A Comparison of Dance/Movement Therapy and Cardiovascular Training on Cortisol Awakening Response in the Elderly

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ABSTRACT

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Aging is associated with numerous chronic conditions as well as an increased stress response. The present study looks at the effects of Dance/Movement Therapy (DMT) on chronic stress (measured by the cortisol awakening response – CAR) in older adults. Healthy older adults (n = 40) aged 60 and over (M=67.45, SD=5.3) were randomized into three groups: DMT (n=12), Aerobic Training (AT; n=14), and Waiting List (WL; n=14). DMT defined as "the psychotherapeutic use of movement to promote emotional, social, cognitive and physical integration of the individual" (ADTA, 2017), was comprised of exercises including gross motor skills, body awareness, and socialization. The AT consisted of high intensity activity on a recumbent bicycle. Both training groups were supervised by a licensed instructor and met three times a week for three months. Participants of all groups provided, before and after their respective program, saliva samples on three days at 0, 30 and 60-minutes after awakening, and had their fitness level evaluated. A group x time interaction was found ($F(2,35)=5.256$, $p=.01$, η^2partial=.231), with the DMT group showing lower salivary cortisol values post-training, while the other two groups showed no change from baseline in their CAR. Maximal aerobic power improved only in the AT group, while DMT showed no group-specific physical functioning improvements. The results are further discussed in terms of physical and psychological mechanisms that could explain the change in cortisol.

Keywords: dance/movement therapy, cortisol, aerobic training, stress, older adults

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Contribution of Authors

Dr. Louis Bherer designed the main research project on which this study is based, and supervised all steps in the preparation of this study and thesis. Co-author Alida Esmail coordinated the whole project, and was involved with co-author David Predovan with participant testing, data collection, and statistical analysis feedback. Co-author Dr. Jens C. Pruessner, has supervised all the cortisol statistical analysis.

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Chapter 1: Introduction

The number of Canadians aged 65 and over have overpassed the number of children under the age of 14, and is expected to grow in the next 15 years to more than 22% of the population (Statistics-Canada, 2017). Unfortunately, this increase in life expectancy is often accompanied by an increase in age-related chronic impairments such as cognitive decline, hormonal dysregulation, cardiovascular disease, and functional deficits. However, these impairments are not inevitable; lifestyle factors have an important effect on the way people age. For example, individuals that perform physical activity regularly throughout life have lower rates of cancer, diabetes, and cardiovascular diseases (Booth, Gordon, Carlson, & Hamilton, 2000).

In particular, hormonal dysregulation, and more specifically cortisol hyperactivity is known to be a normal part of the aging process (Diamanti-Kandarakis et al., 2017). However, this age-related change in cortisol, a stress biomarker, is often associated with negative consequences like increased risks of cardiovascular disease (Whitworth, Williamson, Mangos, & Kelly, 2005), psychiatric disorders (Belvederi Murri et al., 2014; Ehlert, Gaab, & Heinrichs, 2001; Sapolsky, 2000), cognitive deficits (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007), increased frailty (Holanda et al., 2012; Varadhan et al., 2008), and lower mobility (Pulopulos, Puig-Perez, Hidalgo, Villada, & Salvador, 2016). Therefore, preventive strategies that can slow-down those negative changes and improve quality of life should be evaluated. Based on the current literature, some evidence suggest that physical activity has a positive impact on stress (Bräuninger, 2012; Childs & de Wit, 2014; Lucertini et al., 2015). However, it is not clear which type of physical activity has the best potential to reduce stress. In the present paper, we compare a soft multi-modal program and a high intensity aerobic program in relation to passive control group. The objective of the present thesis is to assess if two training programs, aerobic training

(AT) and Dance/Movement Therapy (DMT), can lower morning cortisol secretion in healthy older adults. Results will give us insight into which types of exercise programs can improve stress in older adults.

Chapter 2: Literature Review

2.1. The endocrinology of stress

Hormones are chemical messengers released directly in the circulatory system by endocrine glands that have an effect on distant organs. Unlike neurotransmitters, hormones have a slower speed of communication, and can have both short and long lived effects. The healthy functioning of the hormones is crucial because of their control over many bodily functions from basic needs like hunger, to body and sexual development, and even emotions and mood. Although for many of those hormones the brain is the target organ, the brain is also in charge of the regulation of hormones. As such, the hypothalamus, a small brain structure with specialized nuclei, is a major hub integrating and regulating the endocrine system with the physiological functions and behavior. Typically, the hypothalamus releases hormones affecting the pituitary gland which in turn, will control the release of different other hormones. Those hormones released by the pituitary gland further travel to other peripheral endocrine glands that release multiple hormones affecting specific peripheral organs. For example, in reaction to an environmental threat, the hypothalamus releases a corticotropic-releasing hormone which travels to the pituitary gland and stimulate the release of adrenocorticotropic hormone. This second hormone travels through the bloodstream from the pituitary gland all the way to the adrenal glands where it will stimulate the release of corticosteroid hormones (such as cortisol). Furthermore, those hormones produce a negative-feedback regulation to the hypothalamus and the adrenal gland to better monitor the quantity available in the blood, and to possibly inhibit further release once the desired amount is attained. The overall system exemplified above linking the hypothalamus to the adrenal gland and cortisol is known as the hypothalamic-pituitary-adrenal (HPA) axis, and it is considered to play a central role in the regulation of the physiological response to stress (Smith & Vale, 2006).

As part of the glucocorticoid group, cortisol is a steroid hormone that plays an important role in regulating metabolic, cardiovascular, immune, and behavioral processes (Charmandari, Tsigos, & Chrousos, 2005; Sapolsky, Romero, & Munck, 2000). Due to its wide impact across so many bodily functions, cortisol is always present in the body even in the absence of a perceived stressor, and its release is influenced by bodily and environmental factors (Charmandari et al., 2005; Gaffey, Bergeman, Clark, & Wirth, 2016; Van Cauter, 1996). Normally, over the course of the day the level of cortisol increases drastically post-awakening, reaching a peak 30 to 45 minutes later, after which it goes down rapidly for another 30 minutes, followed by a much slower rate of decrease over the rest of the day. Deviations from this natural fluctuation in cortisol are detrimental due to their association with negative health consequences such as an increase in cardiovascular risk, cognitive decline, lowered mobility, and poor sleep (Hodyl et al., 2016; Pistollato et al., 2016; Pulopulos et al., 2016; Whitworth et al., 2005).

To quantify changes from the natural cortisol secretion pattern, researchers have studied and identified separate components. For example, simply looking at one sample of cortisol at one given time (also known as basal cortisol) it is possible to separate participants based on their high or low concentration of cortisol. However, this method doesn't take into account any variable (individual traits or even environmental stimuli) that might affect the quantity of cortisol released. Other measures use multiple time points in order to identify changes in cortisol secretion, like the cortisol awakening response (CAR) or the diurnal decrease in cortisol from morning to evening. The CAR only looks at the sudden increase and decrease in cortisol in the first hour after awakening (J. C. Pruessner et al., 1997). This biological marker reflecting adrenocortical activity can be calculated by measuring the area under the curve (AUC). Two ways have been developed to measure AUC (Jens C. Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). One measure named area under the curve with respect to ground (AUCg) looks at the total cortisol output post-awakening. This measure reflects the total concentration of cortisol released post-awakening, and it has been shown to be associated with post-traumatic stress syndrome, and positive psychological states or traits (Chida & Steptoe, 2009). The second measurement is called the area under the curve with respect to increase (AUCi), and it only measures the additional cortisol released after awakening (or after the first sampling point). This value reflects the variability in cortisol, or the sensitivity of the endocrine system post awakening, and a higher value indicates greater variability. Lower AUCi has been associated with job stress, fatigue, burnout, and it is possibly related to depression (Chida & Steptoe, 2009). On top of this, it is important to note that both AUC_i and AUC_g are sensitive to general life stress (Chida & Steptoe, 2009).

2.2. Age related changes to cortisol secretion

With advanced age, the control over the timing and the quantity of hormones released in the blood is affected. More precisely in relation to the HPA axis, advanced age is associated with higher values and blunted variation in cortisol secretion (Piazza, Almeida, Dmitrieva, & Klein, 2010). There is evidence to suggest that the negative feedback regulation of the HPA axis is impaired later in life (Diamanti-Kandarakis et al., 2017), this altering the natural inhibition of unnecessary cortisol secretion and resulting in higher than needed circulating cortisol in the blood. Similarly, a second pathway that can lead to increased cortisol level later in life is through repeated exposure to general psychosocial stressors (Otte et al., 2005). Advanced age is also associated with less variability in cortisol secretion both, during the CAR and over the course of the day (Piazza et al., 2010). Although those changes are often seen in the older population, it is important to note that repeated exposure of the body to high levels of cortisol is associated with negative consequences like increased risks of cardiovascular (Whitworth et al., 2005), and psychiatric (Belvederi Murri et al., 2014; Ehlert et al., 2001; Sapolsky, 2000) disorders as well as cognitive deficits (Lupien et al., 2007). Moreover, blunted variation or high levels of cortisol have also been associated with increased frailty (Holanda et al., 2012; Varadhan et al., 2008), and lower mobility (Pulopulos et al., 2016) amongst older adults. Thus, preventive strategies that can reverse or slow down the negative consequences of aging on the stress hormone could help promote a healthy aging process.

2.3. Age related physical functioning changes

Aging is always associated with significant changes in the body that are going to have a major impact on an individual's life expectancy and their quality of life. Although a part of those changes is determined by an individual's genes, modifiable lifestyle factors (like engaging in regular physical activity, having a healthy diet, and social support; (Christensen, Doblhammer, Rau, & Vaupel, 2009; Rizzuto & Fratiglioni, 2014), and indirect lifestyle factors (like stress and quality of sleep; (Grandner, Hale, Moore, & Patel, 2010; Iso et al., 2002) seem to impact longevity, and functional impairments and disability in late life. Adults who don't engage in those preventive activities throughout their life are more likely to develop conditions known to decrease physical functioning and increase their susceptibility to disease (like metabolic syndrome, high cholesterol, and cardiovascular diseases). With age, many components like physical functioning and fitness decrease. Of specific interest is cardiovascular fitness which is known to decline progressively in early adulthood and more significantly in old age, in sedentary adults (Betik & Hepple, 2008). Although this decrease can be caused by age related changes in the body, such as reduced maximal cardiac output, reduced cardiovascular conductance, or reduced muscle blood flow (Betik & Hepple, 2008), the decline can be worsened by a lack of regular physical activity. Even though those changes are expected with age, maintaining a high cardiovascular fitness later in life is known to be associated with a lower risk of all-cause mortality and low incidence of cardiovascular diseases and cancer (Blair et al., 1989; Kodama et al., 2009; Sandvik et al., 1993). Furthermore, an increase in cardiovascular fitness has been associated with improvements in quality of life and well-being which can lead to a better aging process (Folkins & Sime, 1981; Penedo & Dahn, 2005; Rejeski & Mihalko, 2001).

Besides the age-related decline in cardiovascular fitness, sedentary older adults also report a loss of other fitness-related functions including flexibility, balance, and muscle strength which ultimately translate in lower mobility or frailty (Chodzko-Zajko et al., 2009; Rockwood et al., 2004). Although those are changes across a multitude of domains they all contribute to the slowing of movement seen in older adults, and the extent of the decline can be captured in a walking test. For instance, sedentary individuals as well as older people that stop a training program show a decrease in neuromuscular functions which cause a decrease in walking speed and can affect late-age functional independence (Connelly & Vandervoort, 1997; Vandervoort, 2002). In healthy adults, this age-related decline in muscle strength can be even more than 50% when comparing people over the age of 70 with younger adults in their 20's (Murray, Duthie, Gambert, Sepic, & Mollinger, 1985). Like cardiovascular fitness, mobility is expected to decrease with age, but this decrease is larger in individuals with poor health outcomes or lifestyles (Fritz & Lusardi, 2009). As a result, individuals with multiple health or functional impairments will have a slower walking speed than their healthier counterparts (van Kan et al., 2009). Indeed, multiple studies have shown that the walking speed of healthy older people is predictive of adverse outcomes, and even life expectancy (Graham, Ostir, Fisher, & Ottenbacher, 2008; Newman et al., 2006; Studenski et al., 2011). For example, in a large longitudinal study with over 3 000 older adults, walking speed has been associated with cardiovascular disease, mobility limitations, and disability (Newman et al., 2006). On top of this, those in the lowest quartile in terms of performance had a three times higher chance of mortality than those with the best performance. Overall, it is safe to say that maintaining or improving late-age mobility has multiple benefits, with studies showing an increase in quality of life (Schmid et al., 2007), and well-being (Hardy, Perera, Roumani, Chandler, & Studenski, 2007; Purser et al., 2005). Therefore, similarly to cardiovascular fitness, walking speed is a good prognostic tool that reflects physical functioning in older adults. Lastly, frailty, low mobility, and low fitness have all been already linked to dysregulation of the HPA axis in older adults (Holanda et al., 2012; Peeters et al., 2007; Pulopulos et al., 2016; Varadhan et al., 2008).

2.4. Aerobic fitness and stress

In addition to improving physical functioning and preventing late life impairments, being physically active can also impact stress biomarkers and psychological stress components. Aerobic exercise has been shown to have an acute effect on stress biomarkers, as well as an impact on chronic psychological stress biomarkers. The acute relationship between AT and cortisol can be imagined as a spiral, where intense physical activity increases the short-term release of cortisol (Jacks, Sowash, Anning, McGloughlin, & Andres, 2002), and the cortisol facilitates further cardiovascular activation through increased cardiac output and increased blood pressure (Sapolsky et al., 2000). The increase in cortisol release seems to be triggered by exercise of high intensity and of long duration (Jacks et al., 2002; Labsy et al., 2013). In this situation, the presence of additional cortisol in the body is beneficial because it helps an individual in dealing with a perceived physiological stressor – intense physical activity. On the other hand, if there is no real stressor and cortisol is released, then it is probably caused by psychological stress. In this situation, the repeated activation of the HPA system will expose the body to unnecessary high levels of cortisol. In relation to an intense physical activity, the acute increase in cortisol is relatively short-lived, lasting up to two to four hours (Duclos et al., 1998; Duclos, Corcuff, Rashedi, Fougere, & Manier, 1997; Tremblay, Copeland, & Van Helder, 2005). This being mentioned, the acute effect of exercise on cortisol is beyond the scope of this paper, and only the impact of exercise on chronic stress biomarkers is investigated. Studies have shown that by measuring cortisol after at least one day of rest, the diurnal cortisol variation will not be affected by the previous exercise session (Gouarn, Groussard, Gratas-Delamarche, Delamarche, & Duclos, 2005; Labsy et al., 2013). Therefore, in the present study cortisol was measured at least 24h after exercise to only reflect the natural cortisol fluctuation, which is sensitive to chronic general life stress and not related to the acute effect of an exercise event.

In general, studies have shown that high cardiovascular fitness and mobility are associated with lower basal cortisol levels in older adults (Lucertini et al., 2015; Peeters et al., 2007). Those findings suggest that high cardiovascular fitness buffers the age-related HPA-dysregulation (Lucertini et al., 2015). Some studies suggest that by exercising regularly, older adults are more capable of dealing with the negative consequences of psychosocial stress (Childs & de Wit, 2014) and high life events stress (Heaney, Carroll, & Phillips, 2014). Similarly, older adults that exercise regularly show a decrease in the negative impact of HPA over-activity on the immune system (Phillips, Burns, & Lord, 2007). Although there seems to be a clear link between cardiovascular fitness and a healthy HPA axis regulation, some aerobic intervention studies show mixed results, with partial or no change in cortisol post-training (Baker et al., 2010; Hayes et al., 2013). This discrepancy in results has been suggested to be caused by methodological differences between studies and should be further investigated (Corazza et al., 2013).

Numerous review studies have also linked AT to stress-related psychological variables like quality of life, psychological and emotional well-being, including distress, anxiety, and depression (Netz, Wu, Becker, & Tenenbaum, 2005; Penedo & Dahn, 2005; Rejeski & Mihalko, 2001; Taylor et al., 2004). Those findings seem to also be corroborated by population-based studies that linked regular exercising to low levels of neuroticism, anxiety and depression (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006). In addition, other studies have linked regular exercising with an increase in positive affect (Pasco et al., 2011), mental well-being (Cerin, Leslie, Sugiyama, & Owen, 2009), and even positive self-perception (Netz et al., 2005).

Positive effects are not limited to the AT, as other types of training such as strength, endurance, or multi-modal exercising (including dance, yoga, or tai chi) show similar benefits (S. Koch, Kunz, Lykou, & Cruz, 2014; Netz et al., 2005; Pothier & Bherer, 2016; Taylor et al., 2004). Additionally, other types of physical activities might have different benefits on cortisol secretion as well (Corazza et al., 2013), but further studies are needed to help understand the impact of various types of exercises on psychological stress responses.

2.5. Dance/Movement Therapy

Recently, there has been an increase of studies on Dance/Movement Therapy (DMT) with many of them showing physical, psychological, emotional, and cognitive benefits. DMT is defined by the American Dance Therapy Association as “the psychotherapeutic use of movement to promote emotional, social, cognitive and physical integration of the individual” (ADTA, 2017). Based on this conceptual model, DMT has the potential to be used as a health-promoting tool, but more empirical evidence is needed to support this. Moreover, research should also analyze possible mechanisms through which DMT could improve health. It has been already shown that DMT has indeed positive effects on health-related psychological outcomes like the quality of life, subjective well-being, mood, affect, and body image (S. Koch et al., 2014). Moreover, the benefits of DMT can be observed even in clinical populations, where it can effectively decrease symptoms of depression and anxiety. Other studies found the same beneficial effects of dance and DMT on patients suffering from physical or mental illness (Kiepe, Stöckigt, & Keil, 2012). Indeed, dance or DMT was able to improve quality of life and psychological adaptation to breast cancer (Dibbell-Hope, 2000; Sandel et al., 2005), increase vitality, lower negative symptoms, and modulate the levels of serotonin and dopamine in individuals suffering from mild or major depression (Jeong et al., 2005; S. C. Koch, Morlinghaus, & Fuchs, 2007), and even improved mobility and quality of life in Parkinson's Disease patients (Hackney & Earhart, 2009a, 2009b).

Other studies have shown that dance and DMT can be successfully used in older adults to increase physical fitness (Cruz-Ferreira, Marmeleira, Formigo, Gomes, & Fernandes, 2015; Hwang & Braun, 2015; Pacheco, Hoyos, Watt, Lema, & Arango, 2016), to improve mobility (Filar-Mierzwa, Dlugosz, Marchewka, Dabrowski, & Poznanska, 2016; Krampe et al., 2014), quality of life and well-being (Cruz-Ferreira et al., 2015; Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009; Meekums, Vaverniece, Majore-Dusele, & Rasnacs, 2012; Sandel et al., 2005). Furthermore, some studies suggest that dance or DMT might show cognitive and neurological benefits in older adults (Burzynska et al., 2017; Kosmat & Vranic, 2016; Merom et al., 2016; Niemann, Godde, & Voelcker-Rehage, 2016).

2.6. DMT and stress

To understand one of the possible mechanisms through which DMT can improve health, studies should focus on its effect on stress. Although many studies already found that DMT can improve quality of life and well-being, few focused specifically on self-report stress and even fewer on stress biomarkers, like cortisol. However, the growing evidence suggests that DMT could be successful at lowering stress levels in older adults. For example, in a sample of older women over the age of 78, it was showed that DMT can reduce stress related to the relocation in a continuing care retirement community by improving emotional and social connectivity (Kluge, Tang, Glick, LeCompte, & Willis, 2011). Similar results were also found in a group of breast cancer patients undergoing radiotherapy where a 6-session DMT program reduced perceived stress and pain outcomes (Ho & Fong, 2017). Moreover, in a series of random control studies run over multiple centers, Bräuninger (2012, 2014) found that a 10-session DMT program was effective at improving stress management and lowering distress in middle aged individuals suffering from stress. The same beneficial effects were even seen after a 6-months follow-up. No statistically significant effect was found when investigating the effect of DMT on basal cortisol level in older adults suffering from fibromyalgia (Bojner-Horwitz, Theorell, & Maria Anderberg, 2003). To our knowledge, no other study has examined the impact of DMT on the cortisol awakening response, or cortisol in general.

In conclusion, the literature reviewed suggests that AT as well as DMT have numerous benefits on health. In addition, those benefits could extend to stress, by buffering the age-related cortisol dysregulation. The article presented in chapter three investigates the benefits of an AT program and a DMT program relative to a passive control group, on the CAR. The AT program is an intense aerobic exercise meant to improve cardiovascular fitness. On the other hand, DMT is a softer exercise program combining physical activity (gross motor exercises), with psychological components (body awareness, socialization, emotional expression). Due to the difference in the composition of the two training programs, and due to the different physiological and psychological components trained, it is expected that the two programs have different effects.

Chapter 3: Article

Dance Your Stress Away: Dance/Movement Therapy, but Not Cardiovascular Training, Leads to a Lower Cortisol Awakening Response in the Elderly

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3.1. Introduction

Aging is associated with many chronic conditions that can be worsened by stress. In addition, aging itself influences an individual's body sensitivity to stress. Age-related changes of the hypothalamic-pituitary-adrenal (HPA) axis, the main stress system in the body, is known to alter the secretion of cortisol, an important stress hormone (Gaffey et al., 2016). Alterations in the quantity or timing of cortisol secretion can predispose individuals to negative health outcomes, and should therefore be prevented (Gaffey et al., 2016).

In the presence of chronic and acute stressors, the HPA axis is responsible for the production of a cascade of hormones that regulate the production of cortisol. Simply the secretion of cortisol in response to a perceived stressor is enough to inhibit further release (also known as the negative feedback loop). In healthy older adults, an increased in hormonal response to acute stressors is observed. Furthermore, the cortisol negative feedback loop is known to be less effective, potentially causing an overall increase in basal cortisol level, or an increase in the total cortisol output (also known as Area Under the Curve with respect to ground; AUCg) (Chahal & Drake, 2007; Heaney, Phillips, & Carroll, 2012; Nater, Hoppmann, & Scott, 2013). The presence of chronic psychosocial stress can leave its mark on the secretion of cortisol by increasing overall values, and flattening the fluctuation of cortisol after awakening (Gaffey et al., 2016). Although those changes are often seen in older adults, it is important to note that repeated exposure of the body to high levels of cortisol is associated with negative consequences like increased risks of cardiovascular (Whitworth et al., 2005), and psychiatric (Belvederi Murri et al., 2014; Ehlert et al., 2001) disorders. Moreover, blunted variation or high levels of cortisol have been associated with increased frailty (Holanda et al., 2012; Varadhan et al., 2008), and lower mobility (Pulopulos et al., 2016) amongst older adults. Thus, preventive strategies that can reverse or slow down the negative consequences of aging on the stress hormone should be developed to promote a healthy aging.

Physical activity is often prescribed as a preventive activity for healthy aging (Booth, Roberts, & Laye, 2012; Chodzko-Zajko et al., 2009). Previous studies have found that aerobic training (AT) is particularly beneficial in preventing many age-related chronic conditions (such as metabolic syndrome, diabetes, cardiovascular diseases), and improving physical and cognitive functioning (Bherer, Erickson, & Liu-Ambrose, 2013), as well as psychological well-being (Langlois et al., 2012). However, not much is known about its effect on chronic stress biomarkers, such as cortisol awakening response (CAR). There is evidence that greater cardiovascular fitness is linked to lower basal cortisol secretion in older adults, suggesting that cardiovascular fitness might buffer the age-related HPA dysregulation (Lucertini et al., 2015; Peeters et al., 2007). Nevertheless, support for the beneficial effects of cardiovascular training on the cortisol response is mixed. Indeed, a randomized controlled trial examining the effects of a 6-months AT program in a mild cognitively impaired sample found only a partial decrease in basal serum cortisol values (Baker et al., 2010). Similarly, no change in salivary cortisol was observed after six weeks of moderate AT (Hayes et al., 2013). Due to the mixed results, it is not yet clear how physical training such as AT impacts cortisol secretion.

Recently, other emerging training programs used by older adults, like Dance/Movement Therapy (DMT), have also been associated with physical, psychological, emotional, and cognitive benefits. DMT is defined by the American Dance Therapy Association as “the psychotherapeutic use of movement to promote emotional, social, cognitive and physical integration of the individual” (ADTA, 2017). As a result, this type of activity can be considered more ecologically valid and might impact different health-related components that might not be affected by a pure aerobic training program. For example, a recent meta-analysis done by S. Koch et al. (2014) concluded that DMT has indeed positive effects on health-related psychological outcomes like quality of life, subjective well-being, mood, affect, and body image. Other studies have shown that dance or DMT can be successfully used in older adults to increase physical fitness (Cruz-Ferreira et al., 2015; Hwang & Braun, 2015; Pacheco et al., 2016), to improve mobility (Filar-Mierzwa et al., 2016; Krampe et al., 2014), quality of life and well-being (Cruz-Ferreira et al., 2015; Eyigor et al., 2009; Meekums et al., 2012; Sandel et al., 2005).

Although many studies already found that DMT can improve quality of life and well-being, few focused specifically on self-report stress and even fewer on stress biomarkers. Cortisol activity and specifically the CAR is very sensitive to general life stress (Chida & Steptoe, 2009), and a link between DMT and the CAR would indicate a possible beneficial effect of the training program on stress. For instance, the growing evidence suggests that DMT could be successful at lowering stress levels in older adults. For example, in a sample of older women aged 78 and over, the authors showed that DMT can reduce stress related to the relocation in a continuing care retirement community by improving emotional and social connectivity (Kluge et al., 2011). A 6-session DMT program in a group of breast cancer patients undergoing radiotherapy was also found to reduced perceived stress and pain outcomes (Ho & Fong, 2017). Moreover, in a series of random control studies run over multiple centers, Bräuninger (2012, 2014) found that a 10-session DMT program was effective at improving stress management and lowering distress in middle aged individuals suffering from stress. The same beneficial effects were even seen after a 6-months follow-up.

More research is need to evaluate the impact of DMT interventions on stress biomarkers. The only study investigating the effect of DMT on cortisol level in older adults uses a clinical sample suffering from fibromyalgia (Bojner-Horwitz et al., 2003). Although the results showed that DMT might have a potential effect on the basal cortisol level, it was not statistically significant.

Although evidence suggests that being physically active might protect older adults from the negative consequences of high stress exposure (Heaney et al., 2014), it remain unclear if 1) physical training has an impact on the CAR and 2) different physical trainings can lead to different changes in the CAR. Knowing these answers would facilitate the prescription of different types of exercise programs to older adults based on the situation. Therefore, the purpose of this study was to investigate whether two types of physical training programs adapted to an aging population, namely AT and DMT training, can lower morning cortisol secretion in healthy older adults. Furthermore, the study aims to investigate if the change in cortisol secretion is related to cardiovascular changes or other psychological variables. To our knowledge, this is the first study to investigate the impact of a DMT and aerobic training on CAR. Participants were randomly assigned to one of two training groups (DMT or AT), or the wait-list (WL) control group.

It is hypothesised that 1) both interventions would show a decrease in salivary CAR compared to the WL group, and 2) the benefit of DMT on stress response would be larger than the one associated with AT.

3.2. Methods

3.2.1. Participants

Table 1 documents the demographic characteristics of the sample. The present study was part of a larger clinical trial (NCT02455258) and was run indoors at the geriatric institution where the study was approved by the research ethics committee. The participants were recruited from the community and they all provided written informed consent before starting the study. The sample included 40 healthy older adults (75% women), aged 60 and over (M=67.45, SD=5.33). Participants were not eligible if they followed a structured exercising program in the last year, had mobility limitations, if they had a surgery involving general anesthetic in the previous year, if they were diagnosed with any orthopaedic, neurological, cardiovascular or respiratory problems within the last six months, if they were undergoing hormone therapy, if they were smoking in the past five years, or if they consumed two or more standard drinks of alcohol per day. All the women in the study were post-menopausal.

[Insert table 1 here]

3.2.2. Procedure

After a phone interview, the eligible participants were assessed three weeks prior to the beginning of the training program. During the first day of pre-tests, participants underwent a geriatric and neuropsychological examination (MMSE) and were also familiarised with the saliva collection procedure (Stalder et al., 2016). On the second day of pre-tests, participants' mobility (10 Meters Walk Test (10MWT) and fitness level (Maximal Aerobic Power during a graded exercise VO_2Max test) were assessed. A set of questionnaires was also completed during those two days. After the pre-testing procedure, participants were randomly assigned to one of the three groups: Dance/Movement Therapy (DMT; n=12), Aerobic Training (AT; n=14), and Waiting List (WL; n=14), while controlling for gender, age and education level. The post-testing followed the same procedure except there was no medical examination.

3.2.3. Interventions: Training Protocol

For both interventions, the participants trained in small groups three times a week (Monday, Wednesday and Friday) for a duration of three months. All sessions were 60-minutes long, and were planned and conducted by appropriately licensed instructors.

Dance/Movement Therapy (DMT): The DMT was conducted in small groups of 4 to 8 participants by a certified dance/movement therapist and it was designed according to the standards of the American Dance Therapy Association. The sessions were held in a quiet section of a gym of approximately 4.5m x 10m closed by curtains. Each training session started with an opening, followed by a warm up, exploration, and ended with a closure. The overall goal of the therapy was to create a mind-body experience and stimulate creativity by expressing emotions and ideas through movement and dance. In order to achieve this, gross motor exercises involving balance, coordination, flexibility, body awareness, and socialization were used. Throughout the training program, props such as the Octaband©, the CoOper Blanket©, the Elastablast©, colourful scarves, exercise balls, TheraBands™ and tennis balls were used. In addition, the music used was diverse based on the objective of the movements, sometimes brought in by the therapist or suggested by the participants. The therapist chose the structure and procedure of each session so that it follows a natural flow according to what the whole group was comfortable and able to do.

Aerobic Training (AT): The AT was comprised of a warm up, cardiovascular training on a recumbent bicycle (LifeFitness, Kinequip, St-Hubert, Quebec, Canada), and ended with a cooldown session. The cardiovascular training program was adapted for each individual participant based on their maximal aerobic power (MAP) determined from the VO2 peak test at baseline. The warm up and cooldown sessions lasted 10 minutes and were performed on any ergometer preferred by the participant (elliptical, treadmill, or bicycle) and they were encouraged to change them from session to session. The AT was divided in two components which were administered on separate days, alternating one at a time. Component A of the AT was continuous of 20 minutes at 60% of MAP and took place on all Wednesdays. Component B was an interval training made of 2 blocks of 4 to 7 minutes in which the power alternated every 15 seconds between 60% of MAP and 100% of MAP. This component was performed on all Mondays and Fridays. In addition, every month the intensity of all exercises was increased by 5% of MAP for all components. The power was always changed directly by the trainer (a licensed kinesiologist), and because this required a lot of attention, a maximum of two participants could be trained at the same time. This training program has already been used in previous studies and it has been shown to improve aerobic fitness (Berryman et al., 2014).

Waiting List (WL): The participants randomized in the WL formed the passive control group, and they did the same pre- and post-testing evaluations as the other participants. However, at the beginning of the training period they were informed that they were placed on a waiting list and that they will be called in the laboratory when there will be an opening. Furthermore, in order to maintain their eligibility, they were asked to maintain their current lifestyle and refrain from enrolling in any type of physical activity program. As curtesy to the WL participants, they were offered the possibility of enrolling in any of our intervention groups after the WL post-evaluations were recorded. No data were collected from their participation in the training group.

3.2.4. Cortisol Saliva Sampling

To measure changes in salivary cortisol in relation to the training program, participants provided three sets of saliva samples before the beginning of the study and three after the training ended, using salivettes (Sarstedt Inc, Quebec City, Quebec, Canada). The participants were instructed on the procedure and they were made familiar with the saliva sample journal during their first visit to the lab. The instructions provided to the participants were according to the requirements mentioned in the expert consensus guidelines (Stalder et al., 2016). In the saliva sample journal, besides the exact time of the saliva collection, participants also answered questions about the amount and quality of the sleep from the previous night.

The saliva collection was done by the participants in their homes on three non-consecutive week-days during the pre-training and post-training testing period. To measure the CAR, participants were instructed to give the first saliva sample right after awakening, followed by a second sample 30 minutes after awakening, and a third sample 60 minutes after awakening. After the collection, participants were instructed to store the salivettes in their fridge until their next lab appointment when they brought them in. The saliva samples were temporarily stored in a fridge in the laboratory after which they were shipped to Germany for analysis. Free cortisol was measured using a commercially available chemiluminescence-immuno-assay (IBL, Hamburg, Germany). Cortisol area under the curve measurements were calculated from the raw cortisol values according to Jens C. Pruessner et al. (2003). Area under the curve with respect to ground (AUCg) looks at the total cortisol output post-awakening, which reflects the total concentration of cortisol released post-awakening. The second measurement is called the area under the curve with respect to increase (AUCi), and it only measures the additional cortisol released after awakening (or after the first sampling point). This value reflects the variability in cortisol, or the sensitivity of the endocrine system post awakening, and it is more sensitive to sampling error and individual variability (Clow, Thorn, Evans, & Hucklebridge, 2004; Hellhammer et al., 2007).

3.2.5. Fitness and Mobility Assessments

Maximal Aerobic Power (MAP): The maximal aerobic power was calculated as the highest power (in Watts) reached during a continuous graded maximal oxygen uptake test on a stationary bike. If the participant was not able to finish the whole final level, the amount completed was taken into account when calculating the MAP. The oxygen values could not be used because of a gas analysis malfunction during the study. The protocol has been already described previously (Berryman et al., 2013).

10-meter walking test (10MWT): Starting from a stationary standing position, the participants were asked to walk as fast as possible in a straight line for 10 meters. Three trials were recorded per participant before and after the training period with a hand-held stopwatch, and the fastest trial (values were transformed in speed – m/s) was used for statistical analysis. This test is widely used in assessing the mobility of older adults (Middleton, Fritz, & Lusardi, 2015).

3.2.6. Cognitive Assessment:

Mini Mental State Examination (MMSE; Folstein, Folstein, and McHugh (1975): MMSE has been used in this study in order to evaluate general cognitive abilities of all participants as a screening tool. This 5-10 minutes structured interview was administered by a trained neuropsychologist during the first visit to the laboratory. This assessment includes items that measure orientation, registration, attention, calculation, recall, and language. To be eligible for the study, participants had to show no clinically significant impairment in cognition (a score higher than 24/30).

3.2.7. Psychological Assessments:

Geriatric Depression Scale (GDS; (Yesavage et al., 1983): The GDS is a 30-item questionnaire measuring depressive symptoms in the elderly. The scale is considered to have a high degree of reliability, validity and a good sensitivity-specificity ratio (Yesavage et al., 1983).

State-Trait Anxiety Inventory (STAI; (Spielberger, Gorsuch, & Lushene, 1970): This questionnaire measure the extent to which people experience trait-like anxiety symptoms (STAIT). The questionnaire is comprised of 20 self-report questions answered on a 4-point Likert scale. The scale has a high degree of reliability and validity (Kabacoff, Segal, Hersen, & VanHasselt, 1997).

Quality of Life (SF-12; (Ware, Kosinski, & Keller, 1996): SF-12 is a 12-item self-report questionnaire measuring mental (SF12-M) and physical (SF12-P) functioning reflecting quality of life. The scale has been validated and standardised with a general US population, so that a value of 50 represents the mean of the population and the standard deviation of 10 (Ware, Kosinski, & Keller, 1998). As a result, the self-report results are weighed and calculated in relation to the general population. The scale is considered to have a high degree of validity and reliability (Ware et al., 1996).

Lubben Social Network Scale – Revised (LSNS-R; (J. E. Lubben, 1988): LSNS is a 12-item self-report questionnaire that measures social engagement among the elderly. The scale is made from two components that look at family and friend relationships, and it is answered on a 5-point Likert scale, with a higher score indicating more social engagement. LSNS-R is considered to have a high level of validity and reliability (J. Lubben et al., 2006).

Pittsburgh Sleep Quality Index (PSQI; (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989): The PSQI is a 19 individual item self-report questionnaire measuring the sleep quality during the past month prior to the test. The total score can range from 0 to 21 and a value higher than 5 might indicate poor sleep quality. The scale is considered to have a high degree of reliability and validity and a good sensitivity-specificity value (Carpenter & Andrykowski, 1998).

3.2.8. Statistical Analysis:

All statistical analyses were performed using IBM SPSS Statistics software v20 for Windows (IBM, Inc., Chicago, IL). Data distribution was checked by looking at the kurtosis and skewness of all variables, and in order to decrease the impact of extreme outliers a ceiling value of 3 SD away from the mean has been set (Tabachnick, Fidell, & Osterlind, 2001).

In the case of cortisol outliers, the mean and SD was calculated based on all the participants' corresponding day and sample time. In addition, missing cortisol values were replaced with the mean value obtained from the other two days available for the same participant's corresponding sample time (Stalder et al., 2016). In all cortisol analyses, BMI and sex has been used as covariates due to their close link to HPA regulation (Rosmond, Dallman, & Bjorntorp, 1998; Van Cauter, 1996). In addition, to control for the previously documented high inter-individual day-to-day variability of the CAR (Hellhammer et al., 2007; Law, Hucklebridge, Thorn, Evans, & Clow, 2013) the three sampling days have been averaged, and a repeated measure ANOVA has been run using group as a between subjects variable and time (pre/post testing), and hour (wake up: C1, +30 minutes: C2, and +60 minutes: C3) as within subjects variables. The same analyses have been performed on the original cortisol data as well as the corrected data (for outliers and missing data) and no difference has been observed in terms of significant results. Therefore, the corrected data has been used to take advantage of the full sample and increased power. For the physical fitness and psychological variables, a repeated-measure ANOVA was used with group as a between-subject variable and time as within-subject variable. All reported p-values are two-tailed, the significance level was set to .05, and where necessary, Bonferroni corrected post-hoc tests were used.

3.4. Results

3.4.1. Baseline data

All baseline values for each respective group are shown in **Table 1**. The sample did not show any significant difference between groups for the demographic variables. For the variables of interest, there was a significant group difference on the second sample of cortisol (C2: 30 minutes after awakening) with the DMT group showing higher values than the AT group. As a result, in all subsequent analysis involving this variable baseline C2 was used as covariate. Everybody scored in the healthy range on MMSE, and there were no group differences in terms of depression or anxiety.

3.4.2. Cortisol data

Using BMI, sex, and the baseline cortisol difference (C2) as covariates, a 2 (group) X 2 (time of testing) X 3 (hour of sample) repeated measure ANOVA, revealed a significant group X time interaction ($F_{(2,34)} = 5.79$, $p = .01$, $\eta^2_{partial} = .25$; **Figure 1**). Two separate repeated measures ANOVAs performed on the pre-training and post-training data separately, revealed only a group difference post-training ($F_{(2,34)} = 5.94$, $p = .01$), with the DMT group having significantly lower cortisol values than the control group ($p = .01$). The simple effect of time within each group, showed only a significant decrease in cortisol level in the DMT group ($F_{(1,9)} = 10.38$, $p = .01$), while the other two groups showed no significant change from pre- to post-training. The same pattern of group differences to the advantage of the DMT group was also observed when calculating the area under the curve in respect to the ground (AUCg; **Figure 2**), while no change was observed when looking at the area under the curve with respect to awakening (AUCi; **Figure 3**).

[Insert figure 1 here]

[Insert figure 2 here]

[Insert figure 3 here]

3.4.3. Secondary data:

A repeated-measures ANOVA looking at the effects of the training group on the VO_2Max MAP revealed a significant time effect ($F_{(1,37)} = 19.00$, $p < .000$, $\eta^2_{partial} = .34$), and a time X group interaction ($F_{(2,37)} = 15.25$, $p < .000$, $\eta^2_{partial} = .45$; **Table 2**). When looking at the effect of the training program within each group only the AT group showed an augmentation in MAP from pre- to post-training ($F_{(1,13)} = 25.87$, $p < .000$, $\eta^2_{partial} = .67$). When looking at the 10-meter walk test only an effect of time was observed ($F_{(1,37)} = 10.68$, $p = .002$, $\eta^2_{partial} = .22$; **Table 2**). Although the DMT group did show a larger improvement in walking speed (see **Table 2**) there was no group X time interaction. The psychological variables measured (GDS, STAIT, PSQI, SF12-P, SF12-M, LSNS-R, average hours slept/night) showed no significant change after the training program (**Table 2**).

[Insert table 2 here]

3.5. Discussion and conclusion

The present study investigated the effects of a 3-months DMT or AT on the CAR in healthy older adults in relation to a passive control group. It was hypothesised that both physical training programs would decrease cortisol, but DMT was expected to have superior benefits. The results show that unlike AT or the control group, a three months DMT program lowered the total concentration of cortisol released during the first hour after awakening. To our knowledge, this is the first study to find a relationship between DMT and the CAR. As a result, the first hypothesis was only partially supported, as it was expected that both training groups would show a decrease in the CAR AUCg. Nevertheless, the second hypothesis was supported by finding a larger benefit of the DMT over the AT on cortisol secretion. The lack of change in cortisol AUCi is not unexpected due to its known high individual variability and stability over time (Elder, Ellis, Barclay, & Wetherell, 2016). Indeed, studies have shown that the cortisol AUCi is more resistant to change, and usually more than 6 sample days should be used in order to obtain accurate AUCi values (Law et al., 2013; Stalder et al., 2016). In terms of physical functioning, only the AT program improved cardiovascular fitness, while mobility seems to have improved across all three groups. Under a closer look, the DMT group showed the highest improvement in walking speed and was the only group to reach a clinically significant improvement. In addition, no effects of any of the two types of training were found on the psychological variables measured, namely, depression, trait anxiety, sleep quality, quality of life, or social network.

The current literature shows that aging is accompanied by an overall increase in cortisol both throughout the day and after awakening (Piazza et al., 2010). As a result, preventive interventions that can regulate the release of cortisol should be investigated in order to diminish the negative impact of HPA hyperactivity. In the case of this study, the main finding supports the beneficial link between DMT and healthy hormonal stress regulation. Those results complement previous studies demonstrating a similar link between DMT and perceived stress, both in healthy older adults and in clinical populations (Bräuninger, 2012, 2014; Ho & Fong, 2017; Kluge et al., 2011). Notably, the current results suggest that DMT can have an impact on stress-related hormonal regulation independent of perceived psychological effects. Indeed, the present study failed to replicate previous findings relating DMT to perceived quality of life benefits, or psychological well-being (S. Koch et al., 2014). Although links between DMT and health-related psychological outcomes are often observed (S. Koch et al., 2014), other studies have also failed do replicate it (Hackney & Earhart, 2009b; Pacheco et al., 2016), possibly due to methodological differences between studies (S. Koch et al., 2014).

In addition, AT was ineffective in changing the CAR. Although there is a known link between cardiovascular fitness and hormonal regulation (Lucertini et al., 2015), the current study failed to show a decrease in the CAR following improvements in cardiovascular fitness through aerobic training in healthy older adults. Results show this lack of association was not due to an ineffective training program, as can be observed from the increase in VO_2Max MAP which was limited to the AT group. Therefore, simply improving cardiovascular fitness was not sufficient to affect the CAR in healthy older adults. This has already been seen in the literature, with some studies showing a positive link, but not others (Lucertini et al., 2015). Similar to the current findings, Hayes et al. (2013) failed to see a change in basal salivary cortisol following an improvement in aerobic fitness in older adults. However, the 6-week moderate aerobic training showed other hormonal benefits unrelated to cortisol. Moreover, in another 6-week aerobic intervention study, only females showed a decrease in plasma cortisol, even though both men and women improved their aerobic fitness (Baker et al., 2010).

Lastly, the improvement in mobility seen in this study seems to be unrelated to any of the training programs. As a result, this paper failed to replicate the beneficial effects on mobility seen in numerous other studies using both aerobic or DMT interventions (Cruz-Ferreira et al., 2015; Krampe et al., 2014; Macko et al., 1997; Serra et al., 2016). This can be caused by a possible contamination of the control group (Ehlers, Fanning, Awick, Kramer, & McAuley, 2016). Due to a lack of objective follow-up on how much exercise the control group performed during the study it is hard to say if they were fully sedentary. However, although all three groups showed an increase in walking speed, the DMT group had the highest increase in speed of .16 m/s. Moreover, the DMT group is the only one to show a substantial increase in walking speed that reflects clinical significance of .1 m/s (Perera, Mody, Woodman, & Studenski, 2006).

The present study has limitations. In addition to the small sample and the limited number of male participants, the control group challenges the interpretability of the results, due to its passive nature, and due to the improvement in mobility. Future studies should investigate which components of DMT might affect stress by using active control groups that are well monitored. Moreover, sex differences are known to exist in studies investigating cortisol in relation to physical training (Baker et al., 2010). Although the present study used sex as a covariate, due to the small number of males in the sample it was impossible to further investigate this. This should, however, be addressed in the future.

In conclusion, results of this study identify DMT as an effective program in regulating chronic stress hormones in older adults, and suggest that DMT could be an effective program to be implemented with older adults. Although this effect was shown to be independent of cardiovascular fitness, it is possible that the effect of DMT was related to other psychological or mobility factors specific to the DMT program that was not captured through the measures used. Future studies will be needed that clarify which specific components of DMT have a positive impact on the CAR, in order to better understand the mechanism of this relationship and inform the development of more targeted interventions. In addition, future studies should further investigate whether the beneficial effects of DMT on the HPA regulation can lead to a better quality of life, or to fewer impairments that are normally associated with cortisol hypersecretion in older adults in order to confirm the potential direct (or real-life) health implications associated with DMT. The current results therefore suggest that taking part in DMT programs may have benefits in terms of stress levels among older adults, while the mobility benefits need further clarification.

Chapter 4: General Conclusions

4.1. Summary and Conclusions

The aims of the current study were to identify the potential benefits of two physical training programs, namely aerobic training and DMT, on the cortisol awakening response of healthy older adults. The current literature reviewed supports the existence of a possible link between physical activity and stress biomarkers. Although the link between cardiovascular fitness and healthy HPA regulation is already known (Lucertini et al., 2015; Peeters et al., 2007), results from aerobic intervention studies are mixed. Similarly, the literature linking DMT and stress or cortisol is still limited and should be further investigated. To study this relationship, 40 participants were randomly assigned to the two training programs or the passive control group for three months. Before and after this period salivary cortisol samples were taken in addition to physical and psychological measurements.

The article presented showed that a 3-months DMT program lowered the total concentration of cortisol released after awakening. In addition, this change was unrelated to aerobic fitness improvements. While the psychological constructs measured showed no change, mobility improved in all three groups.

The current study complements the existing literature by revealing that physical activity can have a beneficial effect on the CAR independent of aerobic fitness improvement. In addition, the study also opens the door for future research investigating possible mechanism through which DMT can affect stress. For example, it has been suggested that different types of physical activities might have different effects on cortisol secretion (Corazza et al., 2013). This can be caused by the fact that different physical activities have different acute effects on cortisol secretion, or because more multimodal activities might involve other components known to impact hormonal secretion. As a result, DMT, a multi-modal physical activity program, reflects the impact of exercise beyond the cardiovascular component, seen in pure aerobic training.

The unresolved question of this study is mostly dealing with some psychological or mobility components that were not detected through the measurements administered, and that could have influenced the decrease in cortisol in this study. For example, DMT is known to improve emotional expression and regulation, and to improve social functioning (Anderson, Kennedy, DeWitt, Anderson, & Wamboldt, 2014; Bräuninger, 2014; S. Koch et al., 2014). Moreover, the same psychosocial variables are also known to affect stress biomarkers (Chida & Steptoe, 2009; Childs & de Wit, 2014; Lai et al., 2012). In addition, there is some evidence suggesting that interactive dance is more enjoyable than other traditional physical activities (Gao, Zhang, & Podlog, 2014), and it has general positive effects on mood, and well-being (Stevens-Ratchford, 2016). Therefore, the effect of dancing on stress in our study could be related to the participants feeling better, forming a close social network, and enjoying the activity, rather than being merely related to the physical component of the activity, but future studies should further investigate this in more detail.

Similarly, it is not clear whether the improvement in mobility might have influenced hormonal regulation. Even though the DMT group is the only one to have had a clinically significant improvement in mobility, there was a positive change in all three groups. Previous studies have shown that DMT can improve mobility, through a faster walking speed (Krampe et al., 2014), an improved balance (Filar-Mierzwa et al., 2016; Serra et al., 2016), or a better overall physical fitness (Cruz-Ferreira et al., 2015). Moreover, older adults with higher mobility also show a healthier CAR (Pulopulos et al., 2016). Therefore, it is also possible that mobility might play a role in the relationship between DMT and hormonal regulation.

Even though the DMT program improved the CAR, the benefits of the AT should not be overlooked. There are multiple studies reviewed above linking aerobic fitness with healthy outcomes and longevity, and the current results show that AT improves physical fitness even though it doesn't affect cortisol secretion. However, both aerobic fitness and healthy hormonal regulation are important for healthy aging. Therefore, one potential avenue for future research should be to investigate whether a multi-modal program combining both aerobic and DMT components might be able to show combined benefits on aerobic fitness and cortisol secretion. Otherwise, it might be useful to participate in both types of activities (AT and DMT).

Finally, DMT is a new type of multi-domain physical activity program that needs to be further researched and understood. The normal DMT program is comprised of different approaches and interventions, that have been partially investigated (Bräuninger, 2014; de Tord & Bräuninger, 2015). Although they are all based on approaches used in psychotherapy, more scientific data is needed to examine whether they all have similar beneficial effects in the context of DMT. The evidence so far shows that some DMT approaches (like dance improvisation, spatial synchrony, synchrony in efforts or working with a focus) might be more effective than others in some situations (Bräuninger, 2014). In addition, many early studies using DMT are methodologically poor (S. Koch et al., 2014). As a result, future studies should further investigate DMT and its components to better understand its health benefits in aging.

4.2. Limitations

A first limitation of the current study that challenges the generalizations of the results is related to the sample used. The number of the participants was relatively small, and it was mostly comprised of women. As a result, it is not clear if this sample is representative of the general older population. In addition, the current study had strict inclusion/exclusion criteria that limited the participants to those that were physically, psychologically, and cognitively healthy. As a result, the participants used were amongst the top of their age group given that the rate of disabilities increase with age. Having healthy participants also limits the effects of the training programs observed, as impaired individuals might show a different pattern of results. In addition, due to the selection bias, the participants that volunteered to participate in the study form only a subgroup that might not be representative of the whole population.

A second limitation concerns the training programs used. Although, the two active interventions were carefully planned, the amount and type of activity performed by the participants outside of the lab was not monitored. In addition, there was no data collected during the 3-months waiting period for the control group, and therefore it is not clear if they really continued to be sedentary. Even though the training programs used were carefully planned based on the available literature, there can be multiple ways of structuring AT or DMT programs. For example, it is not clear if the AT program would show different effects with a different combination of intensity, duration, or modality. Similarly, the DMT program is very liberal in the way it is structured, and it is not clear if there are some components that have a larger impact.

4.3. Future directions

The work presented as part of this thesis advances the knowledge in the field and leaves room for future studies that should further characterize the impact of different physical activities on the HPA axis. Based on the finding that DMT reduces the CAR, future studies should further investigate the exact components (psychological or physical) that have a beneficial impact. To do this, studies using active control groups can isolate and investigate separate components. For example, a control training group using only gross motor exercises and other similar physical exercises involved in DMT, but without the music, emotional, cognitive, or psychological components involved in DMT would shed light in what part of DMT might have an effect on stress biomarkers.

Secondly, future studies should also investigate the effect of music in DMT on stress biomarkers. Indeed, listening to music has the possibility of evoking a series of emotional responses like empathy, joy, happiness, sadness, or nostalgia that can even translate to physiological changes (Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Trochidis, Sears, Trân, & McAdams, 2013). In addition, music is known to have anxiolytic effects (Yehuda, 2011). For example, individuals listening to classical music in preparation for a stressful interview showed significantly lower subjective anxiety, lower heart rate, and lower systolic blood pressure (Knight & Rickard, 2001). Similarly, relaxing music has shown to reduce salivary cortisol levels in individuals exposed to pre-surgical stress (Miluk-Kolasa, Obminski, Stupnicki, & Golec, 1994). As a result, future studies should investigate in more detail what effect the music component of DMT has on cortisol secretion in older adults.

Furthermore, the relationship between cardiovascular fitness and healthy HPA regulation should be further investigated. To date, it is not clear what drives the beneficial relationship seen in cross-sectional studies, because the results from intervention studies are still inconclusive. Future studies should investigate if AT might have a beneficial effect on cortisol secretion in individuals with very low cardiovascular fitness. This could potentially show if aerobic fitness has a plateau effect on cortisol.

Although there are many opportunities for future studies, the work presents novel findings in that it provides the first evidence linking DMT to a hormonal stress biomarker. Those findings are extremely relevant to today's increasing older population, because it opens the door to alternative novel physical training programs that show physiological benefits. The unique benefits of DMT over other classical physical training programs might influence some individuals to choose this type of training. However, to maximize the health benefits, individuals should practice multiple types of physical activities.

Appendix

Table 1. Baseline Descriptive Data

Characteristic	F or χ^2	p	DMT (SD) n=12	AT (SD) n=14	Control (SD) n=14
Age	F= .12	.89	68.08 (7.59)	67.14 (4.35)	67.21 (4.12)
BMI (kg/m^2)	F= .62	.48	27.81 (5.29)	28.26 (4.67)	26.32 (6.32)
Education Level (years)	F= .75	.48	14.50 (3.12)	16.36 (4.41)	15.21 (4.02)
% Female	X^2=1.91	.39	66.7%	64.3%	85.7%
Attendance	F=.002	.96	90.7 (5.9)	90.9 (8.3)	N/A
MAP (Watts)	F=1.21	.31	118.75 (24.87)	111.64 (24.87)	101.36 (20.63)
10mW (m/s)	F= .83	.44	1.70 (.26)	1.83 (.28)	1.80 (.26)
C1 (nmol/l)	F= .90	.42	4.74 (1.37)	5.53 (1.48)	2.44 (.65)
C2 (nmol/l)	F=4.08*	.03	16.35 (7.89)	10.80 (3.52)	15.29 (4.00)
C3 (nmol/l)	F=1.65	.21	11.06 (4.52)	8.30 (3.69)	10.57 (4.13)
Average hours slept/night	F=.77	.47	7.54 (1.04)	7.31 (1.26)	7.00 (1.03)
Average wake-up time	X^2=63.73	.56	7:04 AM	7:05 AM	6:55 AM
MMSE	F= .634	.54	27.83 (1.53)	28.00 (1.24)	28.43 (1.45)
GDS	F= .05	.96	5.18 (5.93)	4.54 (4.27)	4.77 (5.63)
STAIT	F= .24	.79	30.75 (9.67)	33.21 (7.53)	31.64 (10.35)
PSQI	F=1.14	.33	5.33 (3.60)	7.43 (4.29)	5.64 (3.71)

Abbreviations: BMI: Body Mas Index; VO_2Max MAP: Maximal Aerobic Power obtained during a maximal oxygen uptake test; 10mW: 10 meter walk test speed; C1: Cortisol value at wake up; C2: Cortisol value 30 minutes after wakeup; C3: Cortisol value 60 minutes after wakeup (all cortisol values are average of the three sampling days); GDS = Geriatric Depression Scale; STAIT: State Trait Anxiety Inventory-Trait; PSQI: Pittsburgh Sleep Quality Index.
*$p < .05$.

Figure 1. The change in the Cortisol Awakening Response after controlling for sex, BMI, and C2.

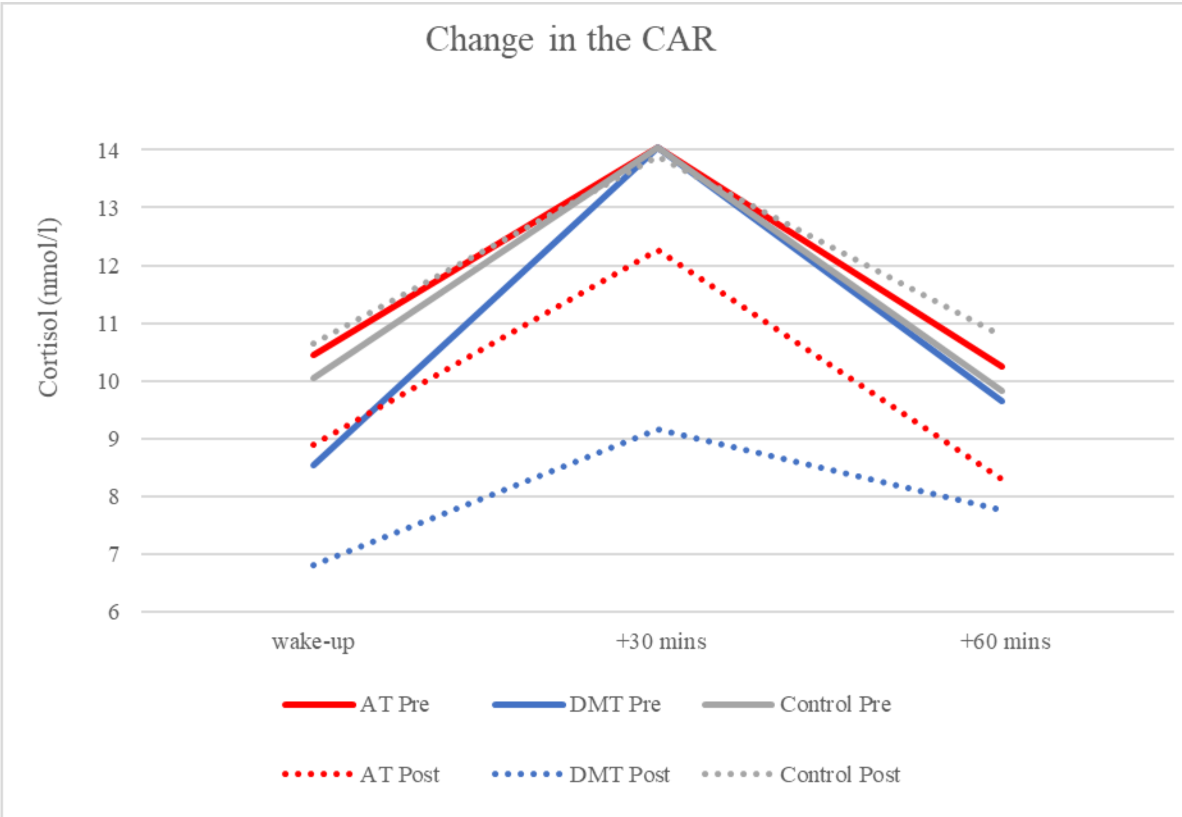

Figure 2. Change in cortisol AUC_g after controlling for BMI, sex, and baseline cortisol difference.

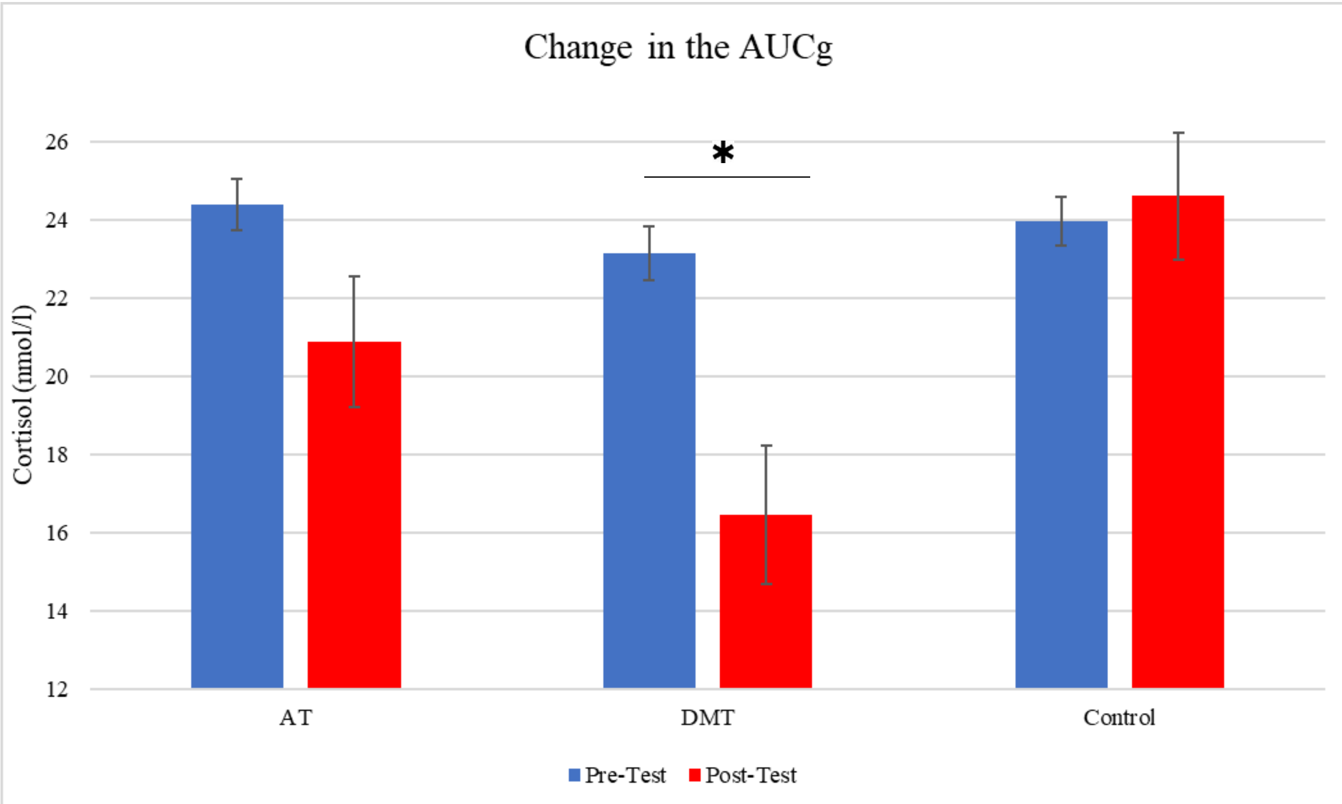

Figure 3. Change in cortisol AUC_i after controlling for BMI, sex, and baseline cortisol difference.

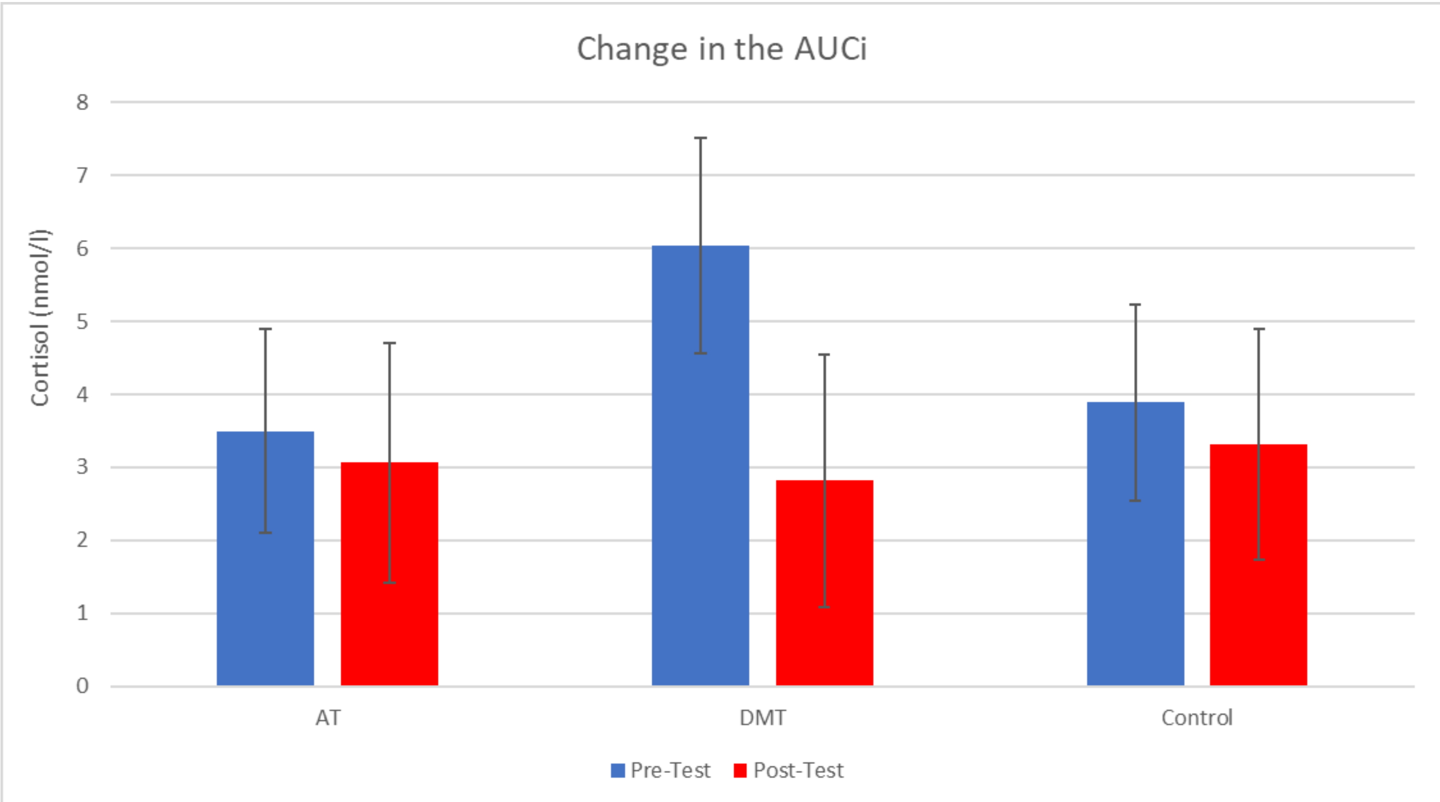

Table 2. The values obtained before (Pre) and after (Post) the training period on secondary variables, for all groups.

	AT			DMT			Control			time X group		time	
	Pre	Post	p	Pre	Post	p	Pre	Post	p	F	p	F	p
MAP (watts)	111.65	127.46	0.00**	118.75	119.83	0.63	101.36	101.64	0.76	15.25	0.00**	19	0.00**
10mW (m/s)	1.83	1.91	0.08	1.7	1.86	0.03*	1.8	1.86	0.29	0.95	0.4	10.68	0.00**
GDS	4.54	4.54	1	5.18	3.73	0.31	4.78	3.69	0.12	0.56	0.58	2.08	0.16
STAIT	33.21	31.57	0.174	30.75	29.92	0.67	31.64	31.43	0.83	0.3	0.74	1.34	0.25
PSQI	7.43	6.5	0.48	5.33	4.67	0.34	5.64	5.21	0.56	0.07	0.93	1.49	0.23
SF12-P	48.87	52.33	0.17	51.87	53.85	0.12	53	53.62	0.68	0.62	0.55	3.63	0.07
SF12-M	49.76	52.39	0.32	53.03	53.51	0.84	52.5	51.84	0.84	0.4	0.68	0.27	0.6
LSNS-R	32.5	31.29	0.47	32	31.67	0.77	29.77	32	0.21	1.41	0.26	0.07	0.8
Hours slept/night	7.31	7.36	0.83	7.54	7.51	0.91	7	7.24	0.27	0.37	0.69	0.39	0.54

Abbreviations: MAP: Maximal Aerobic Power obtained during a maximal oxygen uptake test; 10mW: 10 meter walk test speed; GDS = Geriatric Depression Scale; STAIT: State Trait Anxiety Inventory-Trait; PSQI: Pittsburgh Sleep Quality Index; SF12-P: Quality of Life – Physical Functioning; SF12-M: Quality of Life – Mental Functioning; LSNS-R: Lubben Social Network Scale – Revised.

*p < .05, **p<.01

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