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Autonomic cardiac regulation, blood pressure and cardiorespiratory fitness responses to different training doses over a 12 week group program in the elderly

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ABSTRACT

Aim: The study assessed the effects of different weekly training frequencies performed over a 12 week exercise programme (strength, endurance, balance) on autonomic cardiac activity, blood pressure and cardiorespiratory fitness (CRF) in elderly individuals.
Methods: Fifty-eight individuals participated in the study: 2TG (N = 24, 71.1 ± 6.4 yrs; 19 females, 5 males) performing two, 60 min sessions/week; and 3TG (N = 34, 72.3 ± 7.9 yrs; 25 females, 9 males) performing three, 60 min sessions/week. Time domain and spectral analysis of heart rate variability (HRV) quantified autonomic cardiac regulation.
Results: Natural logarithm (Ln) transformation was applied to all HRV parameters. There were significant reductions in total power (Ln TP) ($p = 0.006$), low frequency (Ln LF) ($p = 0.013$), high frequency (Ln HF) ($p = 0.013$) and root mean square of successive differences (Ln rMSSD) ($p = 0.014$) post training in 3TG after intervention. Diastolic BP (DBP) decreased significantly in both groups (2TG: $P < 0.001$; 3TG: $P < 0.001$). Both groups showed significant improvements in six-minute walk distance (2TG: $P = 0.003$, 3TG: $P = 0.001$). However, there were significant HRV differences between 2TG and 3TG for Ln TP ($P = 0.018$), Ln LF ($P = 0.049$), Ln HF ($P = 0.039$) and Ln rMSSD ($P = 0.049$).
Conclusions: A combined exercise programme resulted in improved DBP and CRF irrespective of training two or three 60 min sessions/week. However, training three, sessions/week induced negative health-related changes in autonomic cardiac activity through reducing HRV parasympathetic function, while HRV was maintained in the group training twice a week.

1. Introduction

Dysregulation of the autonomic nervous system (ANS) is found in chronic disease (Koskinen et al., 2009; Thayer, Yamamoto, & Brosschot, 2010). Heart rate variability (HRV) is accepted as a non-invasive technique to examine ANS function (Besnier et al., 2017) with measures providing an indication of parasympathetic/vagal and sympathetic autonomic cardiac regulation (Kingsley & Figueroa, 2016).

Aging is associated with a progressive rapid decrease in HRV measures (Carter, Banister, & Blaber, 2003; Liao et al., 1996) from the second to the fifth decade (Zulfiqar, Jurivich, Gao, & Singer, 2010). The decrease then slows, with the HRV sympathetic function continuing to decrease, while the decrease in HRV parasympathetic function follows a U-shaped pattern, reaching its nadir in the seventh (Almeida-Santos et al., 2016) or eighth (Zulfiqar et al., 2010) decade followed by a reversal and progressive increase to higher levels characteristic of a younger population (Zulfiqar et al., 2010).

Previous studies have demonstrated an association between the decrease in HRV and the various chronic diseases and

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pathological conditions associated with ageing, such as congestive heart failure, coronary artery disease (CAD), hypertension, postprandial hypotension, sudden death syndromes, asymptomatic left ventricular dysfunction, cardiovascular risk factors and diabetes (Billman, 2002; Routledge, Campbell, Mcfetridge-Durdle, & Bacon, 2010; Ryan, Goldberger, Pincus, Mietus, & Lipsitz, 1994; Sandercock, Bromley, & Brodie, 2005; Thayer et al., 2010). Preservation of autonomic function, in particular parasympathetic function, has been proposed to be a key determinant of health and longevity (Almeida-Santos et al., 2016; Zulfiqar et al., 2010).

Research has demonstrated positive effects of physical activity (PA) on parasympathetic measures of HRV in the elderly (Soares-Miranda et al., 2014). A number of studies have examined the effect of structured exercise training programmes on HRV in the elderly, however findings are conflicting (Boutcher and Stein, 1995; Carter et al., 2003; Leicht, Allen, & Hoey, 2003; Loimaala, Huikuri, Oja, Pasanen, & Vuori, 2000; Perini, Fisher, Veicsteinas, & Pendergast, 2002; Sandercock et al., 2005b; Verheyden, Eijnde, Beckers, Van Hees, & Aubert, 2006). Studies in the field of HRV and exercise have focussed predominantly on aerobic training (Carter et al., 2003; Jurca, Church, Morss, Jordan, & Earnest, 2004; Leicht et al., 2003; Sandercock et al., 2005b) with limited research examining the effect of combined endurance and strength training on such a cohort (Karavirta et al., 2009; Verheyden et al., 2006).

Although regular PA and exercise are critical for the promotion of health and function, there is a decline in PA level and participation in structured exercise programmes with ageing (King, Rejeski, & Buchner, 1998; Schutzer & Graves, 2004). It is well known that there are numerous variables affecting PA level and exercise adherence, with time available and frequency of training being two such variables. In this regard, it was argued that many elderly consider the adoption of moderate PA as time consuming (Chao, Foy, & Farmer, 2000). Research has demonstrated that a lower dose of moderate intensity exercise (72 min/week) is effective in promoting the health of postmenopausal women and could therefore circumvent the issue of time (Church, Earnest, Skinner, & Blair, 2007).

Based on the idea that exercise adherence is important for elderly and that exercise has been shown to improve HRV parasympathetic function, the present study was designed to determine if there is any difference in HRV measures between a two and three day weekly training intervention. We hypothesized that there would be a dose response with enhanced HRV parasympathetic function, blood pressure (BP) and cardiorespiratory fitness (CRF) in a group training three times a week compared with a group training twice a week over a twelve week training period.

2. Methods

2.1. Study participants

One hundred individuals aged between 60 and 86 years from five aged care facilities within the eThekwini Municipality were recruited for the study. Of the participants tested, 79.9% were female while 22.1% were male, representing a greater ratio of females to males (4:1). The South African National Consensus of 2011 reiterates this disparity by reporting a 5.02% difference in ratio in favour of females versus males in the population aged 65 years and older. The greater female to male ratio can further be attributed to the larger number of respondents (54%) who reported to have been widowed. The ethnic distribution of the sample indicates that nearly three-quarters of the patients were of South African Indian origin (74%). Whites and Coloureds (mixed ethnic origin) represented 14% and 11% respectively, while Blacks accounted for the smallest grouping in the sample at 1%. While this composition may not be reflective of the current demographic trends in the province of KwaZulu-Natal or South Africa, all five old age homes used in the study were located in predominately Indian areas within the municipality. The participants were subjected to a medical history and physical examination directed at identifying cardiac risk factors, signs/symptoms upon exertion, and contra-indications to exercise testing/training and physical limitations. The screening and clearance for participation in the study was conducted by a sports and exercise medicine physician.

The eligible participants at each site were initially randomized to either 2TG (supervised exercise session; two days/week) or 3TG (supervised exercise session; three days/week) for a 12 week period. However, only fifty-eight complete sets of data (2TG: N = 24 (19 females; 5 males); 3TG: N = 34 (25 females; 9 males)) were available for analysis upon conclusion of the study. Reasons for incomplete data sets included not attending a minimum of 80% of the exercise sessions (n = 10), illness (n = 16) and the strict criteria relating to the quality of the R–R interval data collected (n = 16). Written informed consent was obtained from all study participants. The study was approved by the Institution's Biomedical Research Ethics Committee (REF; BE 251/11).

2.2. Baseline and post-testing

Testing was conducted at each of the respective aged care facilities 48 h pre the first training session and then 48 h post the final exercise session. Study participants were asked to avoid heavy physical activity, alcohol, smoking, food and caffeine containing food or beverages for 10 h prior to testing. Food ingestion was permitted if chronic medications needed to be taken, provided that there was no eating within two hours prior to testing. Individuals were identified if they deviated from this requirement but were not excluded from participation in the study. Study participants that were on chronic medication/s were requested to continue as per the prescription dictate.

2.2.1. Anthropometric and blood pressure measures

Height and weight measurements were used to calculate body mass index (BMI) which was calculated as follows: BMI = weight/height^2. Resting heart rate (HR) and blood pressure (BP) (Bokang Aneroid Sphygmomanometer CE 0483, Procare Rapport Stethoscope Deluxe-30DR) was measured according to the recommendations of the American Heart Association (Pickering et al., 2005).

2.2.2. Heart rate variability measures

To measure R–R intervals, Suunto HR memory belts (Suunto Team system, model t6, Finland) were used (Sookan & Mckune, 2012). Each participant was fitted with a belt that was placed just below the chest muscles after water was applied to the under surface to ensure good conduction. Each belt was interfaced with the Suunto Team Manager Software programme for purposes of monitoring continuous R–R intervals (Sookan & Mckune, 2012). Each participant sat quietly on a chair in an upright position for 15 min prior to the commencement of HRV recording. Although HRV is higher seated than supine, the seated posture was selected for its practicality and convenience (Acharya, Kannathal, Hua, & Yi, 2005). While both supine and standing recordings are often used in the literature (Botek, Mckune, Krejci, Stejskal, & Gaba, 2014) seated recordings are recommended for comfort, and the chance that a subject will fall asleep during the procedure is less than during supine measures (Buchheit, 2014). R–R interval recording lasted 5 min. These were stored in the Suunto Team Manager Software programme and then later exported as a text file for time domain and spectral HRV analysis using the VarCor PF7 diagnostic device software (DIMEA Group, Olomouc, Czech Republic). The R–R intervals were examined, and all premature ventricular