability which facilitates vascular dilation. The key stimulus of NO release from the endothelium during exercise is the increasing in blood flow, also known as shear stress. Both in vivo and in vitro studies have found that increases in shear stress cause an up regulation of eNOS expression by 4 to 5 fold as compared to the control condition (Jin & Loscalzo, 2010). Therefore, the increase in shear stress during exercise may lead to the up regulation of eNOS, and subsequently the increase in NO production. However, different modes of exercise influence different pattern of vascular shear stress. This can be observed by variations in changes in FMD percentage after an acute bout of exercise. The increase in oxygen uptake during strenuous or moderate intensity acute exercise has been shown to result in an increase in oxidative stress/RONS production (McClean, Harris, Brown, Brown, & Davison, 2015) which can reduce the NO bioavailability in the vasculature (El Assar, Angulo, & Rodríguez-Mañas, 2013; Taddei et al., 2000). Therefore, the lack of decrease in FMD following the Tai Chi session in the current study could be the result of the exercise not being intense enough to induce a RONS response, and therefore not influencing NO bioavailability. According to

Bond et al.(2015), FMD was attenuated immediately after HIIT training and increased at 1+ and 2+ as compared to baseline, but no significant changes were observed at any time point in the moderate intensity exercise. The reduction in NO bioavailability, may therefore have caused the reduction in FMD percentage post exercise.

However, the data presented herein found that an acute bout of 60 minutes Tai Chi exercise caused an increase in FMD in both old and young group (figure 2.7). Compared to baseline, the changes were found to be significant at post 1 hour in both groups and immediately after Tai Chi in young group. As the percentage of FMD is dependent on the availability of NO to facilitate vasodilation, it may be that this improvement in FMD is due to its low to moderate intensity which might provoke lower shear stress, lower oxygen consumption, lower RONS production as compared to other strenuous exercise, increase in antioxidant capacity as what has been observed in figure 2.4. Although these results differ from some published studies, this may be explained by differences in exercise intensity and duration.

The current findings suggest that 60 minutes of low to moderate intensity of Tai Chi is able to induce a mild oxidative stress, which may serve as a stimulus for exercise adaptation if this acute bout were to be undertaken regularly. In addition, this bout of Tai Chi was able to transiently improve FMD. Thus suggesting that a single session of Tai Chi does not impact upon the bioavailability of NO.

2.8 REFERENCE LIST FOR CHAPTER TWO

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CHAPTER 3

THE EFFECT OF 12 WEEKS OF TAI CHI OR ZUMBA GOLD® ON MARKERS OF VASCULAR HEALTH IN UNTRAINED OLDER ADULTS

3.1 ABSTRACT

Introduction: According to the British Heart Foundation, the prevalence of cardiovascular diseases among the ageing population is increasing every year, especially in the over 75's. The higher incidence of cardiovascular disease is likely to be due to increasing oxidative stress and inflammation in the ageing population, which can impair vascular health via reduced bioavailability of NO. However, being more active can reverse some of the effects of ageing, but not all exercise is perceived as suitable for an older age population. Therefore in this study, the effect of 2 different types of exercise, namely Tai Chi and Zumba Gold® was investigated. **Methods:** Participants (aged 65 to 75 years) were recruited and randomized into 2 groups: Tai Chi or Zumba Gold®. All participants took part in a 12 week exercise intervention and blood pressure, vascular function (FMD), total antioxidant capacity, oxidative stress biomarkers (MDA, 8-isoprostane, protein carbonyl), and inflammatory markers in plasma (CRP and TNF-α) were assessed at baseline, mid and upon completion of the programme. **Results:** After 12 weeks of exercise intervention, both Tai Chi and Zumba Gold® groups showed a significant improvement in systolic blood pressure and vascular function. Plasma biomarkers of TAC, MDA, 8-isoprostane, protein carbonyl and CRP were also found to improve but only significantly in TAC in the Tai Chi group compared to baseline. **Conclusion:** 12 weeks of Tai Chi and Zumba Gold® both have the potential to improve vascular function among untrained elderly participants.

3.2 INTRODUCTION

3.2.1 Exercise: Improvement in endothelial function.

As described in chapter 1, it is undoubtable that exercise can benefit older adults. Potential benefits include improvements in vascular health via a lowering of the age-related increase in oxidative stress and inflammation. However, these effects have often been reported in well controlled laboratory conditions, where a standard form of exercise, such as cycling or running, was undertaken. Less is known about the effects of exercise that might be perceived as more appropriate and feasible for older adults such as Tai Chi and Zumba Gold®, especially in sedentary or untrained older adults.

3.2.2 Tai Chi: Can Tai Chi reduce oxidative stress and inflammation?

There are a growing number of studies that have investigated the effect of Tai Chi on oxidative stress in a variety of populations including patients (Chen, Ueng, Lee, Sun, & Lee, 2010; Zheng et al., 2015), healthy (Chang, 2014), and sedentary participants of varying ages (Goon et al., 2009; Huang, Eungpinichpong, Silsirivanit, Nakmareong, & Wu, 2014). However, only a few studies have been undertaken specifically in healthy older age participants. Rosado-Pérez et al.(2012) reported that daily Tai Chi training for six months significantly increased plasma total antioxidant status (TAS), and the antioxidant enzymes superoxide dismutase (SOD) and glutathione peroxidase (GPx) in red blood cells. Plasma lipid peroxidation was decreased (as measured by malondialdehyde (MDA) post exercise training, compared to the control group. In another study from the same researchers, Tai Chi was found to be more effective in increasing expression of antioxidant enzymes and lowering oxidative stress compared to a walking control group (Juana Rosado-Pérez, Ortiz, Santiago-Osorio, & Mendoza-Núñez, 2013). A shorter intervention of 8 weeks also resulted in increased TAS and GPx concentration in both pre- and post-menopausal women (Palasuwan, Suksom, Margaritis, Soogarun, & Rousseau, 2011). However, no significant changes were found in MDA level or endothelial function among elderly participants that undergo 40 minutes/4 times weekly for 3 months post Tai Chi intervention (Suksom, Sirsipatt, Lapo, & Patumraj, 2011).

Results from earlier studies have also demonstrated the beneficial effect of Tai Chi in reducing inflammatory markers such as TNF-α and CRP in healthy older adults, but most of the more recent studies involve patient populations, such as cancer (Irwin et al., 2014), periodontal disease (Mendoza-Núñez, Hernández-Monjaraz, Santiago-Osorio, Betancourt-Rule, & Ruiz-Ramos, 2014), dyslipidemia (Lan, Su, Chen, & Lai, 2008), diabetes (Chen et al., 2010) and individuals with cardiovascular risk factors. At the time of writing, only Lu and Kuo (2012) had assessed the changes of TNF- α in individual older adults, which resulted in a significant increase in TNF-α after 12 weeks of Tai Chi as compared to baseline.

3.2.3 Zumba Gold®: Can Zumba Gold® reduce oxidative stress and inflammation

To date, studies have assessed Zumba® or Zumba Gold® for its effects on cardiovascular fitness, muscle endurance and strength, but none have assessed the effect of this type of exercise on oxidative stress and inflammation. However, a wealth of evidence exists to demonstrates the capability of other similar aerobic types of exercise in improving endothelial function (Antunes, Rossi, Cholewa, & Lira, 2016; Metsios et al., 2014; Tanahashi et al., 2014). According to Santos-Parker et al. (2014), aerobic exercise contributes to improved endothelial function in an ageing population by restoring NO bioavailability, and decreasing oxidative stress and inflammation. Similar results have been found by Fujie et al. (2015), where NOx concentration was increased significantly after 8 weeks of aerobic exercise training. Eight weeks of aerobic exercise also has been shown to improve total antioxidant status (TAS) and GSH concentration in healthy postmenopausal women. Increased antioxidant status, measured by decreased F_2-isoprostane (Done & Traustadóttir, 2016), MDA , PC and 8-OHdG (Alghadir, Gabr, & Al-Eisa, 2016; Atashak et al., 2017) have been reported post moderate aerobic exercise in older age participants.

Existing research has also recognised the effect of aerobic exercise in reducing inflammation in an elderly population. Research from Mohammed and Mawad (2015) for example, has reported a significant decrease in TNF-α and CRP after a 12 week aerobic treadmill-based exercise in healthy elderly men. hs-CRP concentration was similarly decreased post 24 weeks of exercise training 60 - 75% of max heart rate (Alghadir et al., 2016) and post 32 weeks of training at 71 to 85% HR reserve in elderly aged 65 and above (Teixeira, Martins, Neves, Coelho-Silva, & Veríssimo, 2010).

However, the above evidence is provided by studies using aerobic exercise other than Zumba Gold® itself. Whilst it is still unknown whether Zumba Gold® specifically can benefit the elderly in reducing oxidative stress and inflammation, it can be assumed that Zumba Gold® will stimulate the well-characterised effects of aerobic exercise.

3.3 AIM AND OBJECTIVES

It is known that some forms of exercise can improve vascular health in older adults, but not all modes of exercise can elicit these effects. In this study, the effect of 2 different modes of exercise will be assessed. Tai Chi is perceived as low to moderate intensity and Zumba Gold® is perceived as moderate to high intensity (see section 1.1.9.3). Tai Chi includes elements of mindfulness and controlled breathing, whereas Zumba Gold® might be considered as a more standard form of aerobic exercise. Importantly, both forms of exercise have been deemed safe for older adults including those with limited mobility. In this chapter the effect of 12 weeks of Tai Chi or Zumba Gold® on factors influencing physiological health will be assessed. Outcome measures assessing vascular function, oxidative stress and inflammation will be presented. In chapter four the effect of these interventions on factors influencing psychological health and physical function will be assessed.

3.4 RESEARCH DESIGN AND METHODOLOGY

All procedures were undertaken at the School of Sport, Exercise, and Rehabilitation Sciences, University of Birmingham, and the study received ethical approval from the Science, Technology, Engineering and Mathematics Ethical Committee University of Birmingham.

Data was collected pre-training (1st, 2nd and 3rd laboratory visit), mid training (4th laboratory visit) and post training (5th and 6th laboratory visit). The study design is in shown in figure 3.1.

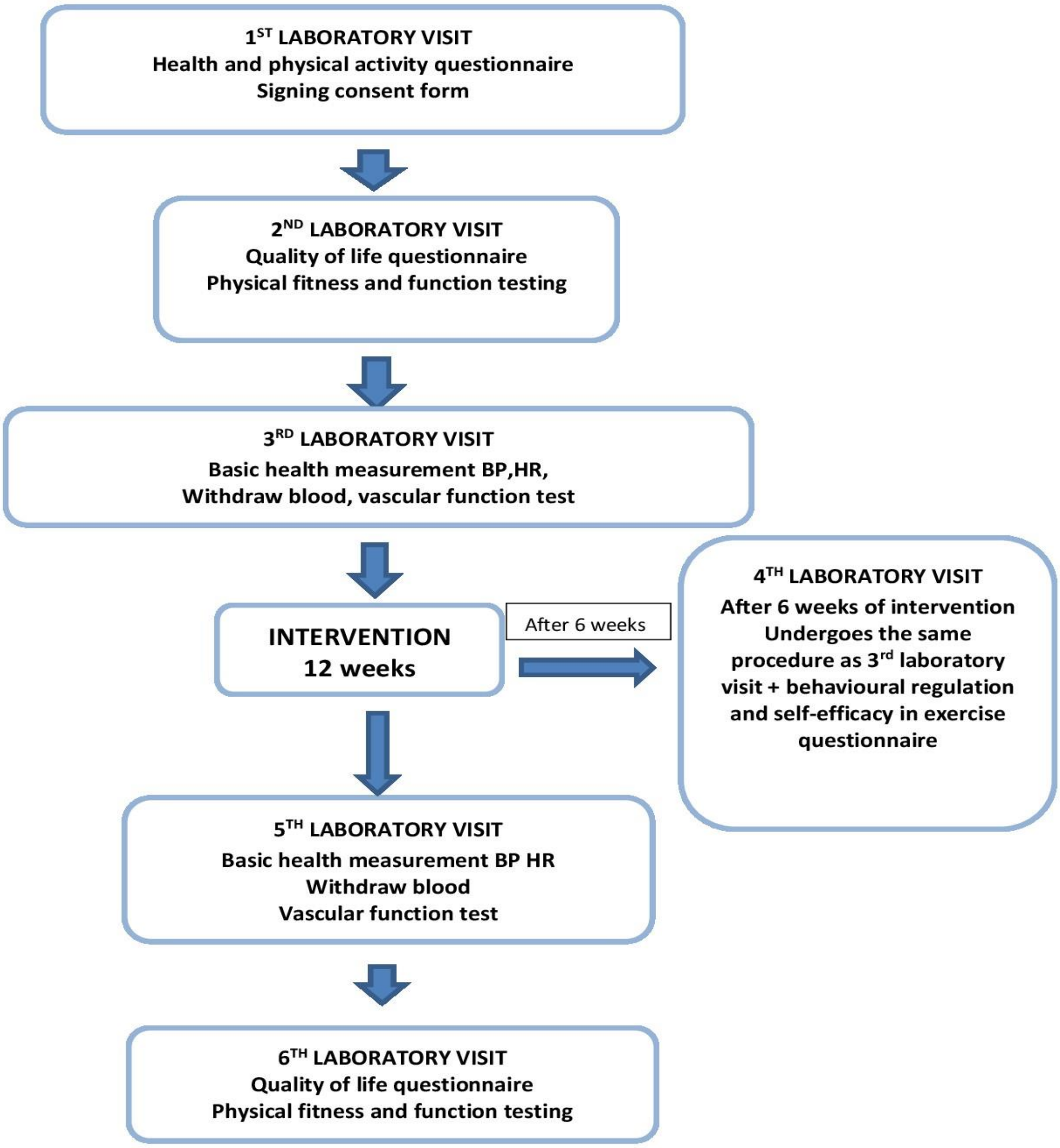

Figure 3. 1: Schematic diagram of the 12 weeks study design protocol.

3.4.1 Pre-training: First Laboratory Visit

Participants were recruited to the study using poster advertisments at local community centres, shops, churches, mosques, and via local media (University of Birmingham intranet, local newspapers and newsletters) and registered interest email lists (1000 Elders Group, University of Birmingham, School of Psychology volunteer email list). Prior to the first meeting, participants were provided with a study Participant Information Sheet. During the first laboratory visit, the outline of the project, the study objectives, aims, and procedures including protocol, risk and benefits of participating in this study were explained to the participants and any questions they had were answered. Once the participants were satisfied, they gave written informed consent and were invited to answer the health and physical activity questionnaire to determine their eligibility.

The health and physical activity questionnaire asked participants about their medical history, ability to be independent in their daily life including dressing, grooming, managing errands and housework and determined their weekly physical activity using the international physical activity questionnaire (IPAQ). Inclusion criteria included volunteers who are non-smokers, no history of cardiovascular disease and independent in their daily living activities. Participants were excluded if they reported on the IPAQ questionnaire to do more than 1500 MET-minutes/week of physical activity, with 3 days of vigorous-intense activity or doing any combination of moderate-intensity, walking or vigorous-intense activity for 7 or more days with 3000 MET-minutes/week (Craig et al., 2003). Participants were then randomized into one of the two exercise groups using a randomization sequence on randomization.org.

3.4.2 Pre-training: Second Laboratory Visit

During the second laboratory visit, participants' height and weight were recorded to calculate body mass index (BMI), physical function and fitness were also assessed (see chapter 4, section 4.4.2). Participants were also invited to answer quality of life questionnaire (see chapter 4, section 4.4.3).

3.4.2.1 Body mass index (BMI)

Height and weight of the participants were measured and calculated for their body mass index based on the formula;

Weight/ (height m)^2 (WHO 1995)

3.4.3 Pre-training: Third Laboratory Visit

After one week, participants were invited to the third laboratory visit for vascular function measurement.

3.4.3.1 Blood sampling

For this laboratory visit, participants were asked to have overnight fasting and required not to refrain from any intense exercise, caffeine, alcohol and tobacco, 12 hours before coming for the laboratory visit. Participants were also reminded not to take any antioxidant vitamins (vitamin C, vitamin E and α-lipoic acid) 72 hours. Fasting blood samples (10ml) were collected by a trained phlebotomist via venepuncture from the antecubital vein while participants were remained at semi-supine position. All blood samples were processed immediately by centrifuging the EDTA tube for 10 minutes, at 3500 x g, 4^{o}C. Plasma samples were kept in -80^{o}C freezer until further analysis.

3.4.3.2 Resting blood pressure

Prior to having blood pressure assessed, participants were asked to lie down in a resting semi-supine position on a bed for at least 20 minutes. The room temperature was set to 22-24 ^{o}C, and low light. Brachial blood pressure was taken immediately after the resting period using an automatic blood pressure machine (Omron M2 Basic, Kyoto, Japan). All measurements were made in triplicate, and the mean value was recorded with 5 minute intervals between measurements.

3.4.3.3 Flow mediated dilation (FMD)

This procedure was undertaken as describe in chapter 2, section 2.4.2.2.3.

3.4.4 Exercise intervention

All participants were randomized as stated at 3.4.1 into 2 groups; Tai Chi or Zumba Gold®. All groups were invited to attend 12 weeks exercise sessions; 3 times per week for 1 hour. All exercise sessions were held at School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham. Compliance with the intervention was determined as attending 70% of the sessions throughout the intervention.

Tai Chi

Participants randomised to Tai Chi group were guided by a certified instructor registered under Tai Chi Union Great Britain (TCUGB). They were instructed to do a one hour Yang-style which consisted of 10 minutes warm up, Shibashi Qigong 18 set of movements, Yang style form, and 10 minutes of cool down. During the session, participants were constantly reminded to have a natural and relaxed breathing, and try to synchronize the breathing with their movements.

Zumba Gold®

Zumba Gold® training was delivered by a certified instructor. Each of the training sessions lasted 60 minutes, consisting of 10 minutes of warm up which included stretching and whole body movements, followed by 40 minutes Zumba Gold® routines. The routines were performed using slow to fast music from the selected rhythms of merengue, salsa, cumbia, flamenco and bachata. All movements involved elements of a cardiovascular workout, balancing, and dynamic stretching. The session was closed with cooling down and stretching session for 10 minutes.

3.4.5 Mid training: Fourth Laboratory Visit

After 6 weeks of intervention, participants were invited to the fourth laboratory visit. During this lab visit, measures from third laboratory visit (3.4.3) were repeated which measured BMI, resting blood pressure, FMD and blood withdrawal. Participants were also given a set of questionnaire, that consists of validated questionnaire; Behavioural Regulation in Exercise BREQ-2 (4.4.5a) and Self-efficacy in Exercise (4.4.5b) (see Chapter 4).

3.4.6 Post training: Fifth Laboratory Visit

After completing the 12 weeks exercise intervention, participants were required to come to the laboratory for their final assessment. During the fifth laboratory visit, participants underwent measurement of BMI, resting blood pressure, FMD and blood withdrawal similar procedure during the third laboratory visit (3.4.3).

3.4.7 Post training: Sixth Laboratory Visit

Two days after the fifth laboratory visit, participants were asked to return to the lab for their final assessment. The similar measurements during the second laboratory visit (3.4.2) (physical function, VO_2 max and quality of life questionnaire) were reassessed in this lab visit.

3.4.8 Blood analysis

3.4.8.1 Total antioxidant capacity, lipid oxidation

Plasma analysis of total antioxidant capacity (TAC), and lipid oxidation (TBARS and 8-isoprostane), were conducted as describe in chapter 2 section 2.4.3.

3.4.8.2 Protein oxidation; protein carbonyl assay

<u>Protein concentration</u>

Prior to measuring the protein oxidation, the concentration of protein concentration in the plasma samples was measured using BCA method (Smith et al., 1985). Briefly, samples were diluted (1:200 dilution; 5µl with 995µl ddH_20) and Bovine serum albumin standards (BSA) were prepared ranging from 0-1 mg/mL. Samples and standards (10µl) were then loaded to a 96 well plate and bicinchoninic acid detection reagent (BCA) and copper sulphate solution were added to the plate (200µl). The plate was incubated at room temperature before being read at 540nm. The protein concentration was determined using absorbance values from the known BSA standard concentration.

<u>Assessment of protein carbonyl</u>

Plasma protein carbonylation was assessed using an ELISA described by Carty et al (2000). Briefly, samples and standards were diluted to a final concentration of 0.05mg/ml using a coating buffer (Sodium carbonate 50 nmM, pH 9.2). Samples and standards (50µl) were loaded into 96 well Maxisorb plate (Nunc, Fisher Thermo Scientific) in duplicate and incubated for 1 hour at 37^{o}C to allow protein binding. Following washing, 2-4-Dinitrophenylhydrazine (DNPH) (1nM in 2M HCl; 50µl) was added and incubated for another 1 hour at room temperature. The plate was washed again to remove unbound DNPH and blocking buffer (0.5% TWEEN-20; 200µl) was loaded to block non-specific binding sites for 1 hour at 37^{o}C. Following wash, primary antibody (mouse IgG anti-dinitrophenyl, 50µl, 1:1000 dilution) was added to the wells and the plate was incubated overnight at 4^{o}C. The plate was allowed to return to room temperature before being washed and secondary antibody (50µl) (anti-mouse IgE horse radish peroxidase conjugate; 1:5000 dilution) was loaded in the well. Following washing, substrate (10ml 0.5M citrate phosphate buffer, pH5, 8µl hydrogen peroxide and 2 mg o-phenyldiamine tablet, 50µl) was added and the plate was incubated in the dark at room temperature. The reaction was stopped with 2M sulphuric acid (50µl) and absorbance was measured at 490nm. The concentration of protein carbonylation was determined using the standard curve calculated from the standard concentration.

3.4.8.3 Inflammatory cytokines; C-Reactive protein (CRP) and Tumor Necrosis Factor alpha (TNF-α)

<u>C-Reactive protein (CRP)</u>

CRP was measured using enzyme-like immunosorbent assay (ELISA) method using a commercially available kit BMS288INST from eBioScience, Vienna Austria. Prior starting the assay, plasma samples were diluted 1:5000 with assay buffer according to the manufacturer instruction. Samples (10µl) were then added into wells, and incubated at room temperature for 2 hours, on a shaker. This assay used an anti-human CRP polyclonal antibody. After washing, substrate solution (tetramethyl-benzidine) (100µl) was added and incubated at room temperature without direct exposure to intense light. Colour development was monitored and stop solution was added. The plate was read at 450nm using spectrophotometer.

Tumor Necrosis Factor alpha (TNF-α)

Plasma concentration of TNF- α was determined using a commercially available Human TNF-α kit according to manufacturer instruction (Thermo Fisher Scientific, Vienna, Austria). Briefly, diluted samples (50µl) were added into samples well that was pre-coated with anti-human TNF alpha coating antibody. A biotin-conjugated anti-human TNF alpha antibody was added and bind to TNF- α captured by the first antibody. Following incubation, the unbound biotin-conjugated anti-human TNF- α was removed during the washing steps. Second incubation will allow Streptavidin-HRP binds to biotin-conjugated and plate was washed after one hour to remove any unbound Streptavidin-HRP. Substrate solution was added and colour development was observed before adding the stop solution. Results was read immediately using spectrophotometer at 450nm.

3.5 STATISTICAL ANALYSIS

Data management and analysis were performed using SPSS 24.0 statistical package for Windows (SPSS Inc. USA). Normal data distribution was analysed using the Shapiro-Wilk's test. Data that were not normally distributed (e.g., antioxidant capacity, 8-isoprostane, CRP, protein carbonyl) were transformed using Log_{10} or square root to normalize the data before analyses were conducted. Baseline differences between the participants in the Tai Chi and participants in the Zumba Gold® group were examined using an independent samples t-test for continuous data and chi-squared test for categorical data. The effects of the intervention were analysed using separate time (pre, mid and post) by condition (Tai Chi and Zumba Gold®) repeated measures Analyses of Variance (ANOVA). Where appropriate, post hoc analyses were conducted, using a separate repeated measure ANOVA for Tai Chi and Zumba Gold®. Spearman's correlation coefficient (*r)* was used to determine the relationship between the absolute changes for all baseline parameters with baseline FMD and absolute changes of FMD from baseline. Significant levels were set at 5% for all analyses and presented as mean ± standard error, unless otherwise stated.

3.6 RESULTS

3.6.1 Characteristics data

Table 3.1 describes the baseline characteristics of the participants in the Tai Chi and Zumba Gold® training study. Only protein oxidation was found to have significantly different as compared to both group at baseline, with Zumba Gold® group has lower protein oxidation of 1.16 nmol/mg compared to 2.97nmol/mg in Tai Chi group, p=.0001.

Table 3. 1: Baseline characteristics for Tai Chi and Zumba Gold® groups.

Parameters	Tai Chi	Zumba Gold®	p
Gender			
Male	4	1	
Female	7	9	
Total	11	10	0.166
Age, mean ± SD	71 ± 3.1	70 ± 3.6	.463
Marital status			
Married/Partner	5	7	
Single/Widowed	6	3	
IPAQ Work (METs-minutes/week)			
Vigorous	0(0)	0(0)	1
Moderate	0(0)	0(0)	1
Walk	0(0)	0(0)	1
IPAQ Transportation (METs-minutes/week)			
Cycling			
Walk	0(0)	0(0)	1
	792(1435)	693(1369)	.918
IPAQ Leisure (METs-minutes/week)			
Walk	198(720)	693(940)	.173
Moderate	0(300)	0(60)	.756
Vigorous	0(0)	0(0)	.349
IPAQ total (METs-minutes/week)	1908 (1327)	1555 (2919)	1.0
Sitting time (hours/week)			
Watch television	12 (14)	21 (26.5)	.175
Computer/internet	14 (10.5)	8 (14.5)	.512
Reading	7 (10.5)	3.5 (8.5)	.468
Socializing	8 (11.5)	5 (4)	.654
Driving	5 (3.5)	4 (6.75)	.557
Hobbies	6 (7)	7 (5.5)	.468
Others	1 (4)	3 (7)	.863
Total	56 (36)	67 (24.6)	.605
BMI (kg/m^2)	27.4 ± 4.8	28.4 ± 3.4	.593
SBP (mmHg)	133.6 ± 22.4	127.8 ± 15.1	.504
DBP (mmHg)	79.8 ± 9.0	78.8 ± 9.8	.807
HR (bpm)	61.5 ± 9.0	66.3 ± 11.1	.284
Total antioxidant capacity (TAC) (μM)	279.9 (87.2)	309.5 (133)	.725
Protein carbonyl (pg/mL)	3.9 (1.9)	1.2 (0.5)	**.0001**
MDA (μM)	10.1 ± 1.9	11.3 ± 1.8	.161
8-isoprostane (μM)	46.1 (38.9)	16.8 (47.7)	.231
CRP (pg/mL)	542.7 (3058.6)	247.1 (585.8)	.397
TNF-α (pg/mL)	6.5 ± 0.3	6.5 ± 0.3	.868
FMD %	3.4 ± 2.1	3.3 ± 1.5	.907
Attendance (%)	73±10.9	73±8.5	0.48

Results are expressed as mean ±SD for data that are normal, and median (IQR) for not normally distributed data (IPAQ, sitting time, TAC, 8-isoprostane, CRP).

3.6.2 Health measurement of BMI and blood pressure

Table 3.2 below shows participant's changes in BMI, SBP and DBP at baseline (pre), 6 weeks of intervention (MID) and after 12 weeks of intervention (POST) in both groups. **BMI**: There is no changes observed in BMI in both group after 2 by 3 (Two groups: Tai Chi, Zumba Gold® by 3 time: pre, mid, post) ANOVAs analysis with no significant on group, time, or group × time interaction effects (p's>.15). **SBP:** SBP was found to be improved at post training in both group after a repeated measures ANOVA analysis. A significant time effect was observed with, $F_{(2,18)}= 9.87$, p=.001, but no group (p=.78) or group × time interaction effect(p=.24). Post hoc analyses revealed that SBP was significant lower at 12 weeks compared to both baseline and 6 weeks. **DBP:** No Similar analyses were undertaken to determine the effect of exercise on DBP and no significant group (p=.76), time (p=.34), or group × time interaction (p=.77) effects were observed.

Table 3. 2: Heath measurement of BMI, systolic and diastolic blood pressure at pre, mid and post exercise intervention in both Tai Chi and Zumba Gold® group.

Data are presented as mean ± SE. # indicates significant different as compared to mid, + indicates significant as compared to pre intervention.

	Group	Pre	Mid	Post
BMI	Tai Chi	27.4 ± 4.8	27.1 ± 4.9	27.2 ± 4.7
	Zumba Gold®	28.4 ± 3.4	28.3 ± 3.4	28.2 ± 3.3
SBP	Tai Chi	133.5 ± 22.4	128.9 ± 22.4	**121.8 ± 19.2$^{\# +}$**
	Zumba Gold®	127.8 ± 15.1	127.3 ± 10.2	**123.0 ± 8.9^{+}**
DBP	Tai Chi	79.8 ± 9.0	79.0 ± 9.6	77.1 ± 9.5
	Zumba Gold®	78.8 ± 9.8	80.9 ± 7.5	79.1 ± 6.9

3.6.3 Biochemical data

Figure 3. 2: Changes in blood biomarkers of total antioxidant capacity, lipid and protein oxidation, and inflammatory cytokines in Tai Chi and Zumba Gold® group.

Data are expressed as means ± SE. # indicates significantly different relative to pre training, and + indicates significantly different compared to mid training.

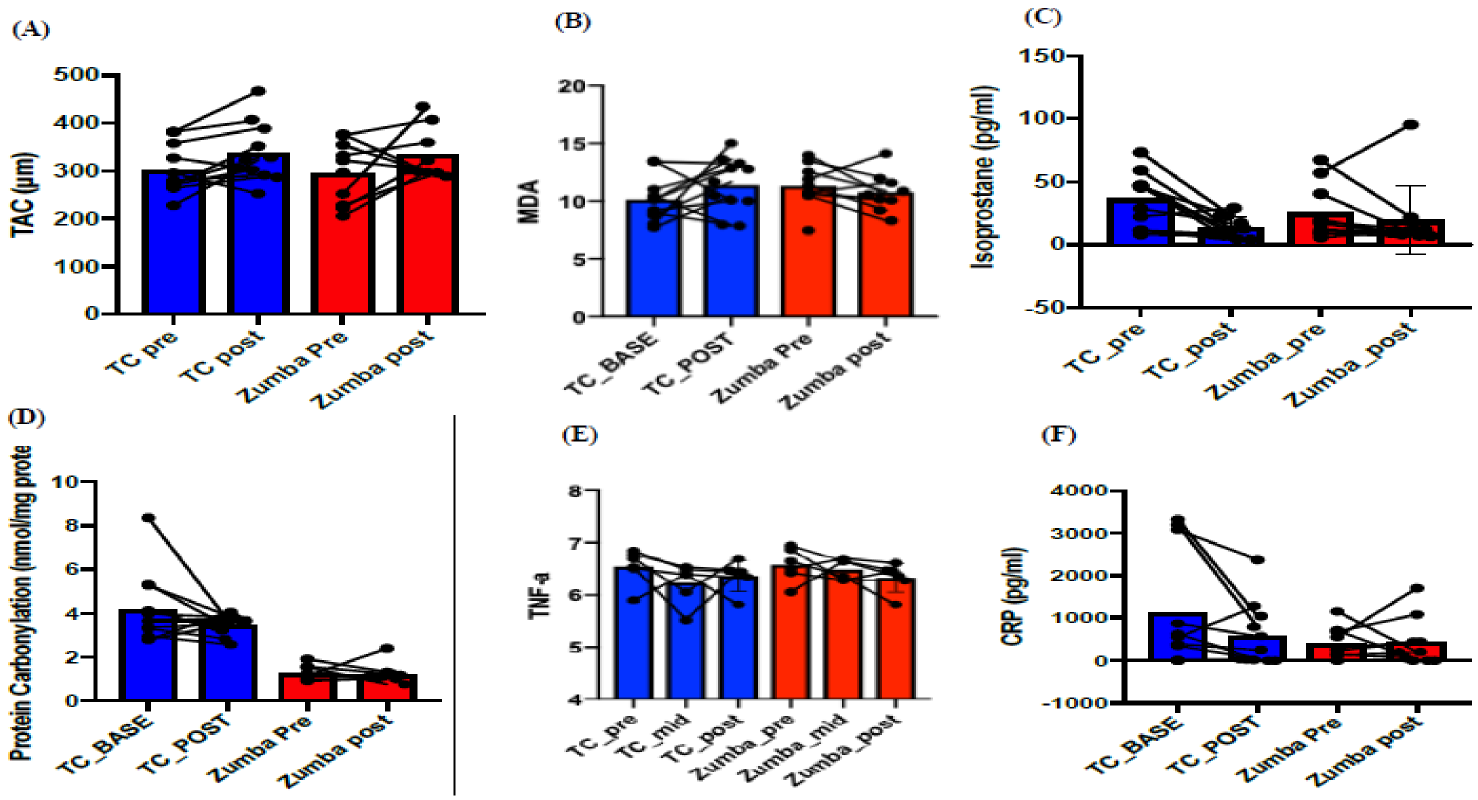

Figure 3.2 provides the experimental data of total antioxidant capacity (TAC), MDA, isoprostane, CRP and TNF-α at baseline, mid and post Tai Chi and Zumba Gold® training (no mid intervention data for isoprostane). All data were analysed using 3 by 2 repetition measure ANOVA's (time x group) **(A) Total antioxidant capacity:** Even though there appears to be an increase in the total antioxidant capacity over time, there was no statistically significant group, time and group x time effects. **(B) MDA:** ANOVA yielded no group or time effect, but a significant time x group effect with $F_{(2,16)} = 3.691$, p= .048, and further post hoc analysis found a significant reduction of the MDA concentration in Zumba Gold® group as compared to baseline, p= .017. **(C) Isoprostane:** There is a time effect observed with $F_{(1,9)}=10.886$, p=.009 but no group or group x time effect. **(D) Protein carbonyl:** Group × Time ANOVA revealed a significant group effect, $F_{(1,6)}=178.25$, p<.001 and time effect, $F_{(2,12)}=3.996$, p=.047, but no significant group x time effect. Further exploration using separated repeated measured ANOVA by group, revealed that post Tai Chi was found to be significant as compared to baseline and mid intervention, p=0.036 and p=0.004. However, no significant difference was found in the Zumba Gold® group. No changes in **TNF-α (E)** and **CRP (F)** concentration after 12 weeks of exercise training in both Tai Chi and Zumba Gold® group with no group, time, group × time interaction effects .

3.6.4 Flow Mediated Dilation (FMD)

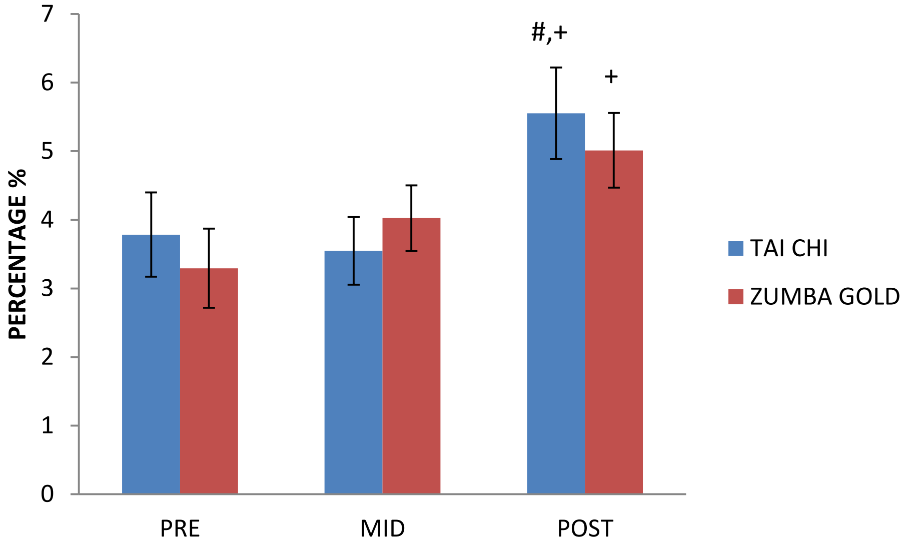

Figure 3. 3: Percentage of flow mediated dilation at baseline, mid and post intervention.

Data are expressed as mean ± SE. # indicates significantly different as compared to pre training, + indicates significantly different compare to mid training.

Figure 3.3 shows the percentage of flow mediated dilation at pre, mid and post training in both groups. Repeated measured analysis found that there is a time effect with $F_{(2,10)}$ =13.364, p=.001, but no significant group (p=0.563) or group × time interaction (p=0.844) effect. Post hoc analysis revealed that there was a significant improvement in FMD post Tai Chi intervention as compared to pre (p=.014) and mid training (p=.031), while FMD significantly improved in the Zumba Gold® group post intervention as compared to mid intervention (p=.029). We then further analysed the percentage of changes at post intervention as compared to baseline in both groups, to investigate which exercise programme that stimulate the largest improvement in FMD. Tai Chi showed the highest percentage with 43% improvement in FMD, while Zumba Gold® resulted in 39%. Further t-test analysis showed that there is no significant different in percentage changes in both group, which indicates that both groups showed similar effect in improving the endothelial function among our elderly participants.

Table 3.3 below showed the correlation coefficient (*r)* table to determine the relationship between the absolute changes for all baseline parameters with baseline FMD and absolute changes of FMD from baseline. There is a significant negative correlation in baseline FMD with absolute changes in FMD, which means that poor endothelial function (lower % FMD) prior starting the exercise intervention will cause higher increased in %FMD. No statistically significant association between changes in FMD and absolute changes in FMD with any other physiological measurements. However, there is a trend towards association between inflammatory cytokines (TNF-α) and changes of FMD; greater decreased in TNF-α associates with greater improvement in FMD. Similar analysis was rerun in Tai Chi and Zumba Gold® separately; broadly, similar findings were found with lower sample size and low power.

Table 3. 3: Correlation between all baseline measurement with baseline FMD and absolute changes of FMD from baseline.

	Baseline FMD	Baseline BMI	Baseline SBP	Baseline DBP	Baseline VO_2 max	Baseline TAC	Baseline MDA	Baseline Isoprostane	Baseline PC	Baseline CRP	Baseline TNF-α
Baseline FMD	1	.127	.143	-.249	-.261	-.028	-.184	-.495	-.062	.071	-.183
Changes FMD	**-.749***	-.266	-.257	.196	.108	-.337	-.064	.248	-.037	.202	.667

*significant correlation $p<0.05$

3.7 DISCUSSION

To the authors' knowledge, this is the first study to compare the effect of a low to moderate intensity exercise (Tai Chi) and moderate to high intensity exercise (Zumba Gold®) on physiological and psychological aspects (chapter 4) of health in an elderly population. The study's primary aim was to measure vascular health by endothelial dependent dilation using a non-invasive technique called flow mediated dilation. The study also aimed to assess markers of oxidative stress and inflammation to provide context and mechanistic insight to potential vascular health improvements caused by the exercise interventions. In addition, the effects of these two types of exercise on physical function (upper and lower body flexibility, agility and leg strength/ endurance), QoL and mental health (anxiety and depression), sleep quality and loneliness were explored. These results are presented in chapter 4.

Following 3 months of exercise training, a significant improvement in endothelium dependent dilation was observed in both groups (figure 3.3). This is in agreement with other exercise training modes of moderate intensity among post-menopausal women with endothelial dysfunction (Swift et al., 2014), and other types of exercise training, including aerobic exercise (Westhoff et al., 2007), as well as a combination of aerobic and resistance exercise (Miche et al., 2006) , and resistance exercise of hand grip exercise (McGowan et al., 2006).

It has been suggested that physical activity has the potential to improve endothelial function by reducing oxidative stress and inflammation (Korsager Larsen & Matchkov, 2016), which seems to be consistent with the present observations. In this study, an increase in antioxidant capacity was observed, as shown in figure 3.2 in both groups. However, only participants undertaking Tai Chi had significantly increased antioxidants post training. Even though a reduction in lipid peroxidation can be seen, in particular in 8-isoprostane, these changes were not statistically significant. Similar non-significant reductions were found for protein oxidation.

In this present study, both types of exercise training had a significant effect on vascular function. The percentage of FMD, as compared to baseline (figure 3.3) was significantly increased. This is in line with other studies that show that adhering to exercise training can contribute to better endothelial function (Jarrete et al., 2014; Miele & Headley, 2017; Negrão, Andrade, de Nazaré Nunes Alves, & Sales, 2018; Sallam, Laher, Sallam, & Laher, 2016). We postulate that the improvement in FMD is due to increasing NO bioavailability, resulting from a decreased oxidative stress in the vasculature. As previously introduced in chapter 1.1.5, bioavailability of NO can be reduced by the presence of oxidative stress. RONS have been implicated in altered expression of ADMA, an antagonist of L-arginine, and the suppression of expression of eNOS (Osto & Cosentino, 2010). In addition, the bioavailability of NO can also be reduced when RONS bind with the available NO in the vasculature, to form peroxynitrate ($ONOO^-$), which will not only reduce the concentration of NO, but also will further cause arteriosclerosis (Bloomer, 2008).

Further, Increasing bioavailability of NO may also be due to the reduction in CRP as has previously been widely reported (Clapp et al., 2005; Leonard et al., 2011; Singh, Devaraj, Vasquez-Vivar, & Jialal, 2007). In this present study, CRP decreased in the Tai Chi group post exercise training as compared to baseline (figure 3.2).

No change in TNF-alpha was detected in response to either intervention. This is in contrast to previous studies (Lu & Kuo, 2012). The possible reason underlying this is maybe due to the low TNF-α concentration in our participants at the baseline. Both the Tai Chi and Zumba Gold® group had a mean of 6.54 and 6.57 pg/mL respectively prior to starting the exercise intervention, as compared to other published data that ranging from 17 to 30 pg/mL (Córdova et al., 2011; Lima et al., 2015).

In sum, the data presented suggest that both Tai Chi and Zumba Gold® can improve endothelial function. Although some changes in markers of oxidative stress and inflammation presented herein give insight into potential mechanisms of action of these modes of exercise, future research is needed to provide more specific data on the mechanism(s) of action by perhaps looking at the expression of eNOS, ADMA, L-arginine and BH_4 concentrations at pre and post exercise.

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CHAPTER 4

THE EFFECT OF 12 WEEKS OF TAI CHI OR ZUMBA GOLD® ON MARKERS OF PHYSICAL FUNCTION AND WELLBEING IN UNTRAINED OLDER ADULTS

4.1 ABSTRACT

Ageing has been associated with increasing cellular damage, which can cause changes in physiological and anatomical health in older adults. Such changes include a reduction in muscle strength, poorer upper and lower body flexibility and which all lead to a reduction in an individuals' capability in daily activities, and can impact quality of life (QoL). Adhering to physical activity is reported to improve physical function and fitness among older age adults, in addition to improvements in fatigue, sleep quality as well as psychological wellbeing, including depression, anxiety and loneliness. However, there are some barriers that prevent older adults from being physically active, thus motivation and ability to overcome these barriers are important. Therefore in this study, changes in physical function and fitness, Qol, psychological wellbeing as well as motivation and barriers to exercise were assessed in untrained older adults after 12 weeks of Tai Chi and Zumba Gold® training. **Methods:** Twenty one physically inactive older adults, aged 70±.9 years old were recruited to undertake 12 weeks of Tai Chi or Zumba Gold®. Assessment of physical function (agility, upper and lower body flexibility, leg strength and endurance), physical fitness (VO_2max test), and self-rated of health-related quality of life (SF-36), fatigue (Multidimensional Fatigue Inventory questionnaire-MFI), depression and anxiety (Hospital Anxiety and Depression Scale-HADS), loneliness (Revised UCLA Loneliness Scale), and sleep quality (Pittsburgh sleep questionnaire) were measured at baseline and following the 12-week interventions. Participant's motivation (Behavioural Regulation Questionnaire-BREQ-2) and self-efficacy for exercise (Self-Efficacy for Exercise questionnaire-SEE) were measured at mid exercise intervention. **Results:** Following both the Tai Chi and Zumba Gold® interventions, 2-way repeated measure ANOVAs (group x time) showed a significant improvement in leg strength and endurance following both Tai Chi and Zumba Gold® exercise intervention with p=.021 and p=.001 respectively. Significant changes were also seen in body agility and physical

fitness among Zumba Gold® participants at post training as compared to baseline with p=.005 and p=.001. However, even though there was an improvement in upper and lower body flexibility in both groups, the results were not statistically significant. Physical and mental fatigue, and feeling of loneliness were improved in the Tai Chi group, while aspects of mental and physical domains as assessed by SF-36 and sleep quality were significantly improved in the Zumba Gold® group. Self-efficacy and motivation in continuing the exercise programme was high in both groups as observed by a higher score in the SEE questionnaire and autonomous regulation in BREQ-2. **Conclusion:** Tai Chi and Zumba Gold® exercise has the capability to reduce fall risk by improving physical function (leg strength, endurance and agility), and may ameliorate mental well-being as observed in the loneliness scale, sleep quality, fatigue and mental and physical health in older adults.

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4.2 INTRODUCTION

4.2.1 Psychological wellbeing; depression, anxiety, loneliness and sleep quality in older adults

Research has suggested that older adults not only have a higher risk of getting CVD, but are also more likely to have poor functional fitness and physical function (Neto & de Castro, 2012). This, combined with an increased likelihood of body pain and fatigue has been reported to contribute to worsening health and dependence on other people in managing their daily activities. Research has shown that, 63 percent of elderly men and 91 percent of elderly women experienced bodily pain and 15 percent of men and 29 percent of women suffer from fatigue (Bergh, Steen, & Waern, 2003; Vestergaard, Nayfield, & Patel, 2009). As introduced in chapter 1 (see 1.1.1), these factors often lead to other mental health disorders such as depression, anxiety and poor sleep quality, as well as loneliness (Hacihasanoĝlu, Yildirim, & Karakurt, 2012).

According to WHO, approximately 15 percent of older adults aged 60 and above are diagnosed with mental health disorders (World Health Organization, 2016), with 3.8 to 15 percent of them having depressive symptoms (Barcelos-ferreira, Yoshio, Steffens, & Bottino, 2013). Depression can be categorised as a mood disorder and defined as painful emotional experiences due to the loss of interest and pleasure in life (Larry L, 2005). Two influences which have been suggested to contribute to the prevalence of depression among the elderly are physical factors such as chronic disease, pain and disability, and psychosocial factors, such as social isolation, financial circumstances and difficulty in adapting illness and disability (Rodda, Walker, & Carter, 2011).

Research has shown that anxiety and depression are closely related, and often share common risk factors (Beekman, Beurs, Dyck, & Tilburg, 2000). According to UK 2000 Survey of Psychiatric Morbidity, 3 percent of older adults aged 70 to 74 years old met the criteria for anxiety and a higher prevalence was reported in clinical populations (Bryant, Jackson, & Ames, 2008; National Statistics Survey, 2016). Findings from previous studies have also suggested that anxiety can affect cognitive function in older individuals and increase mortality rates, especially in older men (Liu, 2015; Van Hout, Beekman, & de Beurs, 2004). In addition previous studies assessing depression in older adults have suggested that depression is also related to loneliness, poor physical function and lower levels of perceived social support (Pronk, Deeg, & Kramer, 2013; Sonnenberg, Deeg, & Van Tilburg, 2013). Loneliness can be defined as distress, or feelings associated with the perception that one's social needs are not met by the quality or quantity of an individual's social relationships (West, Kellner, & Moore-West, 1986). According to Weiss (1973), loneliness can be categorised as emotional loneliness and social loneliness. Emotional loneliness is usually experienced by an individual that has lost their loved ones, which caused lack of intimate attachment, while social loneliness caused by the lack of social network with people that have similar interests and activities. Those who have retired from their working life often experience this type of loneliness. Loneliness can not only cause feelings of stress, pessimism, anxiety and low self-esteem, but also can lead to morbidity and mortality (Laura Alejandra, Francisco, Ayuso-mateos, & Miret, 2018; Nicole & Barbara, 2012). Research has shown that 40 percent of older adults aged 65 and above are reported to be lonely and the level of loneliness is increasing with age (Hawkley & Cacioppo, 2010). Given this, it is important to assess factors that may affect quality of life among elderly.

In addition, another common problem, which may contribute to quality of life is poor sleep quality. The most common sleep disturbances include difficulties in initiating sleep, maintaining sleep and waking in the early morning (Chen et al., 2010). According to Crowley, (2011), more than 50 percent of older individuals experience poor sleep quality. This may impact other health outcomes such as decreasing cognitive ability including memory, reasoning, verbal fluency, depression and anxiety, and increased risk for chronic diseases such as hypertension, obesity and diabetes (Gadie, Shafto, Leng, & Kievit, 2017; Kelley & Kelley, 2017). Research has shown that poor sleep quality may be caused by an inactive lifestyle, lack of physical exercise and excessive daytime napping.

Previous studies have demonstrated that older adults that adhere to exercise programmes or have an adequate physical activity level have a lower risk of mental ill-health, better functional and physical fitness and improved QoL as discussed in chapter 1.1.7 (Brandão et al., 2018; Vagetti et al., 2014; Vermeulen, Neyens, Van Rossum, Spreeuwenberg, & De Witte, 2011). The benefits include reducing anxiety as reported by Herring, Lindheimer, & O'Connor, 2014, Herring, O'Connor, & Dishman, (2010) and Jonsdottir, Rödjer, Hadzibajramovic, Börjesson, & Ahlborg, (2010) but the mechanisms are unclear. However, it has been postulated that regular PA exert the anxiolytic and depression-lowering effects by promoting anti-inflammatory in the brain region which enhanced neurogenesis and neuroplasticity (Archer, Josefsson, & Lindwall, 2014; Moylan et al., 2013). PA was also reported to promote the increase in adenosine concentration in entire brain which stimulates in decreasing the anxiety- and depression-related behaviour (Costa et al., 2012; Mochcovitch, Deslandes, Freire, Garcia, & Nardi, 2016)

A systematic review by Pels & Kleinert, (2016) found that PA can contributed in reducing loneliness but the beneficial effect is depending on the quality of the relationship during the activity, including the relationship between trainer and peers. In addition to that, PA was also found to alter the expression of inflammatory markers that are related to physical health risk that are associated with lonely older adults (Creswell et al., 2012; Hawkley & Cacioppo, 2010). Therefore in this study, we aimed to assess the effectiveness of Tai Chi and Zumba Gold® in improving factors known to affect QoL such as functional fitness, and physical function.

4.2.2 Motivation for exercise

As previously mentioned, levels of physical activity decrease with age (Sjors, Bonn, Trolle Lagerros, Sjolander, & Balter 2014). Most older adults have difficulty remaining physically active due to their health status, fear of falling or getting injured, lack of interest in exercise, lack of time, or that they have not enjoyed exercise in the past (Schutzer, Graves, & Ed, 2010; Tam-seto, Weir, & Dogra, 2016) (As previously introduced in section 1.1.8 of this thesis). Given these barriers to exercise, it is important to explore ways to support people to exercise. Several theories exist which predict the determinants of behaviour (change), and in this thesis the behaviour of interest is exercise. One such theory which provides a framework for behaviour change is Self-Determination Theory (SDT) (Deci & Ryan, 2002). According to SDT, high quality motivation is achieved when three basic psychological needs are met: autonomy, competence, and relatedness. High quality motivation is not only associated with starting and continuing to be physically active, but is also related to health benefits (Ng et al., 2012; Teixeira, Carraça, Markland, Silva, & Ryan, 2012; Yu et al., 2015).

SDT states that there are different types of motivation for exercise, which range from completely non-self-determined to completely self-determined regulation for exercise. When a person exercises because they enjoy the activity, this is called intrinsic regulation, and this is considered as the most self-determined and high quality motivation. People can also be extrinsically motivated to exercise. Integrated regulation reflects engagement with exercise because it fits with the person’s identity and values. Identified regulation reflects engagement with exercise because the person values the outcomes of the behaviour. Even though integrated and identified are extrinsic types of motivation, they are still self-determined and are therefore considered high quality types of motivation. A person can also be motivated to exercise because of internal pressures, such as feeling of guilt when not exercising. This is type of extrinsic motivation is called introjected regulation. When a person exercises due to pressures of others, such as peers or doctors, this is called external regulation. Introjected and external regulation are considered to be lower quality motivation, as they are less self-determined. Finally, amotivation reflects no motivation to exercise, and this is completely non-self-determined, and the lowest quality of motivation (Ryan & Deci, 2000). In sum, high quality motivation or self-determined motivation reflects that a person engages with a behaviour because they either value the activity or its outcomes, whereas lower quality motivation reflect more external reasons for exercising (e.g., feeling guilty when not exercising or being told by somebody else to exercise).

Given the research showing associations between quality of motivation and sustained engagement with exercise as well as health outcomes, the current study will also assess the quality of the motivation during the exercise intervention. Subsequently, associations between motivation and psychological wellbeing, as well as physiological effects of exercise will be examined. In addition, we were also assessed the participants' self-efficacy for overcoming barriers to exercise. This is important as, it will helps us indicates how much efforts that they will spend on doing the exercise, and how long they will preserve with the exercise intervention when they face any obstacle or barrier (Taylor-Piliae & Froelicher, 2004).

4.3 AIM AND OBJECTIVES

This chapter aims to assess the effects of exercise training (Tai Chi and Zumba Gold®) on physical function (upper and lower body flexibility, agility and balanced, lower body strength), physical fitness (aerobic endurance), measures of psychological wellbeing (anxiety, depression, fatigue, loneliness and sleep quality) and overall quality of life. Engagement and motivation to exercise were also assessed and their self-efficacy in doing exercise using the single measurement of Behavioural Regulation in Exercise Questionnaire (BREQ-2) and Self-efficacy in exercise (SEE) questionnaire.

4.4 RESEARCH DESIGN

The exercise interventions were described in detail in chapter 3. Figure 3.1 represents the study design of the 12 weeks of exercise intervention which includes the protocol and the timing of the assessments. Briefly, physical function, physical fitness, health-related QoL and measures of wellbeing (depression, anxiety, loneliness, fatigue, and sleep quality) were measured at baseline and post intervention. Single measurements of motivation and self-efficacy (BREQ-2 and SEE) were taken mid-exercise intervention.

4.4.1 Maximal oxygen consumption (VO_2 max)

Submaximal testing was assessed by incremental treadmill test until they reached their 75% of maximum heart rate, monitored by the heart rate signal from a polar HR transmitter that was placed on the participant's chest. Maximum heart rate was estimated using the equation from (Tanaka, Monahan, & Seals, 2001) specific formula for elderly; HR max= 208-0.7 x age.

Participants started walking on the treadmill (HP cosmos, Germany) at a slow pace of 1.5kph and was increased in 0.5kph every minutes until the participants reached 75% of their maximum heart rate. The time when their heart rate reached 55%, 65% and 75% were recorded, together with the Borg Exertions Scale every 2 minutes. A breath by breath measurement system (Oxycon Pro, Jaegar, Germany) was used to continuous measure oxygen uptake (VO_2) and Carbon dioxide production (VCO_2) each 5 seconds during the whole session. All analysers were calibrated according to the manufacturers guidelines prior to testing and all tests were supervised by the same researcher.

4.4.2 Physical Function Test

To test physical function, the validated Senior Fitness Test (SFT) battery was used, which is a set of tests to measure functional fitness in elderly populations (Jones & Rikli, 2002). We included 4 tests which measured lower body muscular strength (4.4.2.2a), lower body flexibility (4.4.2.2b) upper body flexibility (4.4.2.2c), and dynamic balance/agility (4.4.2.2d).

4.4.2.1 30 seconds chair stand

Participants were required to sit on a chair at a height of 17 inches with their feet flat on the floor, arms crossed with the wrists on the chest. Participants were asked to stand to full rise and return to fully seated posture repeated this procedure as many times as they could for 30 seconds. Participants were reminded to perform this testing using their own preferred speed and capability (Jones, J., Rikli, 2002).

4.4.2.2 Chair sit and reach

Participants were asked to sit on the front edge of a chair at a height of 17 inches with one leg extended forward and another leg bent, with their foot on the floor flexed at 90 degrees. During exhalation, participants placed their hands on top of each other and slowly bent forward to the extended leg and tried to reach the toes. Participants were instructed to stay static in that position while the researcher took the measurement from the tip of middle finger to the top of the shoes. This procedure was repeated with the other leg (Jones, J., Rikli, 2002)

4.4.2.3 Back scratch test

Participant were required to stand straight during this procedure, with one hand bending toward their back and were asked to try to reach down as far as they could. Meanwhile the other hand was placed at the position of the back with palm up, and participants were instructed to try to reach the other hand. The distance from both tips of middle finger was taken and the test was repeated using hands in the opposing positions (Jones, J., Rikli, 2002).

4.4.2.4 Timed up and go

Participants were required to walk a 3 meter walk way starting from a sitting position, and go back to the sitting position to end the test. The time was taken from the signal 'go' from the tester until the participant reached their sitting position again (Jones, J., Rikli, 2002).

4.4.3 Psychological wellbeing.

To assess quality of life, we compiled 5 validated questionnaires that measure self-rated health-related quality of life (SF-36 questionnaire) (Murray, Lefort, & Ribeiro, 1998; Walters et al., 2001), anxiety and depression (Hospital Anxiety and Depression Scale-HADS) (Zigmond, 1983), fatigue (Multidimensional Fatigue Inventory questionnaire-MFI) (Smets, Garssen, & Bonke, 1995), sleep quality (Pittsburgh Sleep questionnaire) (Buysse et al., 1989) and loneliness (Revised UCLA Loneliness Scale) (Russell, Peplau, & Cutrona, 1980).

4.4.3.1. SF-36

The SF-36 is a validated health-related quality of life questionnaire that consists of 36 items assessing 8 domains; general health perception, physical function, role limiting physical health, role limiting emotional problem, energy/vitality, emotional well-being, social functioning, and pain. Some of the items are; “In general, would you say your health is”, “Compared to one year ago, how would you rate your health in general now”, “How much bodily pain have you had during the past 4 weeks”. A composite score for each domain is derived, ranging from 0 to 100, with a higher score indicating a higher quality of life. The domains were then summarized into 2 different components which are the mental and physical components (Jenkinson, 1999).

4.4.3.2 Hospital Anxiety and Depression Scale (HADS)

The Hospital Anxiety and Depression Scale (HADS) is a validated self-assessment of anxiety and depression symptoms. This questionnaire consists of 14 questions, 7 for the anxiety subscale and 7 for the depression subscale. Items are scores on a range from 0 – 3. Items for anxiety include; “I get a sort of frightened feeling as if something awful is about to happened”, “Worrying thoughts go through my mind”, “ I get sudden feelings of panic” while some items for depression includes “I feel as if I am slowed down, “I have lost interest in my appearance”, and “I can enjoy a good book or radio or TV program”. A score of 11 to 21 in a subscale is classified as having anxiety or depression, 8 to 10 as borderline abnormal, and 0 to 7 as normal (Zigmond AS, 1983).

4.4.3.3 Multidimensional Fatigue Inventory questionnaire (MFI)

Fatigue was assessed using a validated Multidimensional Fatigue Inventory questionnaire (MFI) which consists of 20 questions on how participants’ have been feeling in the last 2 weeks. The MFI questionnaire consists 5 dimensions which are general fatigue (‘I feel fit’), physical fatigue (‘Physically I can take on a lot’), mental fatigue (‘I can concentrate well’), reduced motivation and reduced activity (‘I think I do a lot in a day’). Each dimension includes 4 statements and are answered based on 5 Likert scale with 1= yes, that's very true and 5= no, that's not true. A high score indicates higher fatigue (Smets et al., 1995). Subsequently, all scores were converted to percentage score out of a possible 20 for each subscale.

4.4.3.4 Pittsburgh Sleep questionnaire

The Pittsburgh sleep questionnaire is used to assess an individual sleep status in the past month. It consists of 18 items with 7 different components which are sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication and daytime dysfunction. The items include: 'During the past month, how many hours of actual sleep did you get at night', How often have you had trouble sleeping because you feel too cold', 'How often have you taken medicine to help you sleep', and 'How would you like to rate your sleep quality overall'. A total score of 5 and above indicates greater sleep disturbance (Buysse et al., 1989).

4.4.4.4 UCLA Loneliness Scale

Loneliness was measured using 20-item scale, drawn from the Revised UCLA Loneliness Scale (Russell et al., 1980). This self-report questionnaire includes items such as 'I feel in tune with people around me', 'I do not feel alone', 'I am an outgoing person' and 'There are people I can talk to'. This was rated on a four-point Likert scale from 1=never to 4= often. Total scores were calculated by summing all items and ranging between 20 to 80, and a higher score indicated a higher level of loneliness.

4.4.5a Behavioural Regulation in Exercise Questionnaire (BREQ-2)

Participants motivation to attend exercise training was measured using validated Behavioural Regulation Questionnaire (BREQ-2) which consists of 19 items (Markland & Tobin, 2004). Some of the items are; “I exercise because other people say I should”, “I feel guilty when I don’t exercise”, “I exercise because it’s fun” and participants answered using a 5 point Likert scale, where 0= not true for me, and 4= very true for me. The BREQ-2 questionnaire determined 5 types of motivation: amotivation (lack of motivation), external regulation (reward for doing exercise), introjected regulation (approval for doing exercise) and identified regulation (recognized value of activity), intrinsic regulation (self-enjoyment of going exercise). Subsequently, the motivation factors were classed into 2 major groups; controlled motivation factor (external regulation and introjected regulation) and autonomous motivation factor (identified regulation and intrinsic regulation) (Sebire, Standage, & Vansteenkiste, 2008). A reliability analysis using Cronbach’s alpha for BREQ-2 factors were 0.749 and 0.807 for Tai Chi and Zumba Gold® respectively.

4.4.5b Self-efficacy in Exercise Questionnaire

The participant’s confidence to complete the exercise program were measured using a 9 item Self-Efficacy for Exercise (SEE) scale (McAuley, 1993). For this study, SEE was modified by changing ‘’How confident are you right now that you could exercise 3 times per week for 20 minutes if..” to “How confident are you right now that you could complete this exercise program, 3 times per week for 60 minutes if…’’ “the weather was bothering you”, “you were bored by the program or activity”, you “felt pain when exercising’’, and answered based on a 10 point Likert scale between 0= not confident and 10= very confident. The score of the individual items was then added and ranged from 0 to 90. A higher score represented greater self-efficacy for exercise. Reliability analysis of the 9 items were measured using Cronbach's alpha, and scored 0.946 in Tai Chi group and 0.935 in Zumba Gold® group.

4.5 STATISTICAL ANALYSIS

Data management and analysis were performed using SPSS 24.0 statistical package for Windows (SPSS Inc. USA). Data was checked for normality using the Shapiro-Wilk's test. Baseline differences between the participants in the Tai Chi and participants in the Zumba® group were examined using an independent samples t-test for continuous data and chi-squared test for categorical data. The effects of the intervention were analysed using separate time (pre, post) by condition (Tai Chi and Zumba Gold®) repeated measures Analyses of Variance (ANOVAs). Where appropriate, post hoc analyses were conducted, using a separate repeated measure ANOVA for Tai Chi and Zumba Gold®. For the variables which were not normally distributed, ANOVA was not appropriate. Therefore, changes from pre- to post-intervention for these variables (SF-36, MFI, HADS, BREQ-2 and SEE) were analysed using non-parametric analysis of Wilcoxon signed-ranked analysis for the Tai Chi and Zumba Group separately. Significant levels were set at .05 for all analyses and presented as mean ± standard error, unless otherwise stated. The relationship between the changes of well-being with baseline well-being, baseline physiological data and baseline level of motivation and self-efficacy were conducted using Spearman Correlation.

4.6 RESULTS

4.6.1 Characteristics data

Table 4.1 describes the baseline characteristics of the physical function, physical fitness, and self-rated psychological parameters of QoL, fatigue, depression, anxiety, loneliness and sleep quality in the Tai Chi and Zumba Gold® training study. At pre-intervention baseline, there were no group differences in physical function, with the exception of lower body flexibility (Chair sit and reach test). Participants in the Zumba Gold® group had better lower body flexibility, $t(19)= -2.305$, $p=.033$). Participants in both groups were also similar with regards to psychological wellbeing. However, compared to Zumba Gold, participants in the Tai Chi group reported to be more lonely and fatigued (physical fatigue, reduced motivation and activity), but there was no significant difference in overall fatigue.

Table 4. 1: Baseline characteristics on physical function, physical fitness and QoL for Tai Chi and Zumba Gold® groups.

Parameters		Tai Chi	Zumba Gold®	p
Physical Function Test	Back scratch test (cm)	-7.5 ± 7.9	-3.0 ± 7.36	.190
	Chair sit and reach (cm)	-2.82 ± 8.3	6.4 ± 9.9	**.033**
	Timed up and go (seconds)	7.7 ± 1.6	6.9 ± 1.39	.234
	30 seconds chair stand (repetition)	13.5 ± 2.8	14.3 ± 5.2	.693
Physical Fitness	VO_2 max (ml/min/kg)	29.1 ± 8.6	26.6 ± 5.4	.449
Quality of life	Physical Functioning	95 (20)	87.5 (30)	.719
	Role functioning/physical	100 (0)	100 (56)	.54
	Role functioning/emotional	100(0)	100 (33)	.539
	Energy	65 (35)	72.5 (19)	.394
	Emotional well-being	84 (24)	82 (32)	.809
	Social functioning	100 (37.5)	100 (25)	.839
	Pain	90 (32.5)	78.7 (15)	.942
Multidimensional Fatigue Inventory	General Health	80 (15)	67.5 (16.3)	.198
	Physical Fatigue	50 (25)	30 (26.3)	**.026**
	Mental Fatigue	55 (25)	50 (15)	.474
	Reduced activity	45 (35)	27.5 (15)	**.021**
	Reduced motivation	50 (20)	25 (16.3)	**.007**
Hospital Anxiety And Depression Scale (HADS)	Anxiety	4 (7)	5.5 (7.25)	.776
	Depression	1 (5)	2 (5.25)	.914
UCLA Loneliness Scale		56.42 ± 16.48	25.0 ±22.93	**.005**
Pittsburgh Sleep Quality Index		5.3 ± 2.75	5.1 ± 3.35	.886

Results are expressed as mean ±SD for data that are normal, and median (IQR) for not normally distributed data (SF-36, MFI, HADS).

4.6.2 Physical Function

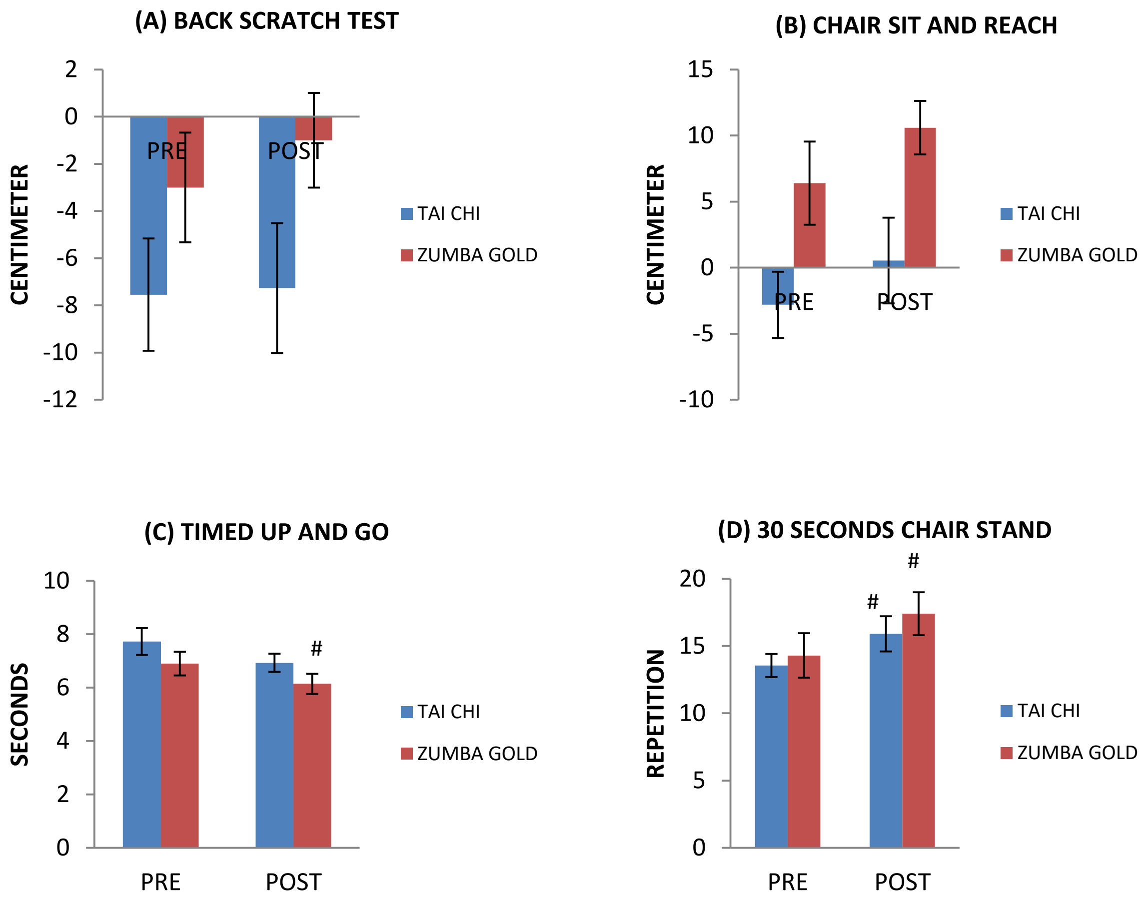

Figure 4. 1: Physical function measurements during pre and post intervention for Tai Chi and Zumba Gold® group.

Physical function measurements during pre and post intervention for Tai Chi and Zumba Gold® group. (A) Back scratch test (B) Chair sit and reach (C) Timed up and go (D) 30 seconds chair stand. Data are expressed as mean ± S # indicates significantly different compared to pre training.

Figure 4.1 shows the changes in functional fitness in both groups from baseline to post training session. (A) No significant time, group or time x group effect was observed for the back scratch test even though the graph showed an improvement on upper body flexibility at Zumba Gold® group post exercise. (B) There was an improvement on the lower body flexibility as been observed in 4.10B, with a significant time effect, $F_{(1,9)}$=5.166 p=.049, and group effect $F_{(1,9)}$ = 7.680 p=.022, but no time by group interaction effect (C) A significant time effect for timed up and go, $F_{(1,9)}$=8.118 p=.019 showed that participants in both groups completed the task faster. There were no group or group x time interaction effects. Further analysis revealed a significantly improvement in agility in Zumba Gold® group at post exercise as compared to pre training with p=.005. (D) There was an increasing in repetition time at the 30 seconds chair stand test at post exercise training in both groups. Repeated measured ANOVA found a significant time effect, $F_{(1,9)}$=20.103, p=.002, but no significant group or group x time interaction effect. Further analysis found a significant improvement in both group at post exercise with p=.021 at Tai Chi group and.001 at Zumba Gold® as compared to baseline.

4.6.3 Physical fitness

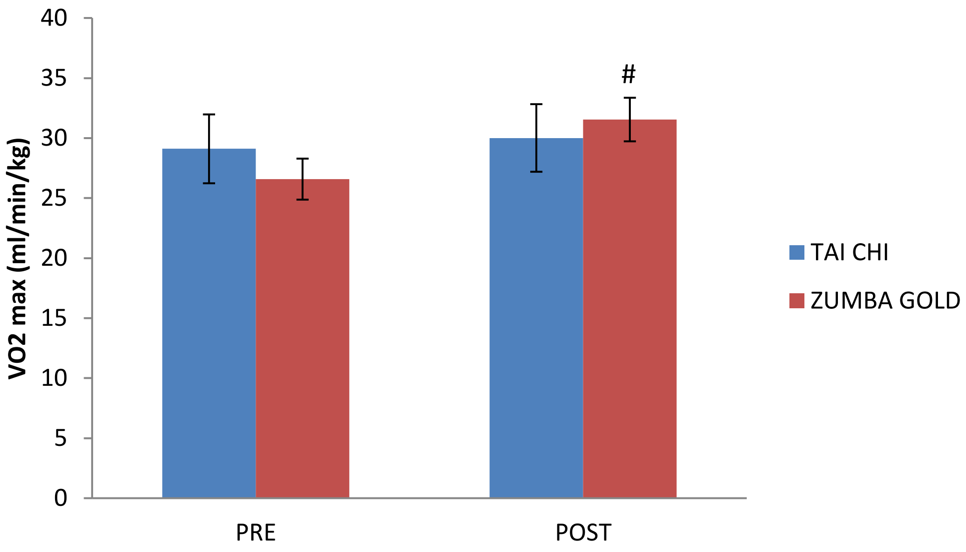

Figure 4. 2: VO_2 max at baseline and post training for Tai Chi and Zumba Gold® group.

Data are expressed as mean ± SE. # indicates significant different as compared to pre training.

Figure 4.2 demonstrate the physical fitness from baseline to post exercise interventions. Significant Time, $F_{(1,7)}=8.075$, $p=.025$, and group x time interaction, $F_{(1,7}=10.447$, $p=.014$) effects were found for fitness. Further analysis showed that physical fitness was improved in Zumba Gold® group with $p<.001$. However, there were no significant change in the Tai Chi group.

4.6.4 Quality of Life Questionnaire

4.6.4.1 SF-36

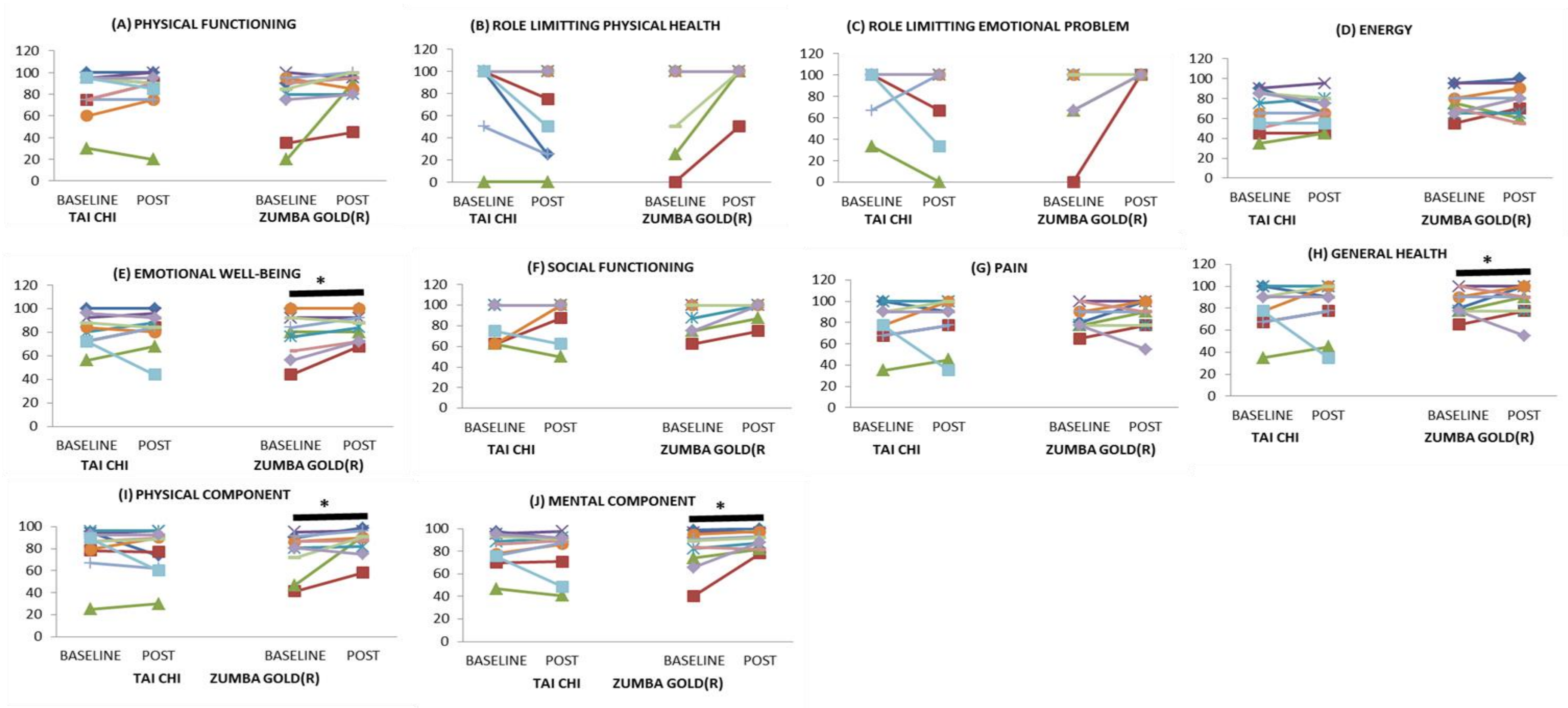

Figure 4. 3: Individual changes in each SF-36 domain at baseline and post intervention in Tai Chi and Zumba Gold® group.

Figure 4.3 describes the individual data of SF-36 domain and components (physical and mental) at baseline and post exercise in both Tai Chi and Zumba Gold® group. Given that data were not normally distributed, even after trying to transform the data, changes in SF-36 were explored using Wilcoxon signed-rank for the Zumba Gold® and Tai Chi group separately. Emotional wellbeing, general health, physical and mental component were found to be improved in the Zumba Gold® after the 12 weeks intervention. However, no significant changes were observed in Tai Chi group.

4.6.4.2 Multidimensional Fatigue Inventory (MFI)

Table 4.2 describes the changes of MFI at baseline and post exercise intervention in both groups. Data are not normally distributed and changes at post intervention were measured using Wilcoxon signed-rank test. Physical and mental fatigue subscales were found to be significantly improved in Tai Chi group. No significantly changes were observed in Zumba Gold® group.

Table 4. 2: Changes in MFI-20 subscales at baseline and post training in both exercise groups.

Data are expressed as median (IRQ)

	Tai Chi				Zumba Gold®			
	Baseline	Post	Changes	p	Baseline	Post	changes	p
General Fatigue	55 (15)	45 (25)	-7.7±21.5	.233	37.5 (31.3)	35 (36.25)	0	.89
Physical Fatigue	50 (25)	35 (20)	-13.2±17.7	**.032**	30 (26.3)	30 (15)	-6±8.4	.058
Reduced Activity	55 (25)	40 (30)	-11.4±22.6	.172	50 (15)	20 (15)	-4.5±10.4	.197
Reduced Motivation	45 (35)	35 (30)	-9.1±19.9	.261	27.5 (15)	22.5 (15)	-1.5±10.4	.606
Mental Fatigue	50 (20)	40 (10)	-8.2±10.3	**.036**	25 (16.3)	45 (12.5)	1.5±8.2	.726

4.6.4.3 Hospital Anxiety and Depression Scale (HADS)

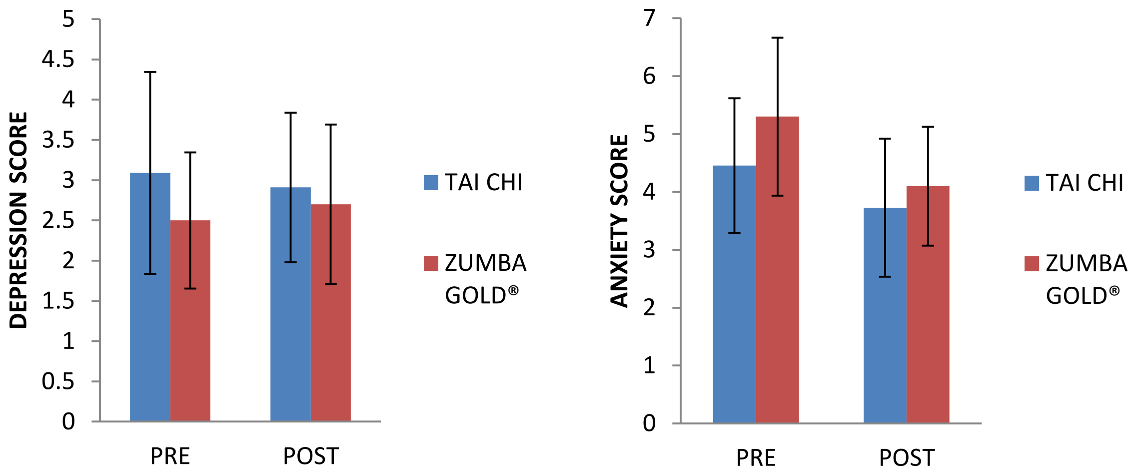

Figure 4. 4: Changes in depression and anxiety in the participants are presented at pre and post 3 months exercise training.

Data are expressed as mean ± SE

Figure 4.4 presents the changes in depression and anxiety scores measured at baseline and post exercise intervention. The Wilcoxon signed-rank test found no significant improvement in depression and anxiety scale among our participants at post 12 weeks of exercise intervention in either group.

4.6.4.4 UCLA Loneliness Scale

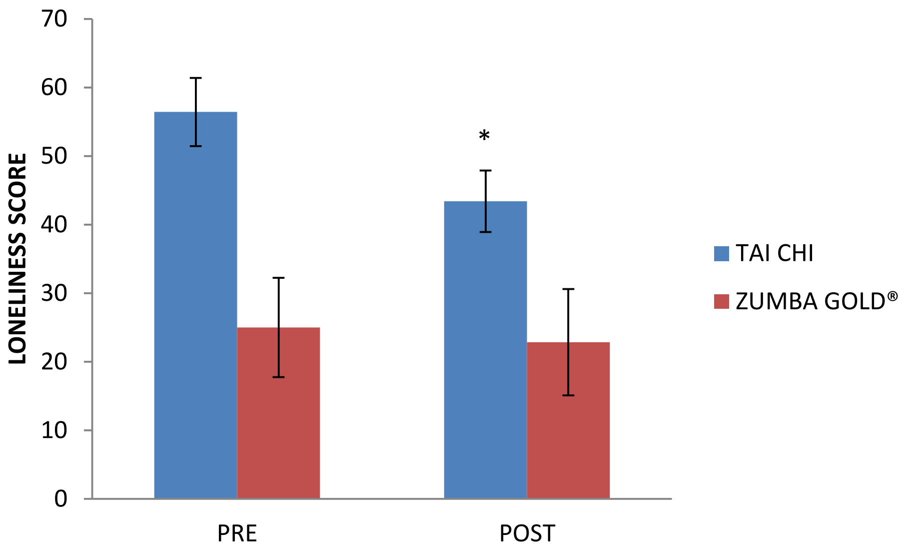

Figure 4. 5: The changes in loneliness scale throughout the 3 months exercise training in Tai Chi and Zumba Gold® group.

Data was expressed as mean± SE, with * indicate significant changes as compared to baseline.

Figure 4.5 depicts loneliness scale at baseline and post exercise intervention in the Tai Chi and Zumba Gold® groups. Loneliness was found to be significantly improved in Tai Chi group after the 12 weeks of exercise intervention using paired sample t-test. However, no significant difference was found in Zumba Gold® group.

4.6.4.5 Pittsburgh sleep quality index

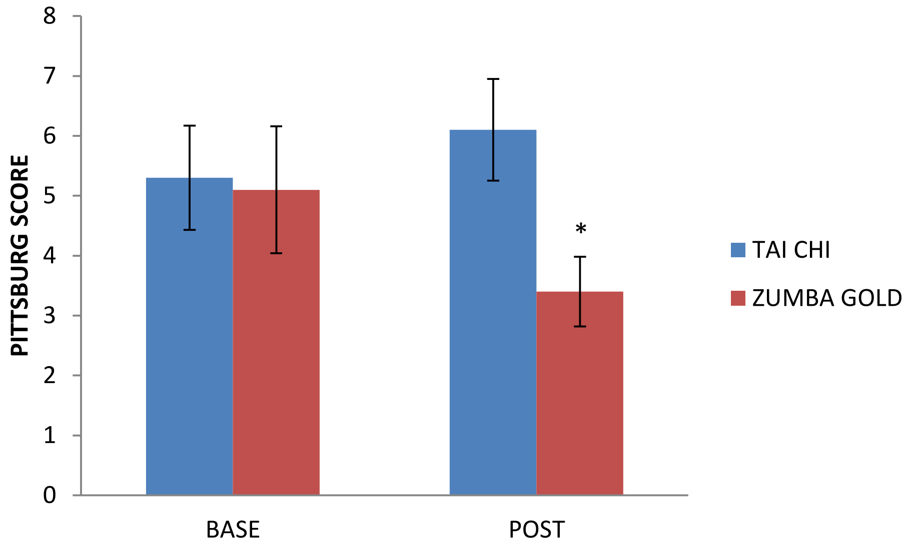

Figure 4. 6: Pittsburgh sleep quality index at baseline and post exercise training in both groups.

Data was expressed as mean ± SE. * indicates significantly different as compared to baseline.

Figure 4.6 shows sleep quality in both exercise groups before and after the intervention. A higher score of 5 and above represents lower sleep quality and thus conversely a lower score indicates a better sleep quality. Both exercise groups reported lower sleep quality at baseline (p=0.892 independent sample t-test). The effect of the exercise intervention on the sleep quality was measured using a 2 by 2 (group*time) repeated measure ANOVA and found type*time effect with $F_{1,9}$=15.625, p=0.031, but no type and time effect. Further analysis found a significant improvement of sleep quality after 12 weeks training only in Zumba Gold® group with p= 0.035.

4.6.5 Behavioural Regulation in exercise (BREQ-2) and Self-Efficacy in Exercise (SEE) questionnaire

Table 4.3 presents the score for the Behavioural regulation in exercise (BREQ-2) and the Self-efficacy in exercise (SEE) questionnaires in the Tai Chi ad Zumba Gold® groups during 6 weeks of exercise training. **BREQ-2;** measured the type of self-determination continuum, which ranges from amotivation to intrinsic regulation. Autonomous regulation is the highest self-determined motivation which combines identified and intrinsic regulation, while control motivation is the lowest self-determination, from external and introjected regulation. Both groups showed a high score in autonomous regulation of 6.5 (Tai Chi) and 6.8 (Zumba Gold®) which could suggest that their adherence towards the exercise training was driven by their own self-determined motivation. No significant difference was found in the autonomous regulation in either group after Wilcoxon signed-rank analysis. **SEE;** measured the confidence in being able to perform an exercise when confronted with specific barriers. Higher SEE scoring indicated a high level of self-efficacy and belief that individuals can perform the exercise training even with certain barriers. Zumba Gold® scored a higher SEE score with 76.3% compared to Tai Chi with 66.8%. However, there is no significant difference in the SEE score in either group after an independent t-test analysis.

Table 4. 3: Summary of the BREQ-2 and SEE score for both Tai Chi and Zumba Gold® group.

Data for BREQ-2 was reported as median (IQR), and SEE as mean ± SD.

	Subscale	Tai Chi	Zumba Gold®	p
Behavioural regulation in exercise (BREQ-2)	Amotivation	0.0 (.0)	0.0 (.0)	.809
	External Regulation	0.25 (1)	0.13(2)	.705
	Introjected Regulation	0.67 (1.7)	1 (1.33)	.654
	Identified Regulation	3.3 (1)	3.1 (.56)	.809
	Intrinsic Regulation	3.3 (.75)	3.6 (.88)	.468
	Control Motivation	1 (1.67)	1.5 (2.8)	.605
	Autonomous Regulation	6.5 (1.5)	6.8 (1.13)	.426
Self-efficacy in exercise (SEE)	Total SEE	60 ± 24.6	68.7 ± 14.6	.348

Table 4.4 below shows the relationship between Autonomous Regulation, SEE and fun (BREQ item 4) and enjoyable (BREQ item 10) using a Spearman correlation. There is a positive interaction between the self-efficacy and Autonomous Regulation with fun and enjoyable factors during exercise with *p<0.05 and **p<0.001. In general, exercise session that are enjoyable and fun can influence the motivation level of the participants to adhere in exercise training.

Table 4. 4: Spearman Correlation between autonomous regulation, SEE and factors that motivating our participants in doing exercise; fun and enjoyable.

	BREQ 4 (fun)	BREQ 10 (enjoyable)
Autonomous Regulation	.614**	.735**
Total SEE	.577**	.544**

*p<0.05, **p<0.001

4.6.6 Correlation between baseline levels of well-being and changes in well-being

Table 4.5 below shows the relationship between a participant's well-being at baseline and post training using a Spearman correlation. There is a negative correlation between the level of well-being at pre training vs post training for some of the parameters which are anxiety, physical fatigue, mental fatigue, sleep quality, and loneliness, *p<0.05 and **p<0.001. In general, those with a poorer level of well-being at baseline showed greater improvement after the exercise training.

Table 4. 5: Spearman Correlation between baseline level of well-being and the changes of well-being after 12 weeks of exercise intervention among participants.

	Baseline Depression	Baseline Anxiety	Baseline General Fatigue	Baseline Physical Fatigue	Baseline Mental Fatigue	Baseline Reduced Activity	Baseline Reduced Motivation	Baseline Sleep Quality	Baseline Loneliness	Baseline Mental Component	Baseline Physical Component
Changes	-.273	**-.547***	-.404	**-.682****	**-.718****	-.399	-.406	**-.464***	**-.519***	-.404	-.417

*p<0.05, **p<0.001

4.6.7 Correlation of baseline physiological data of VO_2 max, SBP, DBP, FMD, CRP and TNF-α with the changes of well-being

Table 4.6 below shows the correlation between the baseline level of VO_2 max, SBP, DBP, FMD, CRP and TNF-α with the changes in well-being in our participants after the 12 weeks of exercise training. There are two variables that show a potential relationship using Spearman correlational analysis. They are: baseline SBP with changes in sleep quality; and baseline FMD with changes in loneliness. This may indicate that an individual with higher baseline SBP may show a greater improvement in sleep quality, and a participant with poorer FMD at baseline may see a greater reduction in the level of loneliness. However, there is no association between other physiological parameters and the changes in well-being.

Table 4. 6: Spearman Correlation between baseline levels of physiological parameters of VO2 max, SBP, DBP, FMD, CRP and TNF-α and changes of well-being after 12 weeks of exercise intervention among participants.

	Changes Depression	Changes Anxiety	Changes General Fatigue	Changes Physical Fatigue	Changes Mental Fatigue	Changes Reduced Activity	Changes Reduced Motivation	Changes Sleep Quality	Changes Loneliness	Changes Mental Component	Changes Physical Component
Baseline VO_2max	.039	.219	-.041	.038	.149	.39	.291	.229	.226	-.345	-.063
Baseline SBP	-.007	.124	.120	.134	-.040	.285	-.044	**-.505***	-.075	.141	.266
Baseline DBP	.102	-.018	0.105	-.009	.017	.168	.106	-.096	.008	-.233	-.074
Baseline FMD	-.146	-.307	-.073	-.104	-.357	-.412	-.358	.03	**-.0587***	.142	-.112
Baseline CRP	-.281	-.196	.190	.205	-.069	.403	-.129	.05	-.244	.168	.005
Baseline TNF-α	.488	-.022	.138	-.148	.046	-.131	.044	-.224	-.053	.249	-.005

*p<0.05

4.6.8 Correlation between baseline levels of motivation, self-efficacy and changes in well-being

Table 4.7 below shows the relationship between the participant's level of motivation (amotivation, external regulation, introjected regulation, identified regulation, intrinsic regulation, control and autonomous motivation) and self-efficacy in doing exercise with changes in well-being at post training using Spearman correlational analyses. There is a relationship between level of intrinsic regulation and autonomous motivation with the changes in physical fatigue among our participants, and a positive relationship between self-efficacy for exercise and changes in the physical component. In general, high motivation to exercise and self-efficacy among participants were related to improvement in physical component and fatigue after the 12 weeks of exercise training. However, no correlation was found between the level of motivation and self-efficacy with changes in other markers of well-being.

Table 4. 7: Correlation between baseline levels of motivation, self-efficacy and changes in well-being.

	Changes Depression	Changes Anxiety	Changes General Fatigue	Changes Physical Fatigue	Changes Mental Fatigue	Changes Reduced Activity	Changes Reduced Motivation	Changes Sleep Quality	Changes Loneliness	Changes Mental Component	Changes Physical Component
Amotivation	-.233	-.255	.188	.384	-.273	.082	-.317	.070	-.219	-.115	.097
External Regulation	.04	-.149	.232	-.118	-.203	-.202	-.08	-.335	-.138	.501	.327
Introjected Regulation	-.160	-.374	.421	.229	.084	.36	-.125	-.290	-.155	.154	.335
Identified Regulation	-.079	.026	-.268	.259	-.283	.073	.210	-.129	-.123	.087	.208
Intrinsic Regulation	.075	-.186	.410	**.499***	-.072	.349	.018	-.133	-.280	-.096	.214
Control	-.113	-.332	.399	.072	-.16	.15	-.138	-.274	-.158	.38	.399
Autonomous	-.027	-.151	.009	**.454***	-.229	.208	.014	-.134	-.322	.042	.236
SEE	.162	.153	.238	.131	-.124	.111	.284	-.219	-.009	.087	**.5***

P<0.05

4.7 DISCUSSION

The findings presented in this chapter provide evidence to suggest that the benefits of exercise reach beyond vascular health to have the capability to improve functional fitness and psychological wellbeing in an ageing population. Early detection of a decline in physical function can help reduce the severity of frailty and detect any impairment in mobility (Clegg, Young, Iliffe, Rikkert, & Rockwood, 2013; Mulero & Zafrilla, 2011). Having a good functional fitness can support the independence of older adults as it will impact upon an individuals' ability to do their own daily activities (Millor, Lecumberri, Gómez, Martínez-ramírez, & Izquierdo, 2013). In addition, a reduction in functional fitness may not only lead to a loss of independence, but can also reduce quality of life and psychological well-being.

In this study, the risk of falling was reduced in both groups after the 12 week exercise programme, as demonstrated by the timed up and go test. This assessment of balance and agility showed improvement in both groups post exercise intervention. However, the improvement was only statistically significant in the Zumba Gold® group ($p=.001$), but there was a trend towards improvement for the Tai Chi group ($p=.06$). According to Jones and Rikli (2002), having an improvement in agility and balance in later life may not only reduce the risk of fall, but could also help in an individuals' ability to perform activities of daily living especially tasks that involve quick manoeuvring, for example attending someone at the front door, getting up to answer the phone or standing up from a chair to go to the bathroom.

Other parameters that are used to predict frailty and fall risk in older adults are assessment of lower body strength and endurance using the 30 second chair stand (Fabre, Ellis, Kosma, & Wood, 2010; Okamoto et al., 2010). This test measures an individual's ability to independently get out of a chair or bath tub, or to climb a few flights of stairs. The data from the current study shows 12 weeks of Tai Chi ($p=.001$) or Zumba Gold® ($p=.021$)

significantly improved lower body strength and endurance in participants compared to pre training. Based on these two outcome measures (timed up and go and 30 seconds chair stand), the 12 weeks of Tai Chi and Zumba Gold® both demonstrate reliable and effective exercise interventions in reducing the risk of frailty and decreasing the risk of falls in older age adults. The results presented here are in line with other studies that report similar outcomes of improving balance, leg strength and endurance following Tai Chi exercise in older adults regardless their health status (Carbonell-Baeza et al., 2011; Manor et al., 2014; Xiao & Zhuang, 2015; Yao, Foley, Kolanowski, & Smith, 2014). Even though there is no reported evidence on the effect of Zumba Gold® specifically in reducing fall risk in older adults, there is evidence available on the effect of dance or dance based exercised in improving balance and agility in older adults (Abreu & Hartley, 2013; Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009; Mckinley et al., 2008; Shigematsu, Chang, & Yabushita, 2002).

According to Yao et al. (2014), Tai Chi is able to improve balance and lower body strength due to the nature of the exercise itself. In Tai Chi, the practitioner will master a balance standing position before continuing to the other movements. This standing position is often called 'feel the ground' and the practitioner will try to balance their weight using both feet. This double leg standing is done with the knees bent depending on an individual's capability, which helps in whole body balance. At this stage, most of the lower body muscles are to support whole body weight which then results in strengthening of the lower limbs. Once the practitioners are comfortable with this balancing posture, the next step, which also involves body balancing, involves a weight shifting movement from double leg standing to one leg standing and includes circular hand movement and rotation. Moving body weight from both legs to a single leg theoretically enhances the use of lower body muscles and improves balance especially during the weight shifting.

In addition, the improvement in body balance and leg strength in Zumba Gold® may be due to the dance steps during the session. As described in chapter 1.1.9.3, Zumba Gold® consists of the combination of Latin dances such as Merengue, Salsa, Cumbia and Reggaeton (Domene, Moir, Pummell, & Easton, 2016). Those dances involve major lower body movement especially in Merengue and Salsa consisting of continuous side to side movements. Whereas, Reggaeton involves mainly hand movements which may contribute to the improvement in upper body flexibility.

In addition to these assessments of balance and agility, the participants in both exercise groups showed an improvement in both upper and lower body flexibility, although the changes did not reach statistical significance. This may be due to the participants' physical function level being scored as 'normal' prior starting the exercise intervention, with 'better' upper and lower body flexibility among the Zumba Gold® group after adjusting for aged and gender respectively (Jones & Rikli, 2002).

Figure 4.1 shows there was a significant time and group effect ($p=.014$) for physical function, and further analysis found that physical function was significantly increased in the Zumba Gold® group after the exercise programme. The increase in physical fitness post Zumba Gold® intervention is in agreement with that reported by previous Zumba® studies (Delextrat, Warner, Graham, & Neupert, 2016; Domene, Moir, Pummell, Knox, & Easton, 2016; Krishnan et al., 2015). Even though the Zumba Gold® may be perceived as moderate intensity and less vigorous as compared to regular Zumba®, the intervention was still sufficient to increase physical fitness after the 12 weeks of intervention in this group of participants. According to a meta-analysis from Huang, Gibson, and Zung, (2005), a significant and greater increase in VO_2 max among elderly but sedentary individuals were associated with a longer period of exercise intervention namely after 16 weeks, with 16.3%

improvement. Based on our data, Zumba Gold® was significantly increased aerobic fitness by 4.9mL/min/kg or 18.7% of improvement at post training. This showed that, Zumba Gold® are able to increased cardiorespiratory fitness similar to other moderate intensity aerobic exercise, with a greater improvement at shorter exercise training period. Such improvement is important as, elderly population experienced reduction of 30-40% of aerobic capacity as compared to young population which contributes to higher independency, abnormal metabolic profile, high blood pressure and deregulation of autonomic function which reduced quality of life (Sousa, Mendes, Abrantes, Sampaio, & Oliveira, 2014)

However, similar improvements in physical fitness were not seen following Tai Chi. Some previous studies show Tai Chi can stimulate in increase in VO_2 max (Wu & Yeh, 2017) although other studies report no change (Lan, Lai, Chen, & Wong, 1998; Suksom et al., 2011). A lack of improvement in physical fitness may be due to the main training objectives employed in this study, which encouraged our participants to master the balance standing position, and proper breathing technique before proceeding to the actual Tai Chi movements and steps. Less experienced Tai Chi practitioners have a tendency to just follow the movements made by the instructor whereas more experienced practitioners will perform Tai Chi energetically (Xiong, He, & Ni, 2011).

It has been widely reported that high levels of physical activity among ageing populations are associated with better quality of life (Lok, Lok, & Canbaz, 2017; Mura, Sancassiani, Migliaccio, Collu, & Carta, 2014; Phoemsapthawee et al., 2017; Vasiliadis & Bélanger, 2018). Emotional well-being, general health, as well as the composite score of physical and psychological quality of life were found to be improved after the intervention in the Zumba Gold® group, but no such changes were found in the Tai Chi group. The beneficial effects of Zumba Gold® on quality of life are in line with previous work in among obesity participants (Cugusi et al., 2016; Domene, Moir, Pummell, Knox, et al., 2016) and low back pain patients (Notarnicola et al., 2015). The findings regarding Tai Chi are somewhat surprising, given that Tai Chi has been reported to improve quality of life in older adults (Nguyen & Kruse, 2012; Taylor-Piliae et al., 2014; Wang et al., 2016), diabetic patients (Ahn & Song, 2012; Lam, Dennis, Diamond, & Zwar, 2008) and kidney disease patients (Chang, Koo, Wu, & Chen, 2017). A possible explanation for these differences is that the self-reported quality of life in the participants of the current study was already high before starting Tai Chi, with scores of 6 out of 8 domains reported to be higher than 80. Therefore, it is possible that there was limited room for improvement. Support for this comes from correlational analyses (table 4.5) which showed that associations between baseline scores and changes following exercise, which revealed that those with lower baseline score, had greater improvements. However, this will need to be confirmed in a larger group of participants.

Participants in the Tai Chi group showed a significant reduction in physical and mental fatigue, and in the Zumba Gold® group, only the change in physical fatigue was borderline significant ($p=.058$). These findings are somewhat in line with previous work, where both a reduction in fatigue (Buffart et al., 2013; Dalgas et al., 2010; Witlox et al., 2018) as well as no changes in fatigue (Hägglund, Boman, & Brännström, 2018) following exercise have been reported. A potential explanation for the differences found between Tai Chi and Zumba Gold® are the baseline differences in fatigue between the groups. Those in the Tai Chi group reported higher levels of fatigue compared to those in the Zumba Gold® group. Another explanation for these findings is that the nature of Tai Chi exercise could have induced increases in calmness. However, both these explanations are speculative and will need to be explored in a larger sample of participants

In the current study, no effects of either Tai Chi or Zumba Gold® were found on depression or anxiety. This is in contrast with a systematic review which showed improvements in mental health measures, such as stress, depression, anxiety, mood disturbance and increasing self-esteem following Tai Chi (Wang et al.,2010). To our knowledge, no studies have explored the effects of Zumba Gold® on wellbeing, but dance movement therapy has shown inconsistent findings on depression (Meekums, Karkou, & Nelson, 2015; Pylvänäinen, Muotka, & Lappalainen, 2015). The inconsistency in the findings in previous studies, as well as the lack of improvements in our own study could be due to the inclusion criteria of the participants. Whereas some studies have specifically examined people with poorer mental health, the current study included healthy participants, and their levels of anxiety and depression were below 7 which is considered to be not depressed or anxious (Stern, 2014).

A systematic review has shown improvements in loneliness following exercise (Pels & Kleinert, 2016). It has been suggested that, such improvement is caused by several factors. First, the social relationship and connection that occurs during activities, builds the self-esteem of the participants and may offer emotional support (Lubans et al., 2016). Second, Lubans (2016) also suggested that PA and exercise affect neurobiological activity by increasing serotonin, monoamine and reducing the stress hormone cortisol, which can give a feel-good effect after exercise, thus contributing to increased happiness and perhaps reducing feelings of loneliness. Third, the involvement of older adults in PA may give them perspective and generate life purpose, which can also lower the feeling of being lonely (Rowe & Kahn, 1997).

The current study used the self-rated Pittsburgh Sleep Quality Index questionnaire (PSQI) to determine the sleep quality at baseline and post exercise intervention in the participants. At baseline, both exercise groups scored more than 5, which indicates poor sleep quality. Sleep quality improved following Zumba Gold®, but no changes were seen following Tai Chi. Benefits of exercise on sleep quality have been reported before in older adults (Bonardi et al., 2016; Brandão et al., 2018; Reid et al., 2010). Several mechanism have been proposed to explain the relationship between exercise and an improvement in sleep quality, which include reduction in inflammatory cytokine (IL-6, TNF-α) and increase in energy expenditure during the day, but based on our results, there was no correlation between changes in sleep quality and baseline of inflammatory cytokines as shown in table 4.6 (Varrasse, Li, & Gooneratne, 2015). However, the differences in sleep quality improvement between the Zumba Gold® and Tai Chi groups could be due to the higher energy expenditure during the Zumba Gold® exercise session. Based on the reported data from Dalleck, Roos, Byrd, and Weatherwax, (2015), one session of Zumba Gold® exercise can exceed 197.9 kcal/session as compared to Tai Chi with 60 kcal/session (Smith, Wherry, Larkey, Ainsworth, & Swan, 2015). Regarding Tai Chi, in contrast to our findings, improvements in the sleep quality have been reported in older adults (Carroll et al., 2015; Irwin, Olmstead, & Motivala, 2008; Lo & Lee, 2010; Nguyen & Kruse, 2012). As previously suggested, the success of Tai Chi is heavily dependent on the experience of the practitioner. Thus, a potential reason for the lack of changes in sleep quality could be related to lower energy expenditure in less experienced Tai Chi practitioners, as the intensity or effort in doing Tai Chi is reported to vary based on the experience of the individual. However, without having information regarding energy expenditure in all sessions, this remains speculation.

Based on our results, participants in the Tai Chi group improved their levels of loneliness following the interventions, which was not evident in participants in the Zumba

Gold® group. To our knowledge, our findings are in line with the only study that was undertaken in Tai Chi by Park and Park (2010), who are the first to explore the effects of Zumba Gold®. It is likely that the group-based aspect of the intervention can reduce the levels of loneliness, however, it has been suggested that these benefits depend on the quality of the relationship during the exercise session. Thus, the difference findings between the Tai Chi and the Zumba Gold® group could be due to different perceptions of the relationships between participants in the different groups. It is also important to note that baseline loneliness was higher in Tai Chi group compared to the Zumba group. Given that the reduction in loneliness was greater in those with higher levels of loneliness, this could be another explanation for the differences between groups.

Based on the above findings, adhering to physical activity may not only be beneficial to older adults for their physical health, but also for their mental health. Unfortunately, research has reported that not all older adults feel motivated to exercise and face barriers to engage in physical activity (Moschny, Platen, Klaaßen-Mielke, Trampisch, & Hinrichs, 2011; Osorio, Raygoza, & Paloalto, 2013; Schutzer et al., 2010). Time is one of the main factors that contribute to discouraging the ageing population to engage with an exercise programme. In this study for example, a withdrawal rate of 40% was recorded due to time commitments, which consisted of 14 participants out of 35 that withdrew from the study. The frequency of the exercise sessions (3 times per week) was stated as too much for 12 participants. This is in line with a review paper by Chao, Foy, and Farmer (2000), that suggested older adults have difficulty in adhering to exercise due to time commitment which includes time to do the session, and time required to travel especially those who rely on public transport.

In summary, both Tai Chi and Zumba Gold® have the capability to reduce the risk of falls in older age adults by improving their lower body strength and balance. Some aspects of mental health also improved in older adults in both the Tai Chi and Zumba Gold groups, but these specific outcomes were different between groups. For example loneliness improved in the Tai Chi group and sleep quality improved in the Zumba Gold® group.

In order to achieve these benefits, it is important that older adults integrate regular exercise sessions into their lifestyle. The average level of self-efficacy was high in both groups, as were levels of autonomous motivation, and the levels of controlled motivation were low, suggesting that the quality of motivation was high in these participants. Together, this data indicates that the participants felt confident in being able to complete the programme and were intrinsically motivated to complete the programme. Future research in a larger participant sample should investigate if these factors are related to the achieved benefits of the exercise programmes.

The findings of this study suggested that, lack of enjoyment and fun during the session could be a barrier that may affect the adherence to continue to exercise. Table 4.4 showed that there is a positive correlation between high SEE score and autonomous regulation with BREQ item 4 and 10 for fun and enjoyment in doing exercise. This is supported by Eyigor, Karapolat, Durmaz, Ibisoglu, and Cakir (2009), that emphasize the mode and enjoyability of an exercise session is a main factor in encouraging older adults to participate in regular exercise. However, the term 'enjoyable' can be very subjective to an individual. Thus, exercise preference appears to be very specific to an individual, suggesting choice of exercise mode is of upmost importance. According to Nieri and Hughes (2016), participants choose Zumba® because they love music and dancing, and other exercise forms are boring as they are described by some as repetitive and monotonous. On the other hand, some Tai Chi practitioners describe Tai Chi as enjoyable due to the calmness, and its meditative effect, that it is easy to follow, and low-impact based on its slow movements (Yao et al., 2014). Thus, exercise preference appears to be very specific to an individual, suggesting choice is of upmost importance.

The results suggest that both Zumba and Tai Chi can elicit beneficial effects for older adults, thereby offering the choice of two quite different modes of exercise in maintaining or improving health in older age.

4.8 REFERENCE LIST FOR CHAPTER FOUR

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CHAPTER 5

DISCUSSION

5.1 GENERAL DISCUSSION

The aim of this thesis was to explore the effects of feasible and acceptable exercise modes on physiological and psychological health in older age adults. Primarily the studies were designed to assess the potential for Tai Chi to improve vascular health, but a comprehensive panel of secondary outcomes were assessed and Tai Chi was compared to Zumba Gold® in order to investigate potential differences as a result of different intensity of exercise. Adhering to an exercise programme is known to be beneficial for health for all ages, but arguably is most beneficial to ageing populations. Unfortunately, as age increases the percentage of older adults that meet physical activity recommendations decrease (Centers for Disease Control and Prevention, 2018). It has been widely reported that low physical activity in this age group can increase the prevalence of cardiovascular diseases (Sallam, Laher, Sallam, & Laher, 2016), reduce the ability of an individual to manage tasks of daily life due to decreasing physical function and fitness (Chou, Hwang, & Wu, 2012), reduce an individuals' QoL (Pernambuco, Gao, & Li, 2012) and further contribute to mental health problems, such as anxiety, depression and loneliness (Garfield, Llewellyn, & Kumari, 2016).

The most common barriers to exercise reported by older age adults are lack of interest/motivation, lack of time and fear of injury or falls (Moschny, Platen, Klaaßen-Mielke, Trampisch, & Hinrichs, 2011). Therefore in this thesis, an intervention was designed using exercise that might be appealing to older age adults, that is safe for this age group and that is undertaken as a group with an instructor. These elements were considered important to achieve a successful intervention, for example, using a trainer led group setting can motivate participants compared to an individual exercise programme (attending gym, home-based exercise) (Ntoumanis, Thøgersen-Ntoumani, Quested, & Hancox, 2017). We selected two exercise modes that are perceived as safe and suitable for older age adults, Tai Chi (Schaller,

1996) and Zumba Gold® (Dalleck, Roos, Byrd, Weatherwax, & Green, 2017). To date, less is known about Tai Chi and although Zumba Gold® has not been well characterised, it is similar to other forms of aerobic exercise. Therefore, we designed an exercise intervention using Tai Chi and Zumba Gold® in older age adult participants to assess changes in endothelial function, physical function and fitness, QoL and mental health (depression, anxiety, and loneliness).

5.2 ACUTE TAI CHI EXERCISE

Chapter 2 presents a study to investigate the effect of a single bout of Tai Chi. It is widely accepted that exercise elicits its beneficial effects via the response to an acute session, which behaves as a mild physiological stress. During exercise, muscle contraction causes an increase in metabolic demand which is accompanied by vasodilation to raise the blood flow to the working muscle tissue (Padilla et al., 2011). This increase in blood flow is believed to increase sheer stress in the vasculature and if repeated this can further cause endothelial adaptation to exercise training (Padilla et al., 2011). In addition, during an acute bout of exercise, the increased metabolic demand causes an increase in RONS and inflammatory cytokines which can stimulate increased expression of antioxidant enzymes (Radak, Chung, & Goto, 2005). Research has shown that this adaptation response will gradually increase if the exercise is repeated and the stimulus continues to challenge the basal state (Fisher-Wellman & Bloomer, 2009).

To date, the study presented in chapter 2 is the first reported to assess the effect of a single Tai Chi session in sedentary old and young participants. The data presented suggests that Tai Chi is a low to moderate intensity exercise, which is in line with other reported data (Lan, Chen, & Lai, 2004; Lan, Chen, Wong, & Lai, 2013; Li, Hong, Chan, & Max, 2001). Both old and young participants heart rate reached a max of 104bpm during the session, which corresponded to 52.6% (young) and 66.4% (old) predicted maximum heart rate. Transient changes were observed in some of the oxidative stress and inflammatory markers (MDA, IL-6 and IL-10) and there was an improvement in FMD post Tai Chi session. These findings suggest that, even though Tai Chi is considered as a slow and less intense form of exercise, it appears capable of inducing transient increases in ROS as measured by lipid oxidation, and increasing in inflammatory cytokines (IL-6 and IL-10), and thus is capable of acting as a mild physiological stress.

5.3 TRAINING STUDY

The training study presented in chapters 3 and 4 assessed the effects of 12 weeks of Tai Chi and Zumba Gold® in older adults. A number of physiological and psychological outcomes were investigated including endothelial dysfunction, physical function and fitness, QoL and mental health (depression, anxiety and loneliness). Ageing is characterised by a decrease in biological function (Veronica, Esther, Nacional, & Ignacio, 2012) that is associated with an increased risk of cardiovascular diseases (Seals, Jablonski, & Donato, 2011), decrease in physical function (Milanović et al., 2013; Vermeulen, Neyens, Van Rossum, Spreeuwenberg, & De Witte, 2011) and poorer QoL (Hacihasanoĝlu, Yildirim, & Karakurt, 2012; Hsu et al., 2014).

As introduced in chapter 1.1.5, a main cause of cardiovascular disease is the impairment of endothelial function, and key factors which may contribute to this are the presence of free radicals during oxidative stress and inflammation. The study presented in chapters 3 and 4 showed that both of the modes of exercise that were tested have the capability to improve vascular function, as shown by the reported increase in FMD percentage. This data is coupled with a reduction in markers of oxidative stress and inflammatory cytokines (8-isoprostane, protein carbonyl and CRP), and a non-significant increase in TAC in both groups. These findings suggest that Tai Chi and Zumba Gold® are both capable of reducing age-related increases in oxidative stress and inflammation.

In addition, older age adults commonly see a reduction in physical function and fitness which can not only cause a loss in independence, but can also contribute to increasing incidence of falls. A high risk of falls has been reported to be due to poor balance and reduced muscle strength and endurance (Wilson, Jackson, Sapey, & Lord, 2017), but exercise can improve both balance and muscle strength. In the present study, two functional measures of balance and strength were assessed: timed up and go test and 30 seconds chair stand. Participants in the Zumba Gold® group showed a significant improvement in these measures after 12 weeks. Looking at the nature of Zumba Gold® routines, this is not surprising given dance routines such as Merengue and Salsa, which involve lower limb muscle movement. For participants in the Tai Chi group, improvements in these assessments were also seen, but these were only statistically significant for leg strength and movement. Even though Tai Chi involves less intense lower limb movement compared to Zumba Gold®, the improvements in the Tai Chi group are likely to be due to the 'feel the ground' philosophy in Tai Chi. Feel the ground is the basic concept of standing with your knees slightly bent, and channelling all your weight equally through both legs, which helps the development of balance and muscle strength, especially calf muscles. Both groups improved upper and lower body flexibility, and in the Zumba Gold® group only, physical fitness was improved. Together these improvements in balance, muscle strength, flexibility and fitness all contribute to enhanced functional ability to be able to conduct everyday tasks in life.

Given the objectively assessed improvements reported herein, it is not surprising that improvements were also found in self-reported QoL, albeit not all changes were statistically significant. Feelings of loneliness were lower following Tai Chi, and this could be due to the social interaction and connection during the 12 weeks of Tai Chi group sessions. However, care should be taken when interpreting these findings given the differences at baseline between the two groups. No changes in depression and anxiety were found following either Tai Chi or Zumba Gold®. It should be acknowledged that the participants in this study had relatively high levels of wellbeing and the lack of changes could, therefore be due to a ceiling effect. To test this, the effects of Tai Chi and Zumba Gold® in older adults with poorer wellbeing should be investigated.

In order to achieve health benefits from an exercise programme, it is important to exercise at the prescribed frequency and intensity. Several factors can influence adherence to an exercise programme and to the maintenance of exercise after an intervention has ended. In the current study, participants were found to have high levels of autonomous motivation, and relatively high levels of self-efficacy. Together, this will have not only helped attendance to the exercise sessions, but this can also have facilitated the continuation of exercise at the end of the programme. It should be noted though that there were individual differences in self-efficacy for exercise. From personal observations and discussions with participants, it was clear that some participants enjoyed the slow and graceful movements of Tai Chi, whereas others enjoyed the dancing routine in Zumba Gold®. Therefore, the enjoyment and fun elements of an exercise mode are important in determining the successful rate of adhering to any exercise programme, especially in this group of older adults (Sjors, Bonn, Trolle Lagerros, Sjolander, & Balter, 2014). This also suggests that it is good to provide choice for people regarding the type of exercise that they can do.

5.4 LIMITATIONS AND DIRECTION FOR FUTURE STUDY

Several limitations in this study need to be acknowledged. Firstly a control (no exercise) group was not included in the training study presented in chapters 3 and 4. A control group or social interaction group could have been implemented to meet 3 times a week, mimicking the exercise commitment, but as a no exercise intervention. This would have allowed assessment of the social interaction alone on outcomes such as loneliness, anxiety and depression. However, there are many reports about the value of social interaction on these outcomes in older adults (Segel-Karpas, Ayalon, & Lachman, 2018; Tiikkainen & Heikkinen, 2005). A control group was planned, but following difficulty in recruiting participants to this study it was not included due to time constraints. Zumba Gold® was used as an exercise control, in the sense that it could be considered an aerobic form of exercise, and the benefits of aerobic exercise have been very well characterised in older age adults. As such, Tai Chi was assessed in comparison to aerobic exercise.

Although FMD is a technique which measures the functional effects of a change in NO bioavailability, NO was not measured in the studies presented. The methodologies available to assess NO robustly are not appropriate for the kinds of studies presented here, as NO is so transient in nature. Further, the measurement of the metabolites of NO, namely nitrite and nitrate, do not give sufficient insight into the bioavailability of NO to draw valid conclusions. Thus FMD was employed as a meaningful methodology representing the a functional measure of NO bioavailability. Further studies in non-human models may offer insight into factors affecting NO bioavailability, such as measuring eNOS expression and the presence of substrate and co-factor which may link to the markers of inflammation and oxidative stress.

Finally, future work could be undertaken to assess changes in muscle mass between baseline and post exercise intervention to better understand the underlying cause of improvement in leg strength and endurance after the exercise programme.

5.5 CONCLUDING REMARKS

Older age adults are at higher risk of cardiovascular diseases. This is contributed to by increased oxidative stress and vascular inflammation which can lead to endothelial dysfunction. This age group are also at risk of not being able to undertake their daily activities and are at heightened risk of falling due to a reduction in physical function and fitness. Exercise can have a beneficial effect on vascular health and physical function and fitness, by minimizing the accumulation of oxidative stress and inflammation associated with ageing. Physical activity can also minimize the risk of falls and improve independence in daily living. The research in this thesis supports the current evidence that adhering to exercise can improve vascular health, improve physical function and aspects of mental health.

The key strengths of this thesis that add to novelty in the ageing research include;

1. Tai Chi can provoke transient oxidative stress and inflammation after an acute one hour session in sedentary young and old participants, which appears similar to other moderate intensity exercise modes.
2. Twelve weeks of Tai Chi and Zumba Gold® improved markers of physiological and psychological health in older age adults
3. Tai Chi is capable of stimulating similar improvements in physical function as an aerobic mode of exercise such as Zumba Gold®, especially in strengthening leg muscles and body endurance.
4. The group exercise interventions investigated in this thesis decreased feelings of loneliness.

5. In order to tailor an exercise intervention for older age adults it is important to include safety, fun and enjoyable elements to motivate participants in continuing the programme.

5.6 REFERENCE LIST FOR CHAPTER FIVE

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APPENDICES

APPENDIX 1: HEALTH SCREENING QUESTIONNAIRE

This is a screening questionnaire to volunteers who are interested in participating in a the research study entitled **The effect of Tai Chi, Zumba Gold® on Oxidative Stress and Inflammation in an Ageing Population** conducted by researchers in the School of Sport, Exercise and Rehabilitation Sciences. Please take a few moments to complete the following questions and return the questionnaire to us. All data will be treated as confidential between researchers.

CONTACT DETAILS:

This section will ask questions regarding your personal information. The personal data are necessary for further contact.

First Name: ___________________________________

Family name: ___________________________________

Gender: Male ☐ Female ☐

Date of Birth:_______

Address:
____

E-mail address: ________________________________

Telephone number: _________________________

Other contact person:
Name: ____________________________
Relation: __________________________

Contact number: ______________________

A. GENERAL HEALTH

This section will ask on your health.

1. Do you consume alcohol? (Please tick all that apply)

☐ Currently ☐ Previously ☐ Never

If you do, how many unit of alcohol did you consume in a week? (Refer figure below)

____

1.5 units
Small glass red/white/rosé wine (125ml, ABV 12%)
2.1 units
Standard glass red/white/rosé wine (175ml, ABV 12%)
3 units
Large glass red/white/rosé wine (250ml, ABV 12%)
2 units
Pint of lower-strength lager/beer/cider (ABV 3.6%)
3 units
Pint of higher-strength lager/beer/cider (ABV 5.2%)
1.7 units
Bottle of lager/beer/cider (330ml, ABV 5%)
2 units
Can of lager/beer/cider (440ml, ABV 4.5%)
1.5 units
Alcopop (275ml, ABV 5.5%)
1 unit
Single small shot of spirits* (25ml, ABV 40%)

2. Do you smoke? (Please tick the appropriate answer)
☐ Currently ☐ Previously ☐ Never

If previously, when did you stop smoking? ______________________________

3. If applicable, please tick all those health conditions listed below that you have suffered from within the past 12 months

☐ Diabetes	☐ High cholesterol	☐ Heart disease (any)
☐ Vascular disease e.g. stroke	☐ Rheumatic fever	☐ Chronic bronchitis
☐ Gout	☐ Rheumatoid arthritis	☐ Osteoarthritis
☐ Kidney disease	☐ Liver disease	☐ High blood pressure
☐ Bronchitis	☐ Asthma	☐ Cancer
☐ Circulatory problems	☐ Emphysema	☐ Osteoporosis
☐ Cataract	☐ Glaucoma	
☐ Other. Please specify___________________		

4. Are you on medication?
☐ Yes ☐ No

If yes, please provide the name of medication: __________________________

B. INDEPENDENT LIVING

This section will ask view on your independent living. This information will help keep track on how you feel and how well are you able to do your usual activity. Please tick **ONE** response which best describes your usual ability over the **PAST TWO WEEKS**.

	Without ANY Difficulty	With SOME Difficulty	With MUCH Difficulty	Unable to do
1. DRESSING AND GROOMING *Are you able to:* - Dress yourself, including tying shoelaces and doing buttons?	☐	☐	☐	☐
- Shampoo your hair?	☐	☐	☐	☐
2. RISING *Are you able to:* - Stand up from an armless straight chair?	☐	☐	☐	☐
- Get in and out of bed?	☐	☐	☐	☐
3. EATING *Are you able to:* - Cut your meat?	☐	☐	☐	☐
- Lift a full cup or glass to your mouth?	☐	☐	☐	☐
- Open a new carton of milk (or powder)?	☐	☐	☐	☐
4. WALKING *Are you able to:* - Walk outdoors on flat ground?	☐	☐	☐	☐
- Climb up five steps?	☐	☐	☐	☐

5. Please tick any categories for which you usually need help from another person:

Dressing and grooming ☐

Rising ☐

Eating ☐

Walking ☐

6. Please tick any aids and devices that you usually use for any of these activities

Cane ☐

Walking frame ☐

Crutches ☐

Wheelchair ☐

Special or built-up chair ☐

Devices used for dressing (button hook, zipper pull, long handled shoe horn etc.) ☐

Built-up or special utensils ☐

Other (please specify) ________________________

	Without ANY Difficulty	With SOME Difficulty	With MUCH Difficulty	Unable to do
7. HYGIENE *Are you able to:*				
- Wash and dry your entire body?	☐	☐	☐	☐
- Take a bath?	☐	☐	☐	☐
- Get on and off the toilet?	☐	☐	☐	☐

8. REACH Are you able to: - Reach and get down a 5lb object (e.g. a bag of potatoes) from just above your head? - Bend down to pick up clothing from the floor?				
- Reach and get down a 5lb object (e.g. a bag of potatoes) from just above your head?	☐	☐	☐	☐
- Bend down to pick up clothing from the floor?	☐	☐	☐	☐

	Without ANY Difficulty	With SOME Difficulty	With MUCH Difficulty	Unable to do

9. GRIP *Are you able to:*				
- Open car doors?	☐	☐	☐	☐
- Open jars which have been previously opened?	☐	☐	☐	☐
- Turn taps on and off?	☐	☐	☐	☐

10. ACTIVITIES *Are you able to:*				
- Run errands and shop?	☐	☐	☐	☐
- Get in and out of a car?	☐	☐	☐	☐
- Do chores such as vacuuming, housework or light gardening?	☐	☐	☐	☐

11. Please tick any categories for which you usually need help from another person:

Hygiene ☐ Reach ☐ Gripping and opening things ☐

Errands and housework ☐

12. Please tick any aids or devices that you usually use for any of these activities:

Raised toilet seat ☐

Bath seat ☐

Jar opener (for jar previously opened) ☐

Bath rail ☐

Long handled appliances for reach ☐

Other (please specify) ☐

C. INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**.

Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.

Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity ➡ ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking ➡ ***Skip to PART 2: TRANSPORTATION***

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**

_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**

_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days *walking* from place to place?

_____ hours per day

_____ minutes per day

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the last 7 days **in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.**

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, trimming trees, pushing a non-motorized lawn mower, or digging **in the garden**?

_____ days per week

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden?

_____ hours per day

_____ minutes per day

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, planting trees, watering plants, sweeping, and raking **in the garden**?

_____ days per week

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden?

_____ **hours per day**

_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, walking and putting household items away, packing and unpacking boxes, vacuuming, mopping floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**

_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** (or dog walking) for at least 10 minutes at a time **in your leisure time**?

    _____ **days per week**

    ☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

    _____ **hours per day**

    _____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

    _____ **days per week**

    ☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

    _____ **hours per day**

    _____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ days per week

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ hours per day

_____ minutes per day

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ hours per day

_____ minutes per day

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ hours per day

_____minutes per day

D. MARSHALL SITTING QUESTIONNAIRE

I am going to ask you about activities you did over the *__last week whilst sitting or lying down__*. Please do not count the time you spent in bed.

For each of the activities only count the time when this was your main activity. For example if you are watching television and doing a crossword, count it as television time or crossword time but not as both.

During the last week (7-Day period), how much time in total did you spend sitting or lying down and……

ITEM	**TIME**	
1) Watching television or videos/DVDs	______ hours	______ minutes
2) Using the computer/Internet	______ hours	______ minutes
3) Reading	______ hours	______ minutes
4) Socialising with friends or family	______ hours	______ minutes
5) Driving or riding in a car, or time on public transport	______ hours	______ minutes
6) Doing hobbies, e.g. craft, crosswords	______ hours	______ minutes
7) Doing any other activities __________________	______ hours	______ minutes

Thank you for taking part in our research

APPENDIX 2: QUALITY OF LIFE QUESTIONNAIRE

Dear Participant,

The following questionnaire is a part of study entitled The effect of Tai Chi, Zumba Gold and Social Interaction on Oxidative Stress and Inflammation in an Ageing Population conducted by School of Sport, Exercise and Rehabilitation Science, University of Birmingham. The purpose of this study is to measure the quality of life among the participants before and after the exercise intervention. We would like to invite you to participate in this study by completing this questionnaire. Please take a few moments to complete the following questions and return the questionnaire to us. All data will be treated as confidential between researchers.

Contact the investigator

If you have any questions, concern or complains about the study at any stage, you may contact:

Nor Fadila Kasim

School of Sport, Exercise and Rehabilitation Sciences,

University of Birmingham

[redacted]

[redacted]

Dr Sarah Aldred

School of Sport, Exercise and Rehabilitation Sciences,

University of Birmingham,

s.aldred.1@bham.ac.uk

0121 414 7284

A. SF36 Health Survey

INSTRUCTIONS: This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

1. In general, would you say your health is:

(circle one)

Excellent……………………………………	**1**
Very good…………………………………..	**2**
Good………………………………………..	**3**
Fair……………………………….………	**4**
Poor…………………………………………	**5**

2. <u>Compared to one year ago</u>, how would you rate your health in general <u>now</u>?

(circle one)

Much better now than one year ago……….	**1**
Somewhat better now than one year ago…	**2**
About the same as one year ago…………..	**3**
Somewhat worse now than one year ago…	**4**
Much worse now than one year ago………	**5**

The following questions are about activities you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?

(Circle one number on each line)

ACTIVITIES	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
3. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports.	1	2	3
4. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf.	1	2	3
5. Lifting or carrying groceries	1	2	3
6. Climbing several flights of stairs.	1	2	3
7. Climbing one flight of stairs.	1	2	3
8. Bending, kneeling, or stooping.	1	2	3
9. Walking more than a mile.	1	2	3
10. Walking half a mile.	1	2	3
11. Walking one hundred yards.	1	2	3
12. Bathing or dressing yourself.	1	2	3

During the <u>past 2 weeks</u>, have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?

(circle one number on each line)

	YES	NO
13. Cut down on the amount of time you spend on work or other activities.	**1**	**2**
14. Accomplished less than you would like.	**1**	**2**
15. Were limited in the kind of work or other activities.	**1**	**2**
16. Had difficulty performing the work or other activities (for example, it took extra effort).	**1**	**2**

During the <u>past 2 weeks</u>, have you had any of the following problems with your work or other regular daily activities <u>as a result of any emotional problems</u> (such as feeling depressed or anxious)?

(circle one number on each line)

	Yes	No
17. Cut down on the amount of time you spent on work or other activities.	**1**	**2**
18. Accomplished less than you would like.	**1**	**2**
19. Didn't do work or other activities as carefully as usual.	**1**	**2**

20. During the <u>past 2 weeks</u>, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups?

(circle one)

Not at all……………………………………	**1**
Slightly……………………………………..	**2**
Moderately…………………………………	**3**
Quite a bit………………………………..	**4**
Extremely………………………………..	**5**

21. How much <u>bodily</u> pain have you had during the <u>past 4 weeks</u>?

(circle one)

None………………………………………..	**1**
Very Mild………………………………..	**2**
Mild………………………………………...	**3**
Moderate……………………………….....	**4**
Severe……………………………………	**5**
Very severe……………………………....	**6**

22. During the <u>past 2 weeks</u>, how much did <u>pain</u> interfere with your normal work (including both work outside the home and housework)?

(circle one)

Not at all……………………………………	**1**
A little bit…………………………………...	**2**
Moderately…………………………………	**3**
Quite a bit…………………………………..	**4**
Extremely…………………………………..	**5**

These questions are about how you feel and how things have been with you <u>during the past 2 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the <u>past 4 weeks</u>.

(circle one number on each line)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
23. Did you feel full of life?	**1**	**2**	**3**	**4**	**5**	**6**
24. Have you been a very nervous person?	**1**	**2**	**3**	**4**	**5**	**6**
25. Have you felt so down in the dumps that nothing could cheer you up?	**1**	**2**	**3**	**4**	**5**	**6**
26. Have you felt clam and peaceful?	**1**	**2**	**3**	**4**	**5**	**6**
27. Did you have a lot of energy?	**1**	**2**	**3**	**4**	**5**	**6**

28. Have you felt downhearted and low?	**1**	**2**	**3**	**4**	**5**	**6**
29. Did you feel worn out?	**1**	**2**	**3**	**4**	**5**	**6**
30. Have you been a happy person?	**1**	**2**	**3**	**4**	**5**	**6**
31. Did you feel tired?	**1**	**2**	**3**	**4**	**5**	**6**

32. **During the <u>past 2 weeks</u>, how much of the time has your <u>physical health or emotional problems</u> interfered with your social activities (like visiting with friends, relatives, etc)?**

(circle one)

All of the time………………………………… 1

Most of the time……………………………... 2

Some of the time..…………………………… 3

A little of the time...………………………….. 4

None of the time….………………………….. 5

How TRUE or FALSE is <u>each</u> of the following statements for you

(circle one number on each line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
33. A seem to get ill more easily than other people.	**1**	**2**	**3**	**4**	**5**
34. I am as healthy as anybody I know.	**1**	**2**	**3**	**4**	**5**
35. I expect my health to get worse.	**1**	**2**	**3**	**4**	**5**
36. My health is excellent.	**1**	**2**	**3**	**4**	**5**

B. Hospital Anxiety and Depression Scales (HADS)

Please read each item and place a tick in the box opposite the reply which comes closest to how you have been feeling <u>in the last 2 weeks</u>. Don't take too long thinking about your replies: your immediate reaction to each item will probably be more accurate than a long thought-out response.

TICK only one BOX in each section

1. I feel tense or 'wound up':

Most of the time	A lot of the time	Time to time, Occasionally	Not at all

2. I still enjoy the things I used to enjoy:

Definitely as much	Not quite as much	Only a little	Hardly at all

3. I get a sort of frightened feeling as if something awful is about to happen:

Very definitely and quite badly	Yes, but not too badly	A little, but it doesn't worry me	Not at all

4. I can laugh and see the funny side of things:

As much as I always could	Not quite so much now	Definitely not so much now	Not at all

5. **Worrying thoughts go through my mind:**

A great deal of the time	A lot of the time	From time to time but not too often	Only occasionally

6. **I feel cheerful:**

Not at all	Not often	Sometimes	Most of the time

7. **I can sit at ease and feel relaxed:**

Definitely	Usually	Not often	Not at all

8. **I feel as if I am slowed down:**

Nearly all the time	Very often	Sometimes	Not at all

9. **I get a sort of frightened feeling like 'butterflies' in the stomach**

Not at all	Occasionally	Quite often	Very often

10. **I have lost interest in my appearance:**

Definitely	I don't take so much care as I should	I may not take quite as much care	I take just as much care as ever

11. I feel restless as if I have to be on the move:

Very much indeed	Quite a lot	Not very much	Not at all

12. I look forward with enjoyment to things:

As much as ever I did	Rather less than I used to	Definitely less than I used to	Hardly at all

13. I get sudden feelings of panic:

Very often indeed	Quite often	Not very often	Not at all

14. I can enjoy a good book or radio or TV programme:

Often	Sometimes	Not often	Very seldom

15. During the past four weeks, how would you rate your sleep quality overall?

Very good	Fairly good	Fairly bad	Very bad
□	□	□	□

C. MULTIDIMESIONAL FATIGUE INVENTORY

By means of the following statements we would like to get an idea of how you have been feeling in the last 2 weeks. The more you disagree with the statement, the more you can tick just one in the direction of "no, that is not true". Please DO NOT miss out a statement.

	Yes, that is true				No, that is not true
1. I feel fit	**1**	**2**	**3**	**4**	**5**
2. Physically I feel only able to do a little	**1**	**2**	**3**	**4**	**5**
3. I feel very active	**1**	**2**	**3**	**4**	**5**
4. I feel like doing all sorts of nice things	**1**	**2**	**3**	**4**	**5**
5. I feel tired	**1**	**2**	**3**	**4**	**5**
6. I think I do a lot in a day	**1**	**2**	**3**	**4**	**5**
7. When I am doing something, I can keep my thoughts on it	**1**	**2**	**3**	**4**	**5**
8. Physically I can take on a lot	**1**	**2**	**3**	**4**	**5**
9. I dread having to do things	**1**	**2**	**3**	**4**	**5**

10. I think I do very little in a day	**1**	**2**	**3**	**4**	**5**
11. I can concentrate well	**1**	**2**	**3**	**4**	**5**
12. I am rested	**1**	**2**	**3**	**4**	**5**
13. It takes a lot of effort to concentrate on things	**1**	**2**	**3**	**4**	**5**
14. Physically I feel I am in a bad condition	**1**	**2**	**3**	**4**	**5**
15. I have a lot of plans	**1**	**2**	**3**	**4**	**5**
16. I tire easily	**1**	**2**	**3**	**4**	**5**
17. I get little done	**1**	**2**	**3**	**4**	**5**
18. I don’t feel like doing anything	**1**	**2**	**3**	**4**	**5**
19. My thoughts easily wander	**1**	**2**	**3**	**4**	**5**
20. Physically I feel I am in excellent condition	**1**	**2**	**3**	**4**	**5**

D. PITTSBURGH SLEEP QUESTIONNAIRE

The following questions relate to your usual sleep habits during the last 2 weeks. Your answers should indicate the most accurate reply for the majority of days and nights in the last 2 weeks. Please answer all questions.

1. During the past month, when have you usually gone to bed at night? ________________

2. During the past month, how long (in minutes) has it usually takes you to fall asleep at night? ____________

3. During the past month, when have you gotten up in the morning? _______________

4. During the past month, how many hours of actual sleep did you get at night?

(This may different than the number of hours you spend in bed)

____

For each of the remaining questions, mark the one best response. Please answer all questions.

5	**During the past month, how often have you had trouble sleeping because you**	**Not during the past months**	**Less than once a week**	**Once or twice o week**	**Three or more times a week**
	a. Cannot get to sleep within 30 minutes				
	b. Wake up in the middle of the night or early morning				
	c. Have to get up to use the bathroom				
	d. Cannot breathe comfortably				
	e. Cough or snore loudly				
	f. Feel too cold				
	g. Feel too hot				
	h. Have bad dreams				
	i. Have pain				
	j. Other reason (s), please describe, including how often you have had trouble sleeping because of this reason (s)				
6	**During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?**				
7.	**During the past month, how would you rate your sleep quality overall?**	**Very good** ☐	**Fairly good** ☐	**Fairly bad** ☐	**Very bad** ☐

E. REVISED UCLA LONELINESS SCALE

Directions: indicate how often you feel the way described in each of the following statements. Circle one number for each.

		Never	Rarely	Sometimes	Often
1	I feel in tune with the people around me	□	□	□	□
2	I lack companionship	□	□	□	□
3	There is no one I can turn to	□	□	□	□
4	I do not feel alone	□	□	□	□
5	I feel part of a group of friends	□	□	□	□
6	I have a lot in common with people around me	□	□	□	□
7	I am no longer close to anyone	□	□	□	□
8	My interests and ideas are not shared by those around me	□	□	□	□
9	I am an outgoing person	□	□	□	□
10	There are people I feel close to	□	□	□	□
11	I feel left out	□	□	□	□
12	My social relationships are superficial	□	□	□	□
13	No one really knows me well	□	□	□	□
14	I feel isolated from others	□	□	□	□
15	I can find companionship when I want it	□	□	□	□
16	There are people who really understand me	□	□	□	□
17	I am unhappy being so withdrawn	□	□	□	□
18	People are around me but not with me	□	□	□	□
19	There are people I can talk to	□	□	□	□
20	There are people I can turn to	□	□	□	□

APPENDIX 3: BEHAVIOURAL REGULATION AND SELF-EFFICACY IN EXERCISE QUESTIONNAIRE

Dear Participant,

The following questionnaire is a part of study entitled '**The effect of Tai Chi, Zumba Gold on Oxidative Stress and Inflammation in an Ageing Population**' conducted by School of Sport, Exercise and Rehabilitation Science, University of Birmingham. The purpose of this study is to identify the reason underlying people's decision to engage in current physical activity and their confidence in doing that. We would like to invite you to participate in this study by completing this questionnaire. Please take a few moments to complete the following questions and return the questionnaire to us. All data will be treated as confidential between researchers.

Contact the investigator

If you have any questions, concern or complains about the study at any stage, you may contact:

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School of Sport, Exercise and Rehabilitation Sciences,
University of Birmingham
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EXERCISE REGULATIONS QUESTIONNAIRE (BREQ-2)

WHY DO YOU ENGAGE IN EXERCISE?

Using the scale below, please indicate to what extent each of the following items is true for you. Please note that there are no right or wrong answers and no trick questions. We simply want to know how you personally feel about exercise. Your responses will be held in confidence and only used for our research purposes.

		Not true for me		Sometimes true for me		Very true for me
1	I exercise because other people say I should	0	1	2	3	4
2	I feel guilty when I don't exercise	0	1	2	3	4
3	I value the benefits of exercise	0	1	2	3	4
4	I exercise because it's fun	0	1	2	3	4
5	I don't see why I should have to exercise	0	1	2	3	4
6	I take part in exercise because my friends/family/partner say I should	0	1	2	3	4
7	I feel ashamed when I miss an exercise session	0	1	2	3	4

8	It's important to me to exercise regularly	0	1	2	3	4
9	I can't see why I should bother exercising	0	1	2	3	4
10	I enjoy my exercise sessions	0	1	2	3	4
11	I exercise because others will not be pleased with me if I don't	0	1	2	3	4
12	I don't see the point in exercising	0	1	2	3	4
13	I feel like a failure when I haven't exercised in a while	0	1	2	3	4
14	I think it is important to make the effort to exercise regularly	0	1	2	3	4
15	I find exercise a pleasurable activity	0	1	2	3	4
16	I feel under pressure from my friends/family to exercise	0	1	2	3	4
17	I get restless if I don't exercise regularly	0	1	2	3	4
18	I get pleasure and satisfaction from participating in exercise	0	1	2	3	4
19	I think exercising is a waste of time	0	1	2	3	4

SELF-EFFICACY FOR EXERCISE

How confident are you right now that you could complete this exercise program 3 times per weeks for 60 minutes if;

no	Items	Not confident very confident
1	The weather was bothering you	0 1 2 3 4 5 6 7 8 9 10
2	You were bored by the program or activity	0 1 2 3 4 5 6 7 8 9 10
3	You felt pain when exercising	0 1 2 3 4 5 6 7 8 9 10
4	You had to exercise alone	0 1 2 3 4 5 6 7 8 9 10
5	You did not enjoy it	0 1 2 3 4 5 6 7 8 9 10
6	You were too busy with other activities	0 1 2 3 4 5 6 7 8 9 10
7	You felt tired	0 1 2 3 4 5 6 7 8 9 10
8	You felt stressed	0 1 2 3 4 5 6 7 8 9 10
9	You felt depresses	0 1 2 3 4 5 6 7 8 9 10