CBÜ Beden Eğitimi ve Spor Bilimleri Dergisi
CBU Journal of Physical Education and Sport Sciences
Cilt: 17, Sayı: 2, 2022
E-ISSN: 2149-1046
DOI: 10.33459/cbubesbd.1131190
URL: https://dergipark.org.tr/tr/pub/cbubesbd

Non-Invasive Assessment of Ultra-Short Time Heart Rate Variability During Wingate Test

Tuncay ALPARSLAN[1*], Ramiz ARABACI[2], Ali Kâmil GÜNGÖR[2]

[1]Aeromedical Research and Training Center, Eskişehir, TÜRKİYE
[2]Bursa Uludağ University, Faculy of Sport Sciences, Bursa, TÜRKİYE

Araştırma Makalesi / Research Article
Gönderi Tarihi (Received): 15/06/2022 Kabul Tarihi (Accepted): 19/11/2022 Online Yayın Tarihi (Published): 31/12/2022

Abstract

The aim of present study was to investigate the sedentary healthy men's ultra-short heart rate variability (HRV) during the Wingate Anaerobic Test (WAnT) (30-sec) and parasympathetic reactivation in the first 60-sec after WAnT. The final sample comprised 101 individuals (Mean±SD; Age=28.9±4.8 years, Height=176.5±5.5 cm, Weight=89.8±8.8 kg). Anaerobic powers were measured by WAnT. Heart rate variability (HRV) was then recorded as 60-sec before the test for 30-sec and 60-sec after the test. HRV was measured by Polar V800 GPS Sports Watch with Heart Rate Monitor and Polar H7 band. To compare the testing stages HRV parameters, repeated one-way analysis of variance (ANOVA) was used. Binary comparisons were determined with the Bonferroni test. The relationship between exercise data of heart rate variability and power average watt was assessed by the Pearson correlation test. The Effect Size Cohen's d was calculated. The main finding of this study is that pre-test (60-sec) HRV values continue to drop dramatically during test (30-sec) and post-test (60-sec) measurements ($p<0.05$). Also, no correlation was observed between performance and HRV data during testing ($r=-0.08$, $p>0.05$). In conclusion, the present study was not observed to sign of HRV recovery during 60-sec after the 30-sec WAnT. HRV recorded in the first 60 seconds after maximum anaerobic exercise program in sedentary healthy men may be considered to exhibit an imbalance in the parasympathetic activity of the autonomic nervous system.
Keywords: Autonomic Nervous System, Wingate Test, Anaerobic Capacity.

Wingate Testi Sırasında Ultra Kısa Süreli Kalp Atış Hızı Değişkenliğinin Non-Invaziv Değerlendirilmesi

Öz

Bu çalışmanın amacı, sedanter sağlıklı erkeklerin Wingate Anaerobik Testi (WAnT) (30-sn) sırasındaki ultra kısa kalp hızı değişkenliğini (HRV) ve WAnT sonrası ilk 60-saniyede parasempatik reaktivasyonu araştırmaktır. Araştırmaya 101 sağlıklı erkek katıldı (Ortalama±SS; Yaş=28.9±4.8 yıl, Boy=176.5±5.5 cm, Ağırlık=89.8±8.8 kg). Anaerobik güç ve kapasite WAnT ile ölçülmüştür. Kalp hızı değişkenliği (KHD) testten önce 60 saniye, test süresince 30 saniye ve testten sonra 60 saniye olarak kaydedildi. KHD, Polar V800 GPS Spor Saati ile Kalp Atış Hızı Monitörü ve Polar H7 bandı ile ölçülmüştür. Test öncesi-sırası-sonrası HRV parametrelerini karşılaştırmak için tekrarlanan tek yönlü varyans analizi (ANOVA) kullanıldı. İkili karşılaştırmalar Bonferroni testi ile belirlendi. Kalp atış hızı değişkenliği egzersiz verileri ile ortalama güç arasındaki ilişki Pearson korelasyon testi ile değerlendirildi. Etki Büyüklüğü Cohen's d hesaplandı. Bu çalışmanın ana bulgusu, ön test (60 saniye) HRV değerlerinin test (30 saniye) ve son test (60 saniye) ölçümleri sırasında önemli ölçüde düşmeye devam etmesidir ($p<0.05$). Ayrıca, test sırasında performans ve KHD verileri arasında anlamlı bir korelasyon gözlenmedi ($r=-0.08$, $p>0.05$). Sonuç olarak, bu çalışmada 30 saniyelik WAnT'tan sonra 60 saniyelik süre boyunca KHD iyileşmesi belirtisi gözlemlenmemiştir. Maksimum anaerobikten testten sonraki ilk 60 saniyede kaydedilen HRV sedanter sağlıklı erkeklerde egzersiz programının otonom sinir sisteminin parasempatik aktivitesinde bir dengesizlik sergilediği düşünülebilir.
Anahtar Kelimeler: Otonomik Sinir Sistemi, Wingate Testi, Anaerobik Kapasite.

* **Corresponding Author:** Tuncay ALPARSLAN, E-mail: tuncayalparslan@hotmail.com

INTRODUCTION

Heart rate variability (HRV) is defined as the ability of the heart to produce fluctuations in both beats in response to conditions such as exercise (Marek, John, Robert, Kleiger, Moss & Schwartz, 1996). HRV was used to determine the sympathetic and parasympathetic nervous system exercise-recovery relationship (Dong, 2016).

HRV is a method used to evaluate autonomic heart function (Myllymäki et al., 2012) and It has been used in the field of sports science to investigate the parasympathetic and sympathetic effects of exercise on the heart (Hnidawei, Mjalll & Zayed, 2010). Exercise is associated with increases in parasympathetic activity, indexed by greater vagal-mediated HRV (Chalencon et al., 2012; Edmonds, Sinclair & Leicht, 2013; Kiviniemi et al., 2006; Melanson & Freedson, 2001; Sartor et al., 2013). The period following acute exercise is thought to be particularly critical to the cardiovascular system (Kannankeril & Goldberger, 2002). Sudden changes in cardiac autonomic regulation occur, which may alter cardiovascular homeostasis. The sudden drop-in heart rate immediately after exercise is due to the regulation of vagal tone. During recovery, the sympathetic nervous system becomes more active (Goldberger et al., 2006). To measure parasympathetic activation after exercise, indices such as heart rate recovery (HRR) and HRV have been used (Barak et al., 2010). Exercise is done in aerobic and anaerobic format. In aerobic exercise, changes occur in heart rate and respiratory volume to meet the oxygen needs of the muscles (Jia et al., 2017). Anaerobic exercise includes intense physical activities of very short duration, fueled by the energy sources within the contracting muscles, and independent of the use of inhaled oxygen as an energy source (ACSM, 2013). Studies on HRV are mostly related to aerobic exercise (Ansell, Jester, Tryggrstad & Short, 2020; Dorey, O'brien & Kimmerly, 2019; Mamatha, Rajalakshmi, Rajesh &Smitha, 2019; Masroor et al., 2018). To date, some studies on anaerobic exercises had been conducted (Esco & Flatt, 2014; Nakamura et al., 2015) ultra-short HRV. However, these studies are not able to fully explain HRV during anaerobic exercise and recovery. Since aerobic exercise continues for a long time, evaluation of HRV and interpretation of the information obtained are easier. If HRV data are collected systematically during anaerobic exercises and especially in a maximum exercise that lasts less than 60-sec, useful information can be obtained about changes in the cardiac autonomic nervous system.

For high-intensity activity with minimal rest time, aerobic strength and capacity should be excellent (Mendez-Villanueva et al., 2012). Although there are physical and physiological differences in athletes training in different sports (Bosquet, Papelier, Leger & Legros, 2003), the use of HRV in sports science for training and recovery monitoring is increasing (Plews, Laursen, Stanley, Kilding & Burcheit, 2013). The reason why HRV has such a wide application area is that autonomic regulation is an important data both during and after training and in training planning (Hottenrott, Hoos & Esperer, 2006).

There are however fewer data on cardiovascular recovery following supramaximal exercise. There is less data on recovery after supramaximal exercise. It was previously reported that after 30 seconds of supramaximal exercise, Heart Rate (HR) and cardiac output increased for 5 minutes, and total peripheral resistance decreased compared to pre-exercise (Rezk et al., 2006; Teixeira et al., 2011; Terziotti, Schena, Gulli & Cevese, 2001). Esco and Flatt (2013) found that LnRMSSD measured under ultra-short duration (<60sec) in college athletes is consistent with 5-minute period recordings under resting and post-exercise conditions. Nakamura et al. (2015) tested the possibility of the ultra-short-term LnRMSSD (measured in 1-min post 1-min stabilization period) to detect training-induced adaptations in futsal players. In HRV, recovery occurs differently according to different training methods. In the study of Triposkiadis et al., (2009), athletes showed a slower return of parasympathetic activity during short-term recovery after an interval (intense) training method relative to constant exercise intensity.

The aim of present study was to investigate the sedentary healthy men's ultra-short HRV during the WAnT (30-sec) and parasympathetic reactivation in the first 60-sec after WAnT. We hypothesize that 30-sec max exercise will alter cardiovascular autonomic regulation and result in incomplete vagal restoration after 60-sec of recover.

MATERIAL AND METHOD

Participants

131 healthy men voluntarily participated in the study through the announcement. Thirty participants were excluded from the present study due to their busy schedules. The final sample comprised 101 individuals (Mean ± SD; Age = 28.9±4.8 years, Height = 176.5±5.5 cm, Weight=89.8±8.8 kg). All participants were reported being free from illness and injury in the last six months and no medical drugs were used in the past one week before the experiments took place. Informed consent was obtained from all participants. According to the International Physical Activity Questionnaire-Short Form (IPAQ-SF) applied before the tests, the participants were 14.3% high, 43.7% medium, and 42.0% low physically active. The experiments were approved by the Eskişehir Osmangazi University research ethics committee (Approved date 21.05.2020 and number 2020-10).

Study Design

Data collection for each participant occurred on the weekday during the morning hours (i.e., from 10:00 am to 12:00 am). Moderate water consumption was allowed for each volunteer during the tests. All measurements were performed in a quiet and air-conditioned (temperature 22-24 °C, humidity 33-45 %) room. The participants were warned not to perform any physical activity the day before the tests and not to use stimulants such as food and medicine or coffee for two hours before the test days. The tests were performed in groups of 5 or 6 participants on different days on weekdays for two months. Anthropometric measurements were measured by body analyzer and anaerobic powers were measured by WAnT. HRV was then recorded as 60-sec (T1) before the test for 30-sec (T2) and 60-sec after the test (T3).

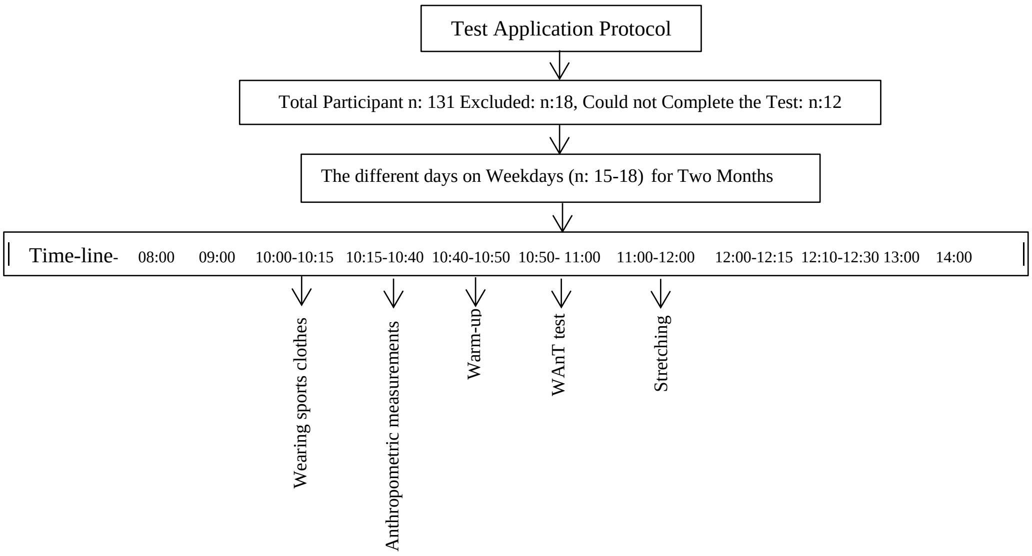

Figure 1. Test application protocol and measuring times

The physical activity levels of the volunteers were determined with the short form of IPAQ-SF (International Physical Activity Questionnaire-Short Form). The validity and reliability study of the IPAQ is a 7-item scale designed to determine the physical activity levels of individuals 15 years old and over (Saglam et al., 2010; Silva-Batista et al., 2013). The scale is structured to provide information on participation in physical activity and can be applied independently of cultural factors. The methodological criteria that were applied were those proposed by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (Marek et al., 1996).

Measurements

Body Composition: The height of the participants was measured as recommended by the International Society for the Advancement of Kinanthropometry (ISAK) and with a 1/10 cm sensitivity (Holtein Harpenden 601, Holtain Ltd., UK). The body weights of the participants were measured with a scale of 1/10 kg using the scale model of the InBody brand 270 models (Biospace Co., S. Korea) body analyzer. To obtain the Body Mass Index (BMI) values of the participants InBody brand 270 models (Biospace Co., S. Korea) body analyzer was used, and measurements were performed according to the procedure specified in the device manual. The data obtained were recorded in %.

Anaerobic capacity test: WAnT of the volunteers was performed by using a Wattbike brand ergometer using WAnT (Wattbike WPM ModelB, Wattbike Ltd., UK). The reliability study for a 30-sec run-down sprinkle in Wattbike has already been done (Driller, Argus & Shing, 2013). It records a calculation of the average power in each 5-sec interval of a 30-sec test and provides a peak power value based on the highest 5-sec average and, a rate of deterioration. Participants completed the same warm-up protocol performed during the orientation session and then immediately began the WAnT, a 30-sec maximal anaerobic exercise test on a cycle ergometer against 7.5% of their body mass (Bar-Or, 1987). During this test, participants were encouraged verbally to exert maximal effort. The mean power, peak power, and relative power were measured by the WAnT.

Heart rate variability: HRV was measured by Polar V800 GPS Sports Watch with Heart Rate Monitor and Polar H7 band (Polar Electro, Kempele, Finland). The Polar V800 is valid to detect RR intervals with an error of 0.09% and an intra-class correlation coefficient of > 0.99 (Giles et al., 2016). The heart rate data were stored in a personal computer using Polar FlowSync Software (version 3.0.0.1337). HRV analyses were processed in Kubios HRV standard heart rate variability analysis software for Mac (Biosignal Analysis and Medical Imaging Group, Department of Physics, University of Kuopio, Finland, version 3.1.0.1) with time, frequency, and nonlinear domain analysis. A sampling rate of 1000 Hz was chosen, and recordings were transferred to a PC via a v800 USB interface. Before the exercise test, each subject was instructed to lie on the exercise mat in a dimly controlled climate-controlled laboratory for 10 minutes following the recommendations adopted (ESC & Naspe, 1996). HRV was recorded 60-sec before the test, 30-sec during the test, and 60-sec after the test. The spectral response provided by the system was broken down into 3 bands: very low frequency (0.003–0.04 Hz), low frequency (0.04–0.15 Hz), and high frequency (0.15–0.4 Hz). The nonlinear analysis techniques used in this study were the Poincare´ plot and the detrended fluctuation analysis. The Poincare´ diagrams were obtained by plotting the RR values of n on the x-axis and the RR values of n+1 on the y-axis. The SD1 axis indicates short-term variability, whereas the SD2 axis indicates long-term variability (Makivić et al., 2013). Recordings were subsequently imported into Kubios HRV version 3.3.1 software (Tarvainen et al., 2014) for offline analyses. Specifically, we computed heart rate (beats per minute) as well as the mean of R-R intervals in milliseconds (Mean RR), the standard deviation of R-wave to R-wave intervals (SDNN) and root mean square of successive R-R intervals (RMSSD), the natural logarithmic transformation of the square root of the mean squared differences between successive R-R intervals in milliseconds (LnRMSSD), percentage of successive RR intervals that differ by more than 50 ms (pNN50), as three time-domain measures of heart rate variability with the absolute power of the low-frequency band (LF), the absolute power of the high-frequency band (HF) and the ratio of LF- to- HF power (LF/HF).

Data Analysis

Data is presented in means and standard deviations (SD). The differences based on magnitudes (Batterham & Hopkins, 2006) were calculated to check the differences in the pre and post moments. To compare the intra-group HRV parameters, repeated one-way analysis of variance (ANOVA) was used. Binary comparisons were determined with the Bonferroni test. The assumption of sphericity was tested using Mauchly's test and the Greenhouse-Geiser correction factor to the degrees of freedom was used for all positive tests. The relationship between exercise data of heart rate variability and power average watt (PAW) was assessed by the Pearson correlation test. The Effect Size Cohen's d was calculated, which was considered small (0.20), medium (0.50), or large (0.80). All calculations were made with SPSS version 22, statistical software (SPSS Inc., Chicago, IL, USA), and the level of significance was set at $p<0.05$.

RESULTS

The data obtained from our study shows respectively the descriptive characteristics of the participants in table 1, the performance values of the participants in table 2, the comparisons between the T1, T2, and T3 HRV values of participants and anaerobic capacity in Table 3, and Figure 2 shows the relationship between anaerobic average power of participant and exercise HRV parameters.

Table 1. Descriptive characteristics of the participants (n=101)

Descriptive Characteristics	Mean ± SD			Min	Max
Age (years)	28.9	±	4.8	22	38
Height (cm)	176.5	±	5.5	165	189
Weight (kg)	79.8	±	8.8	63.7	101
BMI (kg.m^{-2})	25.5	±	2.1	21,1	31.8
Body fat (%)	21.1	±	4.7	9.8	33.2

As shown in Table 1, participants were 28.9±4.8 age, 176.5±5.5 height, 79.8±8.8 weight, 25.5±2.1 BMI, and 21.1±4.7 body fat.

Table 2. WAnT Performance values of the participants (n=101)

Performance Values	Mean ± SD			Min.	Max.
0-5 sec avg	710	±	121.5	407	963
6-10 sec avg	600	±	88.2	358	792
11-15 sec avg	515.7	±	74.7	283	685
16-20 sec avg	455.2	±	64.5	309	620
21-25 sec avg	396	±	62.3	242	655
26-30 sec avg	340	±	55.5	217	525
Power 5-sec max (W)	700	±	141.8	0	963
Max 5 sec (W/kg)	8.9	±	1.6	0	12.5
Power 5-sec minimum (W)	337.8	±	56.4	217	525
Fatigue (%)	51.2	±	10.2	16	76
Power Average (W)	512.5	±	67.3	332	659
Power / Mass (W/kg)	6.4	±	0.7	4.7	8.5
Cadence avg (rpm)	124.7	±	8.7	108	178
Power Peak (W)	787.2	±	177.8	0	1124
Energy (kCal)	16.4	±	1.9	11.3	20.7
Speed avg (km/h)	51.9	±	2.7	43.8	59.9
Distance (m)	431.7	±	21.2	365	476

Table 2. WAnT performance values of participants were found 337.8 ± 56.4 Power 5 sec min. (W), 51.2 ± 10.2 Fatigue (%), 512.5 ± 67.3 Power Average (W), 6.4 ± 0.7 Power / Mass (W/kg), 787.2 ± 177.8 Power Peak (W) respectively.

Table 3. The Comparison of HRV values before, during and after the test

Variables	T1 Mean ± SD	T2 Mean ± SD	T3 Mean ± SD	F	Bonferroni Pairwise comparisons	$\eta_{partial}^2$	Cohen's d
Mean RR (bpm)	542.2 ± 74.7	400.1 ± 45.7	366 ± 38.9	707.4*	1-2*;1-3*;2-3*	0.876	0.94
SDNN (ms)	31.1 ± 17.8	15.4 ± 15.8	7.5 ± 7.9	102.1*	1-2*;1-3*;2-3*	0.508	0.71
RMSSD (ms)	21.5 ± 19.6	15.9 ± 22.9	9.1 ± 12.7	16.1*	1-2*;1-3*;2-3*	0.139	0.37
pNN50 (%)	3.7 ± 5.5	4.1 ± 10	1.5 ± 4.6	5.14*	1-3*;2-3*	0.049	0.22
LFnu (ms^2)	78.5 ± 14.6	70.6 ± 24.8	71.6 ± 24.8	4.78*	1-2*	0.046	0.21
HFnu (ms^2)	21.3 ± 14.5	29.1 ± 24.6	28.1 ± 24.6	4.63*	1-2*	0.044	0.21
LF/HF	6.5 ± 5.3	63.6 ± 398.9	6.5 ± 6.6	2.07		0.020	0.14
LnRMSSD	2.7 ± 0.8	2.1 ± 1.1	1.6 ± 0.9	48.19*	1-2*;1-3*;2-3*	0.325	0.57

$F^{\dagger}$estimates of a population variance; $\eta_{partial}^2$ effect size as partial eta squared; Significance level was accepted as $p<0.05$*****

Table 3 shown the comparison statistics for the pre-test, test, posttest HRV values. The main effect of test implementation revealed statistically significant differences in all HRV parameters (except of LF/HF). Mean RR ($F=707.4$, $p<0.05$, $\eta_{partial}^2=0.876$), SDNN ($F=102.1$, $p<0.05$, $\eta_{partial}^2=0.508$), RMSSD ($F=16.1$, $p<0.05$, $\eta_{partial}^2=0.139$), pNN50 ($F=5.14$, $p<0.05$, $\eta_{partial}^2=0.049$), LFnu ($F=4.78$, $p<0.05$, $\eta_{partial}^2=0.046$), HFnu ($F=4.63$, $p<0.05$, $\eta_{partial}^2=0.044$), LnRMSSD ($F=48.19$, $p<0.05$, $\eta_{partial}^2=0.325$). For the Mean RR, SDNN, RMSSD and LnRMSSD were found significant differences between T1 and T2, T1 and T3, T2 and T3 in Bonferroni test. Also were founded significant differences between T1 and T3, T2 and T3 for the pNN50, T1 and T2 for the LFnu, T1 and T2 for the HFnu. The effect size was considered large (Cohen's d = 0.94 for Mean RR), to medium (Cohen's d = 0.71 for SDNN ms., Cohen's d = 0.57 LnRMSSD) to small (Cohen's d = 0.37 for RMSSD ms., Cohen's d = 0.22 for pNN50 %, Cohen's d = 0.21 for LFnu and HFnu ms^2) to trivial (Cohen's d = 0.14 for LF/HF).

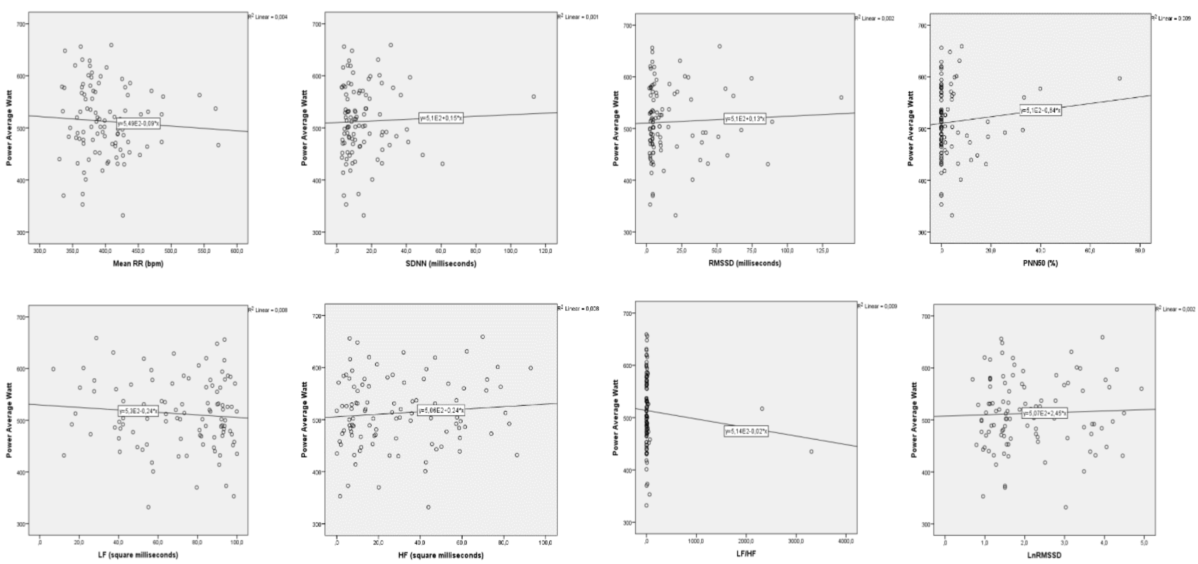

Figure 2. The Relationship between exercise data of HRV and Power Average (W) by Pearson correlation test.

When figures 2 was examined, there were no significant relationship between Average Power and Mean RR (r=-,077 p>0,439), SDNN (r=0,036 p>0,718), RMSSD (r=0,048 p>0,633), PNN50 (r=0,098 p>0.327), LFnu (r=-0,092 p>0,355), HFnu (r=0,092 p>0.356), LF/HF (r=-0,095 p>0,342), LnRMSSD (r=0,040 p>0.691).

DISCUSSION

In the current study, the changes in HRV values in the first 60-sec after 30-sec of maximal exercise were evaluated. The main finding of the present study was that the HRV values before the test (60-sec) continued to decrease in the measurements during the test (30-sec) and after the test (60-sec). The interesting result is that HRV values continue to decrease dramatically after the test. Also, no correlation was observed between performance and HRV data during testing. In the study, it was observed that the Mean RR, RMSSD, SDNN, pNN50, HFnu, LnRMSSD, which are thought to be mostly related to the parasympathetic activity (Task Force, 1996), did not show sign of recovery during 60-sec after the 30-sec WAnT.

In studies of Barak et.al. (2014) recorded during the 5-min recovery period vagal symptoms of men and women after the 30-sec WAnT. It was observed that none of the vagal HRV indices were restored during the 5-min recovery period after the 30-sec WAnT. It also noted the lack of vagal reactivation after high-intensity exercise (Buchheit, Laursen & Ahmaidi, 2007; de Oliveira et al., 2013). On the other hand, Goldberger, Le, Lahiri, Kannankeril, Ng & Kadish, (2006) demonstrated that raw RMSSD measured in segments of 60-sec or less reflected parasympathetic rebound immediately following exercise. Esco et al., (2018) demonstrated that after the maximal exercise, athletes are in the direction recovery of vagal symptoms, it had been also reported that there is a significant positive correlation between 1-min measurement and 5-min measurement records of SDNN and RMSSD values. In some studies, it was stated that 1 minute ultra-short measurements before and after exercise would be sufficient to evaluate HRV parameters (Chen et al., 2011; Esco & Flatt, 2014; Esco et al., 2018). But these results are related to athletes. Morales et al. (2014) observed that the application of high-intensity training program applied to judo athletes caused a decrease in vagal modulation. The reason for this imbalance of the autonomic nervous system was considered as a sympathetic stimulus restricting parasympathetic activity after training.

Thirty-second supramaximal physical exertion greatly alerts the sympathovagal system. The magnitude and time-course of vagal and sympathetic recovery depend on the preceding exercise intensity (Pierpont & Voth, 2004). High-intensity exercise induces prolonged vagal reactivation and HRV recovery, with a progressive increase of high and low-frequency HRV power indices that still might not reach resting values after 10 minutes (Perini et al., 1989; Smit, Halliwill, Low & Wieling, 1999), 15 minutes (Gladwell, Sandercock & Birch, 2010; Javorka, Zila, Balharek & Javorka, 2002; Pober, Braun & Freedson, 2004) or even 1-hour (Javorka et al., 2002).

In the present study, it was tried to determine whether there is a marker for recovery whether vagal symptoms are activated immediately in 60-sec after 30-sec of Wingate anaerobic power test. However, there was no marker in the direction of sympathovagal healing. Short-term anaerobic exercise has been associated with lactic acid (Vincent et al., 2004). Maximal exercise is associated with enhanced anaerobic metabolism with catecholamine production and sympathetic activity (Pierpont, Stolpman & Gornick, 2000). Vagal reactivation may be delayed after exercise due to the slow removal of accumulated metabolites (lactate, H^+, Pi, etc.) during intense physical exercise (Buchheit et al., 2007; Coote, 2010). Metaboreceptors with sympathetic afferents might be activated by accumulated waste products during exercise possibly suggesting an alternative mechanism for sympathetic predominance and delayed restoration of vagal tone (Smith & Hill, 1991). Additionally, maintained sympathetic outflow evoked by the arterial baroreceptors' response to more vigorous and rapid changes in pressure after exercise might delay parasympathetic reactivation as well (O'Leary, 1993). Miyamoto et.al. (2003) observed a blunting of the HR response to vagal stimulation due to upregulation of sympathetic activity. In this study, it is an important finding of this study that sedentary individuals have a longer recovery period in vagal symptoms compared to previous studies with athletes.

The limitations of this study are that women are not included in the study and that HRV values after Wingate exercise are taken in different resting positions. Because HRV values taken in different resting positions have been found to outcome with different results. HRV observations were reported by Barantkhe et al., (2008) in the supine position, Schouwenberg et al., (2006) in the upright position and (Barak et al., 2014) in the upright seated position. In future research, ultra-short HRV values of athletes and sedentary can be examined in different resting positions after maximal anaerobic exercise like Wingate test.

CONCLUSION

In conclusion, the present study was not observed to sign of HRV recovery during 60-sec after the 30-sec WAnT. HRV recorded in the first 60 seconds after maximum anaerobic exercise program in sedentary healthy men may be considered to exhibit an imbalance in the parasympathetic activity of the autonomic nervous system. It has estimated that it brings about a decrease in vagal modulation. However, this imbalance considered to be mainly provoked with an inhibition of the parasympathetic activity by sympathetic stimulation.

Conflict of interests: The authors state that there is no conflict of interest.

Authors' Contribution: Study design; TA., RA., - Data collection; TA., AKG - Statistical analysis; TA., RA., - Manuscript Preparation; TA., RA., AKG

Information on Ethics Committee Permission
Committee: Osmangazi University research ethics committee
Date: 21.05.2020
Decision / Protocol number: 220/10

REFERENCES

ACSM. (2013). *ACSM's Guidelines for Exercise Testing and Prescription*. Lippincott Williams & Wilkins.

Ansell, S. K. D., Jester, M., Tryggestad, J. B., & Short, K. R. (2020). A pilot study of the effects of a high-intensity aerobic exercise session on heart rate variability and arterial compliance in adolescents with or without type 1 diabetes. *Pediatric Diabetes*, *21*(3), 486–495. https://doi.org/doi.org/10.1111/PEDI.12983

Bar-Or, O. (1987). The Wingate anaerobic test an update on methodology, reliability and validity. *Sports Medicine*, *4*(6), 381–394. https://doi.org/10.2165/00007256-198704060-00001

Barak, O. F., Jakovljevic, D. G., Gacesa, J. Z. P., Ovcin, Z. B., Brodie, D. A., & Grujic, N. G. (2010). Heart rate variability before and after cycle exercise in relation to different body positions. *Journal of Sports Science & Medicine*, *9*(2), 176–182

Barak, O. F., Klasnja, A., POPADIC GACESA, J., & GRUJIC, N. G. (2014). Gender differences in parasympathetic reactivation during recovery from Wingate anaerobic test. *Periodicum Biologorum*, *116*(1), 53–58

Barantke, M., Krauss, T., Ortak, J., Lieb, W., Reppel, M., Burgdorf, C., Pramstaller, P. P., Schunkert, H., & Bonnemeier, H. (2008). Effects of gender and aging on differential autonomic responses to orthostatic maneuvers. *Journal of Cardiovascular Electrophysiology*, *19*(12), 1296–1303. https://doi.org/10.1111/j.1540-8167.2008.01257.x

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57. https://doi.org/10.1123/ijspp.1.1.50

Bosquet, L., Papelier, Y., Leger, L., & Legros, P. (2003). Night heart rate variability during overtraining in male endurance athletes. *Journal of Sports Medicine and Physical Fitness*, *43*(4), 506–512

Buchheit, M., Laursen, P. B., & Ahmaidi, S. (2007). Parasympathetic reactivation after repeated sprint exercise. *American Journal of Physiology-Heart and Circulatory Physiology*, *293*(1), H133–H141. https://doi.org/10.1152/ajpheart.00062.2007

Chalencon, S., Busso, T., Lacour, J.-R., Garet, M., Pichot, V., Connes, P., Gabel, C. P., Roche, F., & Barthélémy, J. C. (2012). A model for the training effects in swimming demonstrates a strong relationship between parasympathetic activity, performance and index of fatigue. *PloS One*, *7*(12), e52636. https://doi.org/10.1371/journal.pone.0052636

Chen, J.-Y., Lee, Y. L., Tsai, W.-C., Lee, C.-H., Chen, P.-S., Li, Y.-H., Tsai, L.-M., Chen, J.-H., & Lin, L.-J. (2011). Cardiac autonomic functions derived from short-term heart rate variability recordings associated with heart rate recovery after treadmill exercise test in young individuals. *Heart and Vessels*, *26*(3), 282–288. https://doi.org/10.1536/ihj.51.105

Coote, J. H. (2010). Recovery of heart rate following intense dynamic exercise. *Experimental Physiology*, *95*(3), 431–440. https://doi.org/10.1113/expphysiol.2009.047548

De Oliveira, T. P., de Alvarenga Mattos, R., da Silva, R. B. F., Rezende, R. A., & de Lima, J. R. P. (2013). Absence of parasympathetic reactivation after maximal exercise. *Clinical Physiology and Functional Imaging*, *33*(2), 143–149. https://doi.org/10.1111/cpf.12009

Dong, J. (2016). The role of heart rate variability in sports physiology. *Experimental and Therapeutic Medicine*, *11*(5), 1531–1536. https://doi.org/10.3892/etm.2016.3104

Dorey, T. W., O'Brien, M. W., & Kimmerly, D. S. (2019). The influence of aerobic fitness on electrocardiographic and heart rate variability parameters in young and older adults. *Autonomic Neuroscience*, *217*(60-70). https://doi.org/10.1016/j.autneu.2019.01.004

Driller, M. W., Argus, C. K., & Shing, C. M. (2013). The reliability of a 30-s sprint test on the Wattbike cycle ergometer. *International Journal of Sports Physiology and Performance*, *8*(4), 379–383. https://doi.org/10.1123/ijspp.8.4.379

Edmonds, R. C., Sinclair, W. H., & Leicht, A. S. (2013). Effect of a training week on heart rate variability in elite youth rugby league players. *International Journal of Sports Medicine*, *34*(12), 1087–1092. https://doi.org/10.1055/s-0033-1333720

ESC, T. F. O. F., & Naspe, T. (1996). Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. *Eur. Heart J*, *17*, 354–381

Esco, M R, & Flatt, A. A. (2014). Ultra-short-term heart rate variability indexes at rest and post-exercise in athletes: evaluating the agreement with accepted recommendations. *Journal of Sports Science & Medicine*, *13*(3), 535–541

Esco, Michael R, Williford, H. N., Flatt, A. A., Freeborn, T. J., & Nakamura, F. Y. (2018). Ultra-shortened time-domain HRV parameters at rest and following exercise in athletes: an alternative to frequency computation of sympathovagal balance. *European Journal of Applied Physiology*, *118*(1), 175–184. https://doi.org/10.1007/s00421-017-3759-x

Flatt, A. A., & Esco, M. R. (2013). Validity of the ithleteTM smart phone application for determining ultra-short-term heart rate variability. *Journal of Human Kinetics*, *39*(1), 85–92. https://doi.org/10.2478/hukin-2013-0071

Giles, D., Draper, N., & Neil, W. (2016). Validity of the Polar V800 heart rate monitor to measure RR intervals at rest. *European Journal of Applied Physiology*, *116*(3), 563–571. https://doi.org/10.1007/s00421-015-3303-9

Gladwell, V. F., Sandercock, G. R. H., & Birch, S. L. (2010). Cardiac vagal activity following three intensities of exercise in humans. *Clinical Physiology and Functional Imaging*, *30*(1), 17–22. https://doi.org/10.1111/j.1475-097X.2009.00899.x

Goldberger, J. J., Le, F. K., Lahiri, M., Kannankeril, P. J., Ng, J., & Kadish, A. H. (2006). Assessment of parasympathetic reactivation after exercise. *American Journal of Physiology-Heart and Circulatory Physiology*, *290*(6), 2446–2452. https://doi.org/10.1152/ajpheart.01118.2005

Hnidawei, M. A., MjallI, M., & Zayed, Z. (2010). The upper limit of physiological cardiac hypertrophy in elite male athletes. *American Journal of Applied Sciences*, *7*(10), 592–597. https://doi.org/10.1007/s00421-004-1052-2

Hottenrott, K., Hoos, O., & Esperer, H. D. (2006). Heart rate variability and physical exercise. Current status. *Herz*, *31*(6), 544–552. https://doi.org/10.1007/s00059-006-2855-1

Javorka, M., Zila, I., Balharek, T., & Javorka, K. (2002). Heart rate recovery after exercise: relations to heart rate variability and complexity. *Brazilian Journal of Medical and Biological Research*, *35*, 991–1000. https://doi.org/10.1590/s0100-879x2002000800018

Jia, Z., Bonde, A., Li, S., Xu, C., Wang, J., Zhang, Y., Howard, R. E., & Zhang, P. (2017). Monitoring a person's heart rate and respiratory rate on a shared bed using geophones. *Proceedings of the 15th ACM Conference on Embedded Network Sensor Systems*, 1–14. https://doi.org/10.1145/3131672.3131679

Kannankeril, P. J., & Goldberger, J. J. (2002). Parasympathetic effects on cardiac electrophysiology during exercise and recovery. *American Journal of Physiology-Heart and Circulatory Physiology*, *282*(6), 2091–2098. https://doi.org/10.1152/ajpheart.00825.2001

Kiviniemi, A. M., Hautala, A. J., Mäkikallio, T. H., Seppänen, T., Huikuri, H. V, & Tulppo, M. P. (2006). Cardiac vagal outflow after aerobic training by analysis of high-frequency oscillation of the R–R interval. *European Journal of Applied Physiology*, *96*(6), 686–692. https://doi.org/10.1007/s00421-005-0130-4

Makivić, B., Nikić Djordjević, M., & Willis, M. S. (2013). Heart Rate Variability (HRV) as a Tool for Diagnostic and Monitoring Performance in Sport and Physical Activities. *Journal of Exercise Physiology Online*, *16*(3), 103–131

Mamatha, S. D., Rajalakshmi, R., Rajesh Kumar, T., & Smitha, M. C. (2019). Effect of aerobic exercise and yoga on heart rate variability (HRV) parameters in young adults. *International Journal of Physiology*, *7*(1), 19–22. https://doi.org/10.3389/fphys.2021.657274

Marek J. Thomas Bigger A., John Camm, Robert E., Kleiger Alberto Malliani Arthur J., Moss Peter, J. Schwartz, M., & Cardiology, T. F. of the E. S. of. (1996). Heart rate variability, standards of measurement, physiological interpretation, and clinical use. *Circulation*, *93*(5), 1043–1065. https://doi.org/10.1161/01.CIR.93.5.1043

Masroor, S., Bhati, P., Verma, S., Khan, M., & Hussain, M. E. (2018). Heart rate variability following combined aerobic and resistance training in sedentary hypertensive women: A randomised control trial. *Indian Heart Journal*, *70*, 28–35. https://doi.org/10.1016/j.ihj.2018.03.005

Melanson, E. L., & Freedson, P. S. (2001). The effect of endurance training on resting heart rate variability in sedentary adult males. *European Journal of Applied Physiology*, *85*(5), 442–449. https://doi.org/10.1007/s004210100479

Mendez-Villanueva, A., Edge, J., Suriano, R., Hamer, P., & Bishop, D. (2012). The recovery of repeated-sprint exercise is associated with PCr resynthesis, while muscle pH and EMG amplitude remain depressed. *PloS One*, *7*(12), e51977. https://doi.org/10.1371/journal.pone.0051977

Miyamoto, T., Kawada, T., Takaki, H., Inagaki, M., Yanagiya, Y., Jin, Y., Sugimachi, M., & Sunagawa, K. (2003). High plasma norepinephrine attenuates the dynamic heart rate response to vagal stimulation. *American Journal of Physiology-Heart and Circulatory Physiology*, *284*(6), H2412–H2418. https://doi.org/10.1152/ajpheart.00660.2002

Morales, J., Álamo, J. M., García-Massó, X., López, J. L., Serra-Añó, P., & González, L.-M. (2014). Use of heart rate variability in monitoring stress and recovery in judo athletes. *The Journal of Strength & Conditioning Research*, *28*(7), 1896–1905. https://doi.org/10.1519/JSC.0000000000000328

Myllymäki, T., Rusko, H., Syväoja, H., Juuti, T., Kinnunen, M.-L., & Kyröläinen, H. (2012). Effects of exercise intensity and duration on nocturnal heart rate variability and sleep quality. *European Journal of Applied Physiology*, *112*(3), 801–809. https://doi.org/10.1007/s00421-011-2034-9

Nakamura, F. Y., Flatt, A. A., Pereira, L. A., Ramirez-Campillo, R., Loturco, I., & Esco, M. R. (2015). Ultra-short-term heart rate variability is sensitive to training effects in team sports players. *Journal of Sports Science & Medicine*, *14*(3), 602–605

O'Leary, D. S. (1993). Autonomic mechanisms of muscle metaboreflex control of heart rate. *Journal of Applied Physiology*, *74*(4), 1748–1754. https://doi.org/10.1152/jappl.1993.74.4.1748

Perini, R., Orizio, C., Comandè, A., Castellano, M., Beschi, M., & Veicsteinas, A. (1989). Plasma norepinephrine and heart rate dynamics during recovery from submaximal exercise in man. *European Journal of Applied Physiology and Occupational Physiology*, *58*(8), 879–883. https://doi.org/10.1007/BF02332222

Pierpont, G. L., Stolpman, D. R., & Gornick, C. C. (2000). Heart rate recovery post-exercise as an index of parasympathetic activity. *Journal of the Autonomic Nervous System*, *80*(3), 169–174. https://doi.org/10.1016/S0165-1838(00)00090-4

Pierpont, G. L., & Voth, E. J. (2004). Assessing autonomic function by analysis of heart rate recovery from exercise in healthy subjects. *The American Journal of Cardiology*, *94*(1), 64–68. https://doi.org/10.1016/j.amjcard.2004.03.032

Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., & Buchheit, M. (2013). Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. *Sports Medicine*, *43*(9), 773–781. https://doi.org/10.1007/s40279-013-0071-8

Pober, D. M., Braun, B., & Freedson, P. S. (2004). Effects of a single bout of exercise on resting heart rate variability. *Medicine and Science in Sports and Exercise*, *36*(7), 1140–1148. https://doi.org/10.1249/01.MSS.0000132273.30827.9A

Rezk, C. C., Marrache, R. C. B., Tinucci, T., Mion, D., & Forjaz, C. (2006). Post-resistance exercise hypotension, hemodynamics, and heart rate variability: influence of exercise intensity. *European Journal of Applied Physiology*, *98*(1), 105–112. https://doi.org/10.1007/s00421-006-0257-y

Saglam, M., Arikan, H., Savci, S., Inal-Ince, D., Bosnak-Guclu, M., Karabulut, E., & Tokgozoglu, L. (2010). International physical activity questionnaire: reliability and validity of the Turkish version. *Perceptual and Motor Skills*, *111*(1), 278–284. https://doi.org/10.2466/06.08.PMS.111.4.278-284

Sartor, F., Vernillo, G., De Morree, H. M., Bonomi, A. G., La Torre, A., Kubis, H. P., & Veicsteinas, A. (2013). Estimation of maximal oxygen uptake via submaximal exercise testing in sports, clinical, and home settings. In *Sports Medicine* *43*(9), 865–873. https://doi.org/10.1007/s40279-013-0068-3

Schouwenberg, B. J. J. W., Rietjens, S. J., Smits, P., & de Galan, B. E. (2006). Effect of sex on the cardiovascular response to adrenaline in humans. *Journal of Cardiovascular Pharmacology*, *47*(1), 155–157. https://doi.org/10.1097/01.fjc.0000198519.28674.cc

Silva-Batista, C., Urso, R. P., Silva, A. E. L., & Bertuzzi, R. (2013). Associations between fitness tests and the International Physical Activity Questionnaire—Short form in healthy men. *The Journal of Strength & Conditioning Research*, *27*(12), 3481–3487. https://doi.org/10.1519/JSC.0b013e31828f1efa

Smit, A. A. J., Halliwill, J. R., Low, P. A., & Wieling, W. (1999). Pathophysiological basis of orthostatic hypotension in autonomic failure. *The Journal of Physiology*, *519*(1), 1–10. https://doi.org/10.1111/j.1469-7793.1999.0001o.x

Smith, J. C., & Hill, D. W. (1991). Contribution of energy systems during a Wingate power test. *British Journal of Sports Medicine*, *25*(4), 196–199. https://doi.org/10.1136/bjsm.25.4.196

Tarvainen, M. P., Niskanen, J.-P., Lipponen, J. A., Ranta-Aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV–heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, *113*(1), 210–220. https://doi.org/10.1016/j.cmpb.2013.07.024

Teixeira, L., Ritti-Dias, R. M., Tinucci, T., Júnior, D. M., & de Moraes Forjaz, C. L. (2011). Post-concurrent exercise hemodynamics and cardiac autonomic modulation. *European Journal of Applied Physiology*, *111*(9), 2069–2078. https://doi.org/10.1007/s00421-010-1811-1

Terziotti, P., Schena, F., Gulli, G., & Cevese, A. (2001). Post-exercise recovery of autonomic cardiovascular control: a study by spectrum and cross-spectrum analysis in humans. *European Journal of Applied Physiology*, *84*(3), 187–194. https://doi.org/10.1007/s004210170003

Triposkiadis, F., Karayannis, G., Giamouzis, G., Skoularigis, J., Louridas, G., & Butler, J. (2009). The sympathetic nervous system in heart failure: physiology, pathophysiology, and clinical implications. *Journal of the American College of Cardiology*, *54*(19), 1747–1762. https://doi.org/10.1016/j.jacc.2009.05.015

Vincent, S., Berthon, P., Zouhal, H., Moussa, E., Catheline, M., Bentue-Ferrer, D., & Gratas-Delamarche, A. (2004). Plasma glucose, insulin and catecholamine responses to a Wingate test in physically active women and men. *European Journal of Applied Physiology*, *91*(1), 15–21. https://doi.org/10.1007/s00421-003-0957-5