Journal of Human Sport and Exercise
E-ISSN: 1988-5202
jhse@ua.es
Universidad de Alicante
España

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Journal of Human Sport and Exercise, vol. 12, núm. 3, 2017, pp. 680-688
Universidad de Alicante
Alicante, España

Original Article

Resting cardiac autonomic activity and body composition following a 16-week high-intensity functional training intervention in women: A pilot study

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ABSTRACT

High-Intensity Functional Training (HIFT) is an increasingly popular mixed modal high-intensity training style with little empirical evidence regarding adaptations. The objective of this study was to examine alterations in resting cardiac autonomic activity through the measurement of heart rate variability (HRV) and body composition in women following 16-weeks of HIFT. Nine apparently healthy females (35.8 ± 9.3 years old) participated in this study. Resting heart rate (RHR), HRV, and body composition measures were collected pre and post 16-weeks of the HIFT intervention. The markers of HRV used were the Root Mean Square of Successive Differences (RMSSD) and High-Frequency (HF) power. Body composition markers used were body fat percentage (BF%) and body mass (BM). A natural log transformation (ln) was applied to HRV markers prior to analysis. Paired sample t-test showed significant reductions in post RHR ($p = 0.018$) and BF% ($p = 0.012$). However, no significant changes were observed in post lnRMSSD ($p = 0.501$), lnHF ($p = 0.760$), or BM ($p = 0.285$). 16-weeks of HIFT was not sufficient to alter makers of HRV. Importantly, the participation in 16-weeks of HIFT elicited improvements in basic health measures (RHR and BF%) in recreationally active females. **Key words:** VAGAL TONE, EXERCISE, BODY MASS, HEART RATE.

Cite this article as:
Bechke, E., Kliszczewicz, B., Feito, Y., Kelemen, H., & Nickerson, B. (2017). Resting cardiac autonomic activity and body composition following a 16-week high-intensity functional training intervention in women: A pilot study. *Journal of Human Sport and Exercise, 12*(3), 680-688. doi:https://doi.org/10.14198/jhse.2017.123.12

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Submitted for publication June 2017
Accepted for publication August 2017
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2017.123.12

INTRODUCTION

Currently, less than one in five women in the United States participate in recommended amounts of aerobic and strength exercise (Carlson et al., 2010). Common deterrents of physical activity amongst women include lack of time, lack of motivation, and a fear of incompetence regarding resistance exercises (Edwards, 2014). Recently, high intensity functional training (HIFT) has demonstrated a greater adherence amongst general population participants (Heinrich, 2014), and possesses three of the top five projected fitness trends of 2017 (i.e., Body Weight Training, High-Intensity Interval Training, and Strength Training) (Thompson, 2016). HIFT is a mixed modality training program commonly performed in a group environment and employs both resistance based exercise and aerobic conditioning while being performed at high-intensities with minimal rest (Heinrich et al., 2014). These qualities address the aforementioned deterrents amongst female participants, providing the rational that HIFT would be an appealing and suitable style of training intervention for women (Carlson et al., 2010; Heinrich et al., 2014; Thompson, 2016).

Despite the attractiveness of this style of training, little research exists to suggest the effectiveness of HIFT on basic physiological measures amongst females. A common evaluation of physiological improvements following an exercise intervention is achieved through changes in body composition (e.g. body mass and body fat percentage). However, this fails to provide a holistic representation of overall adaptation. In this regard, the measure of cardiac autonomic activity (such as, heart rate variability and heart rate) provides a pragmatic and noninvasive evaluation of the homeostatic condition, which indicates a readiness to respond to physiological stressors (Stanley et al., 2013).

Parasympathetic nervous system (PNS) activity is responsible for the control of mechanisms that regulate a multitude of systems (e.g. cardiovascular, digestive & respiratory systems) at rest and is pivotal in returning these systems to a homeostatic state when a disturbance such as exercise occurs (Borresen & Lambert, 2008; Stanley et al., 2013). Chronic challenges to homoeostasis through exercise provide stimulus for cardiac autonomic adaptation and improve basal measures of PNS activity (Kiviniemi et al., 2007). The indirect measure of systemic PNS control can be accomplished through the analysis of cardiac modulations via vagal activity (Stanley et al., 2013). Therefore, the analysis of vagal activity provides an indirect evaluation of the body's adaptation and response to exercise. A common measure of vagal activity is heart rate variability (HRV), which can be achieved through the quantification of modulations in beat-to-beat intervals derived from a electrocardiogram or a beat-to-beat measuring device (Malik, 1996; Buchheit et al., 2007). In general, greater variation amongst beat-to-beat intervals indicates a greater degree of vagal control (i.e. greater HRV). Greater vagal activity has been related to improved recovery status and in broader terms a decrease in morbidity and mortality (Dekker et al., 2000). A proven intervention to elicit positive adaptations in cardiac autonomic function (HRV and resting heart rate [RHR]) (Yamamoto et al., 2001; Kiviniemi et al., 2007) and body composition is exercise.

Currently, there is a scarcity of research evaluating cardiac autonomic adaptation following exercise interventions in the female population. The relationship between HRV and the homeostatic condition make it a viable marker for the examination of physiological improvements following exercise interventions. HIFT is an understudied style of exercise that provides an appeal for the general female population, leading to the importance of the evaluation in its effectiveness as an exercise intervention. The evaluation of cardiac autonomic activity in conjunction with body composition provides a non-invasive and comprehensive evaluation of adaptation. Therefore, the purpose of this study was to evaluate the effectiveness of a 16-week HIFT intervention on body composition and resting cardiac autonomic function in female participants. We hypothesized this intervention would improve both body composition and markers of resting autonomic function.

MATERIALS AND METHODS

Participants

Participants were recruited via word of mouth from a local CrossFit™ (CF) affiliate in the local metropolitan area. During their first visit, participants reviewed the procedures of the study, signed a consent form, and filled out a health history questionnaire. Participants were considered "low risk" based on established guidelines (Whaley et al., 2005). All individuals reporting any orthopedic conditions, or suffering from cardiovascular, pulmonary, or metabolic disease were excluded from the study. The University Institutional Review Board approved all testing protocols and procedures prior to commencing data collection.

A total of 12 low risk females with at least three-weeks of CF experience were recruited. However, after the 16-weeks of training, three of these participants were excluded due to premature ventricular complex (PVC) abnormalities in their R-R recordings. Therefore, a total of nine women (35.8 ± 9.25 y; 161.8 ± 9.27 cm) were evaluated for pre and post intervention measures.

Measures

Anthropometric assessments

Anthropometric and body composition measures were completed PRE and POST 16-week intervention. Height (cm) and body mass (BM, kg) were measured using an electronic physician's scale (Tanita WB 3000, Arlington Heights, IL) with the participants standing barefoot, with feet together, and in light and comfortable clothing (e.g. shorts and t-shirt). Body fat percentage (BF%) was determined via dual-energy X-ray absorptiometry (DXA) (Lunar iDXA, General Electric Healthcare, Madison, WI) following manufacturer's recommendations. Total body estimates of BF%, were determined using the manufacturer's recommended procedures and supplied algorithms. Participant characteristics can be seen in Table 1.

Table 1. Pre-post intervention measures; BF%, BM, BHR, lnRMSSD, and lnHF

	N	Pre	Post	% Change	p Value	Cohen`s D	Effect Size
BF %	9	25.8 ± 5.51	22.9 ± 4.64*	12.08 ± 8.23	0.012	.57	.27
BM (kg)	9	61.1 ± 10.96	59.9 ± 9.61	0.23 ± 4.84	0.285	.11	.06
RHR (bpm)	9	63 ± 5.98	58.8 ± 7.31*	6.15 ± 6.17	0.018	.56	.27
lnRMSSD (ms)	9	3.69 ± 0.53	3.78 ± 0.45	5.98 ± 3.87	0.501	.18	.09
lnHF (ms^2)	9	3.86 ± 0.41	3.91 ± 0.43	30.21 ± 18.6	0.760	.12	.06

Measures of adaptation are presented as mean ± SD for the following measures; Body Fat Percentage (BF %), Body Mass (BM) Resting Heart Rate (RHR) Log Transformation of the Root Mean Square of Successive Differences (lnRMSSD) Log Transformation of High Frequency (lnHF)
* $p < .05$ is significantly different from Pre-intervention values

Heart Rate & Heart Rate Variability

Prior to measuring HRV, each participant was fitted with a Polar Heart rate monitor. HRV was assessed using a Polar Team[2] heart rate monitoring system (Lake Success, NY) while participants laid in a supine position on a matted floor in a quiet, dimly lit room. A ten-minute HRV recording was collected before and after the 16-week HIFT intervention. The files obtained were transferred from the Polar Team[2] system software and analyzed through the online Kubios Heart Rate Variability Analysis Software (Kubios HRV 2.2). The first five-minutes of the recordings were considered an adjustment period and were discarded. The last five-minutes of each ten-minute recording were used to analyze HRV and RHR. All files were examined for ectopic/non-sinus beats, which were replaced by the adjacent R-R interval when observed (Kiviniemi et al., 2007). Any segments containing three or more ectopic beats were excluded from the analysis (Parekh & Lee, 2005; Kiviniemi et al., 2007).

The time domain of the root mean square of the successive differences (RMSSD), and frequency domain as high frequency (HF) power (0.15-0.40 Hz) of the power spectral density were the selected markers of HRV for this study. RMSSD and HF are sensitive markers of vagal activity and have been used in several studies (Yamamoto et al., 2001; Goldberger et al., 2006; Kiviniemi et al., 2007; Kliszczewicz et al., 2016). In addition, RMSSD is not significantly influenced by breathing frequency and is capable of measuring parasympathetic activity in short periods of time (Esco & Flatt, 2014). To assess RMSSD, the R-R recordings were converted into a tachogram, which plots the successive R-R intervals (y-axis) against the number of beats within the recording (x-axis). From the tachogram, the five-minute segments were calculated for RMSSD (ms). Multiple components to the frequency domain exist (i.e., VLF, LF, HF, LF:HF); however the most widely accepted frequency marker of vagal activity is HF (ms^2) (Malik, 1996; Billman, 2013). The analysis of the frequency domain was performed by creating a power spectral analysis, derived from the application of the fast Fourier transformation to the R-R intervals of the sampled recording [8].

Procedures

All data were collected in the University's Exercise Physiology Laboratory (EPL). Participants reported to the EPL on two separate occasions for baseline and post intervention measures. The first visit occurred two-weeks prior to the initiation of the training period (PRE). After signing the informed consent, measures of body composition and cardiac autonomic activity were collected. The training style chosen for the 16-week HIFT intervention was CF, which took place at a local affiliate. During the intervention period, all participants were asked to adhere to the affiliate’s instructions and participate in at least two of the seven available training days. All training sessions and workouts were designed and directly supervised by a certified CF instructor/coach. The investigators did not have any control of the programming used throughout the 16-weeks and the instructors did not have access to any of the participant’s laboratory data. Within two-weeks of finishing the 16-week intervention, all participants reported back to the EPL to complete post-testing (POST) measures.

Analysis

Participants’ data was entered into Excel 2015 (Microsoft Co., Redmond, WA), and all statistical analyses were conducted using SPSS, version 24 for Mac (SPSS, Inc., Chicago, IL). A Shapiro-Wilk test was performed to determine the normality of the HRV distribution within the population. The data set violated normality; therefore, a natural logarithmic transformation was applied to RMSSD and HF data prior to further analysis (lnRMSSD and lnHF). A paired sample t-test was used to assess differences between pre and post-intervention values for body composition and cardiac autonomic markers following the 16-week intervention. Significance was set to alpha ≤ 0.05. Data is presented as means ± standard deviations.

RESULTS

A total of nine participants were analyzed for pre and post intervention measures. Following the intervention, a non-significant decrease in BM occurred, while a significant decrease in BF% was observed. Paired samples t-test did not reveal any significant differences in lnRMSSD and lnHF PRE and POST intervention. RHR measures were significantly lower following the 16-week HIFT intervention. All PRE and POST measures are presented in Table 1 and are presented as means, standard deviations, and percent change. injuries were reported during the 16-week training period.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to evaluate the effectiveness of a 16-week HIFT intervention in female participants through the measure of body composition (i.e. BF% and BM) and resting cardiac autonomic function (i.e. RHR and HRV). The primary findings of this study revealed a positive time dependent change in BF%, and RHR following the 16-week intervention (Table 1). However, no significant differences in BM or the HRV markers lnRMSSD and lnHF occurred after 16-weeks.

Exercise Training and Chronotropic Adaptation

Though HIFT is relatively new, it is well established that traditional single modality exercise training programs (e.g. aerobic and resistance) are pragmatic applications to elicit improvements in RHR within the general population (Levy et al., 1998; Yamamoto et al., 2001; Carter et al., 2003; Tulppo et al., 2003). For instance, Yamaoto et al. (Yamamoto et al., 2001) used an endurance-training program to examine RHR changes following six-weeks of training in healthy college aged males. This exercise intervention demonstrated an approximant 22% reduction in RHR. Similarly, Zarins et al. (Zarins et al., 2009) implemented a twelve-week intervention to examine vigorous aerobic exercise training in sedentary postmenopausal women and observed positive alterations in RHR (approximately 5% reduction). The findings of the current study support the literature in regards to positive chronotropic adaptation to exercise interventions (Levy et al., 1998; Yamamoto et al., 2001; Carter et al., 2003; Tulppo et al., 2003;). The changes observed in this study are relatively modest and likely due to an already lower baseline among our female participants (i.e. 63 ± 5.98 bpm). Previous evidence suggests that participants who posses a lower RHR at the beginning of an exercise intervention have a diminished potential for chronotropic improvements (Hickson et al., 1981; Stanley et al., 2013). Moreover, the modest improvements in RHR seen in our study may be a result of the age of our female participants who average 36 years old. Cater and colleagues (Carter et al., 2003) showed that females 40 years of age had blunted physiological improvements following a 12-week exercise interventions compared to aged matched males and younger participants.

To date, few studies have examined changes in HRV following mixed modal training programs such as HIFT within the female population; thus, making this study a novel venture. The general application of exercise training has proven to be an efficient mechanism to elicit favorable changes in indexes of HRV (e.g. RMSSD and HF) (Tulppo et al., 1998; Jurca et al., 2004; Kiviniemi et al., 2007). However, the literature presents conflicting results involving HRV adaptation following various populations and exercise interventions (Melanson et al., 2001; Tulppo et al., 2003; Forte et al., 2003; Kliszczewicz et al., 2016). For instance, Tulppo et. al. (Tulppo et al., 2003) observed increases in measures of lnHF in a group of sedentary men following an eight-week aerobic training intervention in moderate and vigorous exercise groups (9.2% change, 7.7% change, respectively). In addition, an eight-week aerobic exercise intervention amongst sedentary postmenopausal women elicited significant positive changes in RMSSD (24.9% change) and lnHF (10.6% change) (Jurca et al., 2004). Lastly, Melanson and Freedson (Melanson & Freedson, 2001) observed significant increases in both RMSSD (~40%) and lnHF (~7%) as early as 12-weeks of moderate-vigorous aerobic training in adult sedentary males. In direct contrast to these findings, a dynamic resistance training study performed by Forte et al. (Forte et al., 2003) observed non-significant changes in HRV following a 16-week period of low and high-intensity exercise in older females. In a similar HIFT intervention study conducted over a 15-week period amongst college aged males and females, no significant changes in resting lnRMSSD or lnHF were observed (Tulppo et al., 1998). This discrepancy within the literate suggests that intrinsic factors such as training status, age, and sex may influence autonomic adaptations in response to exercise interventions.

Influence of Aging on Vagal Activity

Age is a physiological factor that has been shown to have an inverse relationship with vagal control of the heart both at rest and during periods of exercise (Ryan, Goldberger et al., 1994; Tulppo et al., 1998; Yeragani et al., 1997; Carter et al., 2003). Tulppo et al. (Tulppo et al., 1998) observed vagal activity in apparently healthy males during rest and throughout various stages of a bicycle graded exercise test within young (24-34yr), middle-aged (35-46yr), and older (47-64yr) participants. Analysis showed the young participants had significantly higher HF values than the older group at rest and during the acute exercise bout. Importantly, an increase in age not only influences resting HRV, but it also has been shown to reduce HRV responsiveness to exercise interventions with increases in age (Carter et al., 2003). Though this relationship is understudied, the influence of age on vagal activity following an exercise intervention was investigated by Carter et. al (Carter et al., 2003), who compared four groups of recreational runners (20-year-old men and women, and 40-year-old men and women) prior to and following four-weeks of aerobic training. Upon completion of the intervention the younger groups demonstrated significantly greater alterations in HF when compared to the older age groups, which further emphasizes the importance of age on vagal activity (Carter et al., 2003).

Influence of Sex on Vagal Activity

Even though age plays an important role in vagal control and its responsiveness to exercise (Tulppo et al., 1998; Carter et al., 2003), sex has been shown to influence indexes of resting HRV in women, who tend to have greater resting vagal tone than men (Ryan et al., 1994; Kuo et al., 1999). This relationship was observed by Ryan et al. (Ryan et al., 1994) who compared resting HRV between physically active men and women, and found that women showed significantly greater HF than men. In addition, Kuo et al. (Kuo et al., 1999) found similar results among women showed greater HF up to the age of 45 when compared to men. These studies suggest that sex, independent of other factors (e.g. training status), positively influences resting HRV. This is an important observation in that elevated basal levels of vagal activity could result in diminished returns following exercise interventions. This concept is further demonstrated by the previously mentioned study conducted by Carter et al. (Carter et al., 2003) who compared pre and post HF measures following an aerobic training intervention between 20-year and 40-year old males and females. All groups demonstrated a positive increase in vagal activity; however, the 40-year old female group elicited the smallest change following the intervention and did not reach significance, suggesting that not only age, but sex blunted the training response.

Responders and Non-responders

Upon further investigation, a responder (n = 5) vs. non-responder (n = 4) relationship within the group population was observed. Responders showed increases in lnRMSSD and lnHF, while the non-responder group showed a decrease in these values. The responder vs. non-responder trends appear to have an inverse relationship with BF% (Figure 1). Though it is outside the scope of the study to determine the mechanisms between responders and non-responders in exercise interventions and vagal activity, these observations provide an intriguing rationale that a relationship exists. Therefore, future studies should include a larger sample size as well as groups stratified by body composition to better understand this relationship.

Based on the findings of the present study, 16-weeks of HIFT was successful in eliciting improvements in RHR and BF% in recreationally active females. However, the HIFT intervention was not sufficient enough to significantly alter markers of resting vagal tone (lnRMSSD and lnHF). Though this was a novel attempt to evaluate basic adaptations following HIFT training in females, it was not without its limitations. The final sample size of this study was relatively small, future studies should include a larger sample size in order to account for participant attrition. These findings also demonstrate the need to account for physiological factors such as age, sex, physical activity status, and body composition when evaluating vagal activity. It is important to note that HIFT demonstrated an ability to improve basic health measures despite the lack of changes in resting vagal tone, and should not be considered a detouring factor in HIFT participation. Research in cardiac autonomic adaption in females related to HIFT and other high-intensity styles of training is still limited and should be further investigated in order to better understand the physiological responses.

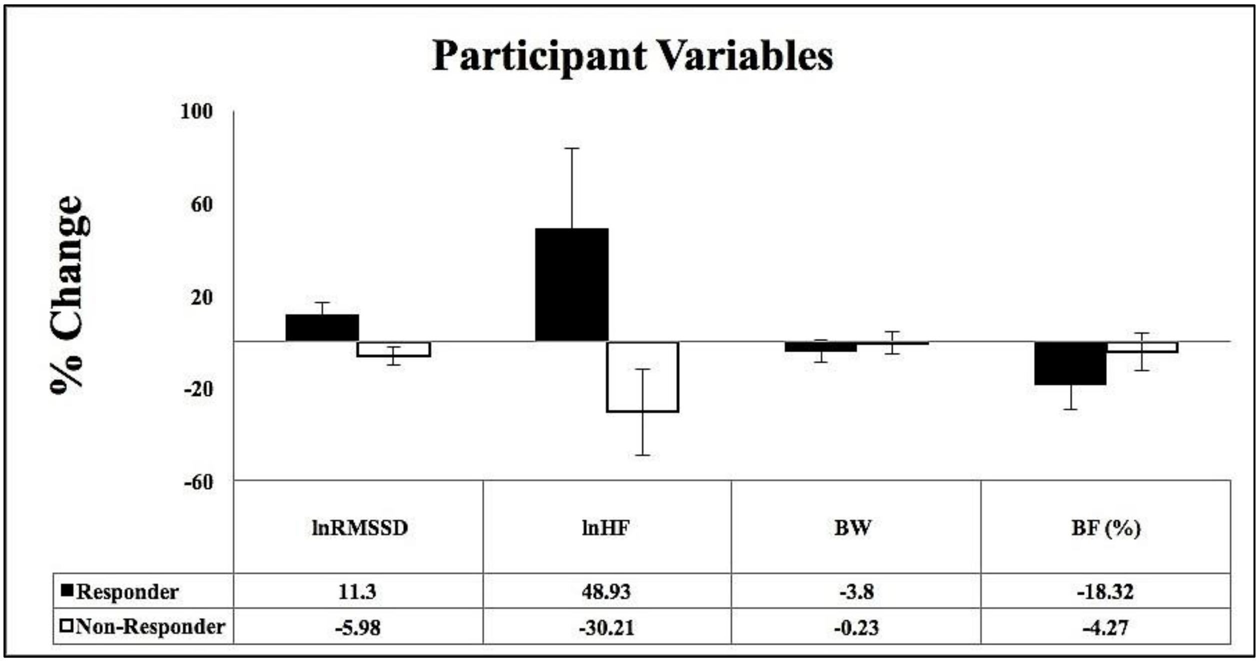

Figure 1. Responders vs. non-responders; lnRMSSD, lnHF, BW, BF

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