Chronic Effect of Different Load Distributions on the Autonomic Heart Rate Modulation

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ABSTRACT


The purpose of the current study was to assess and compare the chronic effect of exercise training and different external training load distributions (ETL) on the autonomic heart rate (HR) modulation of 21 healthy adult women who were randomly divided into 3 groups: Linear Load (LL, n = 8); Undulating Load (UL, n = 8), and Control Load (CL, n = 5). They were assessed before (A1) and after (A2) 12 aerobic training sessions: Heart rate variability (HRV) at rest (HRVrest) and post exercise (HRVpost-exercise), Heart Rate at Rest (HRrest), incremental shuttle walk test (ISWT) and HRV threshold (HRVT). The internal training load (ITL) was calculated using the Foster method. The ETL in the CL group Zone 1 was greater than that of the LL and UL groups (P = 0.008). There was no significant difference (P = 0.575) between the ITL of the CL (13474 ± 1059 a.u.), LL (12650 ± 1411 a.u.), and UL (12734 ± 846 a.u.) groups. All variables showed significant differences (P<0.05) from A1 to A2, with the exception of HRrest for CL and LL and of HRVpost-exercise for CL. The effect size was great for HRVpost-exercise and HRVT in the UL group (ES = 2.07 and 2.97). The findings indicate that the subjects improved in aerobic capacity, HRVT speed and HRrest regardless of the load distribution. However, the CL group needed more ETL than the LL and UL groups in Zone 1. The ITL did not differ during the sessions, indicating that the ETL periodization increased the chronic adaptations of the proposed training, especially for UL.

Key Words: Autonomic Nervous System, Load, Periodization
INTRODUCTION

The way training load is distributed may lead to different adaptations in the aerobic performance of athletes and physical exercise practitioners. The magnitude of these adaptations is related to the handling of acute variables that guide the ongoing physical training process, namely: the intensity, the volume, the recovery time and, above all, the frequency and the weekly distribution of training sessions (4). According to Impellizzeri and colleagues (14), these variables configure the external training load (ETL) and the level of stress imposed by the ETL determines the internal training load (ITL). The ITL consists of the physiological responses of the body to the training stress, which is determined by the ETL combined with individual physiological and psychological characteristics (13).

Among the methods used to quantify ITL, it is worth highlighting those based on the heart rate variability (HRV) behavior or on the rate of perceived exertion (RPE) (10,24,26). The RPE session method used to quantify and monitor ITL has been investigated in different exercise/physical and sports training situations (12,13,21), and it emerges as a valid and simple alternative with low implementation cost. On the other hand, HRV has been used to check aerobic training adjustments, adaptations, monitoring, and prescription (2). One of the parameters used to prescribe ETL in aerobic training is the HRV threshold (4) that allows controlling the aerobic exercise training zones and intensity (27).

Given the behavior of different weekly ETL distributions in the aerobic training, the planned and organized models imply greater magnitude of chronic adaptations in comparison to the non-periodized ones (15). Thus, the linear and the undulating (non-linear) periodizations promote increased muscle strength in athletes and in physical exercise practitioners in comparison to the non-periodized programs (8). There is gradual exercise intensity increase in the linear model and the undulating one shows daily or weekly changes in the volume and intensity of sessions (3). These periodization models are constantly studied for muscle strength and muscle power (11).

There are few studies comparing the different ways to periodize the aerobic training load in athletes (11,29), especially when it comes to healthy adult women. Unlike the studies conducted with athletes (21,22), the ratio between the ITL accumulation due to ETL prescription and the chronic responses of aerobic training in individuals seeking improved fitness and health has not been established. Thus, the aim of the current study is to evaluate and compare the chronic effect of exercise training with different ETL distributions on the autonomic heart rate modulation in healthy adult women. The hypothesis is that the three groups will present positive chronic responses in the HRV variables with greater increase in the planned and organized ETL groups.

METHODS

Subjects
The current study was approved by the Research Ethics Committee of the Local Institution, as recommended by Resolution 466/12 of the National Health Council (950.277/2015). Twenty-seven (27) healthy adult women over 40 yrs old were selected after they agreed to participate in the study. All volunteers were classified as sedentary according to the International Physical Activity Questionnaire (IPAQ). That is, they did not show moderate or
vigorous physical exercise frequency of at least 3 times·wk⁻¹ during 30 min, or even 5 times·wk⁻¹ of light exercise. The sample’s weekly physical activity time was 37 ± 12 min. None of the subjects had heart, pulmonary or metabolic diseases. Smokers and former smokers were excluded from the study as well as participants with body mass index (BMI) greater than 35 kg·m⁻². They were all asked about the use of any substance capable of changing the autonomic heart rate modulation, such as alcoholic and/or stimulant drinks, beta-blockers, etc. None of them was undergoing hormone replacement therapy.

This study used the GPower software (version 3.1.3) for sample calculation in which the effect size of 0.75 (ɑ = 0.05) and the statistical power of 80% were adopted, which resulted in a minimum n of 8 subjects considering the analysis of variance for repeated measures. After a familiarization session, the 27 subjects were randomly assigned to three groups comprising 9 women by a drawing conducted using the following website, www.randomization.com, with blinding of both the researcher and the participants.

The aerobic training load distribution was linear (LL) in the first group, undulating in the second group (UL), and there was no load distribution control in the third group, which held a free training structure and was defined as control load (CL). During the experiment sequence, 6 subjects were eliminated from the study, four of them from the LL group (three of them did not meet the required training frequency and one presented infection in the upper respiratory tract). One LL volunteer was eliminated due to infection in the upper respiratory tract and one UL volunteer was eliminated due to dengue fever. Thus, the study was concluded with 21 volunteers divided as follows: CL, n=5; LL, n=8; and UL, n=8. The sample characteristics are shown in Table 1. No differences were observed among the groups.

Table 1. Sample Characteristics.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Age (yrs)</th>
<th>Height (m)</th>
<th>Body Mass (kg)</th>
<th>BMI (kg·m⁻²)</th>
<th>% Fat</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>VO₂ peak (mL·kg⁻¹·min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL (n=5)</td>
<td>50.2 ± 12.9</td>
<td>1.63 ± 0.1</td>
<td>71.4 ± 12.2</td>
<td>26.2 ± 4.2</td>
<td>30.2 ± 5.6</td>
<td>115 ± 11</td>
<td>77 ± 7</td>
<td>35.4 ± 11.4</td>
</tr>
<tr>
<td>LL (n=8)</td>
<td>48.4 ± 12.2</td>
<td>1.61 ± 0.1</td>
<td>72.7 ± 12.7</td>
<td>27.2 ± 4.7</td>
<td>32.1 ± 4.4</td>
<td>118 ± 12</td>
<td>75 ± 9</td>
<td>31.8 ± 11.2</td>
</tr>
<tr>
<td>UL (n=8)</td>
<td>48.2 ± 11.5</td>
<td>1.64 ± 0.1</td>
<td>73.2 ± 13.1</td>
<td>26.3 ± 5.3</td>
<td>29.8 ± 4.5</td>
<td>117 ± 12</td>
<td>79 ± 7</td>
<td>32.2 ± 7.6</td>
</tr>
</tbody>
</table>

CL = Control Load Group; LL = Linear Load Group; UL = Undulating Load Group; BMI = Body Mass Index; % Fat = Fat percentage; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; VO₂ peak = Indirect maximal oxygen in the incremental shuttle Walk Test [VO₂ peak = 3.1 + (0.038 x ISWT distance); Dourado et al., 2013].

Procedures

A session was held to familiarize the volunteers with all the procedures adopted in the study before the evaluations started. Anthropometric and body composition measurements (body weight, height, blood pressure, and % fat) were performed in the same day, as well as the familiarization with the Incremental Shuttle Walk Test (ISWT). The rate of perceived exertion by Foster (10) was applied at the end of the session. Pre-training time (A1) evaluations were conducted 48 hrs after the familiarization session. Forty-eight (48) hrs later, the first training session began.
The study lasted for 5 wks with a total of 12 sessions and intervals from 48 to 72 hrs between the training sessions. The post-training (A2) evaluation was performed 48 hrs after the end of session 12, as shown in Figure 1.

![Randomization Groups](image)

**Figure 1. Illustration of the Study Phases.**

Samples were collected in the morning. The temperature of the experiment room was kept between 22 and 25°C with relative humidity between 40 and 60%. The subjects had been previously instructed: (a) not to drink stimulating beverages such as coffee, tea, and soft drinks; (b) not to drink alcoholic drinks; (c) not to perform strenuous physical exercises; and (d) to eat a light meal at most 2 hrs prior to the testing.

**Recording and Analysis the Heart Rate (HR) and R-R Intervals (iR-R)**

The analyses of heart rate variability (HRV) at rest (HRV<sub>rest</sub>), post-exercise (HRV<sub>post-exercise</sub>), heart rate at rest (HR<sub>rest</sub>), and of the Incremental Shuttle Walk Test (ISWT) by Singh et al. (28) were conducted in A1 and in A2. In order to collect the HR<sub>rest</sub> and HRV<sub>rest</sub>, the subjects were kept in supine position for 10 min with no talking or moving. Next, the HR and iR-R were recorded for 10 min, during which the subjects maintained spontaneous breathing that was monitored and recorded by the evaluator. The HR<sub>rest</sub> and HRV<sub>rest</sub> were checked before the ISWT and the HRV<sub>post-exercise</sub> was checked right after it was finished. With respect to the HRV<sub>post-exercise</sub>, the subjects had to sit in a chair 3 sec after the ISWT was concluded and rest for 5 min (5).

**Incremental Shuttle Walk Test (ISWT)**

The ISWT was performed in a 10-meter-long covered and airy hallway marked by cones. The initial cadence of 0.5 m·s<sup>-1</sup> was increased by 0.17 m·s<sup>-1</sup> every minute until the subjects showed exhaustion. The speed was controlled by beeps emitted by the Beat Training & Test® (CEFISE, Nova Odessa, Brazil). Since the protocol was not applied to subjects with chronic respiratory diseases, it was extended to 15 levels (1500 m) to minimize the ceiling effect (7).

The heart rate data in HRV<sub>rest</sub> and in ISWT were obtained through a Polar RS800CX® heart rate monitor (Polar Electro, OY, Kempele, Finland), which was validated to record both at rest and during exercise with accuracy better than 2 ms in comparison to the ECG method (18). The recorded R-R intervals (iR-R) were transferred through an interface to a compatible computer. Then, the heart rate signals were processed to calculate the HRV using the Kubios HRV® (Biomedical Signal Analysis Group, University of Kuopio, Finland), which calculated the
HRV values based on iR-R. All iR-R with differences greater than 20% of the previous adjacent interval were automatically filtered and inappropriate heartbeats were eliminated. Inadequate heartbeats represented values lower than 1.43% in each analysis.

Indices such as the rMSSD (root mean square of the successive differences between the normal adjacent RR intervals, in a time interval) and the heart rate at rest were analyzed during HRV_{rest} and HRV_{post-exercise}. The heart rate variability threshold (HRVT) was obtained by the SD1 index calculated by Poincaré plot. Next, the ISWT phase speed was matched with the SD1 values. The HRVT in ISWT corresponded to the first phase of the incremental exercise in which the difference between the SD1 of two consecutive phases was less than 1 millisecond (16). The HRVT was identified by visual inspection performed by 3 independent examiners, and it was defined when at least 2 concordant assessments occurred. It was possible to identify the HRVT of the 21 analyzed volunteers in both A1 and A2.

**Monitoring the External Training Load (ETL) and Internal Training Load (ITL)**

Based on the HRVT, 3 different intensities were used to quantify the aerobic ETL prescribed to the groups, namely: Zone 1, low intensity training <HRVT; Zone 2, training in HRVT; and Zone 3, high intensity training >HRVT. These intensities were based on the description by Seiler (27). The researchers controlled and recorded the volume of the distance traveled in meters for each training zone of the experimental groups (LL and UL). The subjects in the control group (CL) recorded the session they had performed as well as the distance traveled in each training zone, and it was up to them choosing the session. The CL group was only requested to respect the interval time and the frequency between the training sessions. All groups performed the training sessions in the morning and at the same location.

The internal training load (ITL) was monitored according to Foster (10). The ITL was obtained 30 min after the end of each session, in all 12 sessions. The subjects indicated the degree of perceived exertion according to the Borg CR10 rating perceived exertion (RPE). The perceived value reported by the subjects was multiplied by the total session time in minutes in order to calculate the ITL (9). The ITL corresponded to the sum of the load calculated in the 12 sessions. The data were expressed in arbitrary units (a.u.).

**External Training Load (ETL) Distribution**

The volunteers in the LL trained with linear load and continuous increase from Zone 1 to Zones 2 and 3, between the 1st and the 4th week. The UL performed the same training sessions; however, the load ranged from Zone 1 to Zones 2 and 3 in the same training week. The CL performed free trainings in Zones 1, 2, and 3 without any load distribution control; they performed three sessions per week. On the other hand, the LL and UL performed the same type and number of sessions; however, the load distribution was different. Both groups participated in 5 sessions 1 (S1), 4 sessions 2 (S2), and 3 sessions 3 (S3).

In S1, the subjects jogged or walked for 30 min at 20% <HRVT in Zone 1. In S2, they performed 3 sets of 8 min in HRVT with 2 min of active recovery at 20% <HRVT, totaling 30 min. In S3, they performed 3 sets of 6 1-min repetitions at 20% >HRVT, with 1 min of active recovery at 20% <HRVT, totaling 36 min (Table 2).
Table 2. Distribution of Training Sessions for LL and UL.

<table>
<thead>
<tr>
<th>Week</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T1 = Test 1</td>
<td>S1</td>
<td>S1</td>
<td></td>
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<tr>
<td>2</td>
<td>S1</td>
<td>S1</td>
<td>S2</td>
<td>S2</td>
<td>T2</td>
</tr>
<tr>
<td>3</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>T2</td>
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<tr>
<td>4</td>
<td>S2</td>
<td>S2</td>
<td>S3</td>
<td>T2</td>
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<tr>
<td>5</td>
<td>S3</td>
<td>S3</td>
<td>T1</td>
<td></td>
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</tbody>
</table>

**Load Distribution of Aerobic Training and Increasing Linearly**

- **1** = Familiarization
- **T1**

**Training Load Distribution Undulation Variation During the Week**

- **1** = Familiarization
- **T1**

T1 = Test 1; T2 = Test 2; S1 = session 1 (30’ at 20% <HRVT); S2 = session 2 (3 x [8’ at HRVT/ 2’ at 20% <HRVT], totaling 30’); S3 = session 3 (3 x [6 x 1’ at 20% >HRVT/ 1’ at 20% <HRVT], totaling 36’).

**Statistical Analysis**

The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. The mean and standard deviation (SD) were used after the data normality was assumed. The analysis of variance of one factor (One-Way ANOVA) was performed with repeated measurements to compare all the variables among the 3 groups (CL, LL, and UL), and the Post Hoc Tukey test was used whenever necessary. The paired t-test was used to check the intragroup differences from A1 to A2. The adopted significance was P ≤ 0.05.

In addition, besides the comparison analyses, the effect size (ES) for the difference between A1 and A2 among the variables was calculated based on the descriptions by Cohen (6), in order to analyze the magnitude of the effects after the training period. These effects may be small, medium or large. The reference values described by Cohen (6) are considered small if (0.20 ≤ d < 0.50), medium if (0.50 ≤ d < 0.80), and large if (d ≥ 0.80).

**RESULTS**

The ETL quantified in each training zone is shown in Table 3. A significant difference was found between the distance covered in Zone 1 by the CL in comparison to that covered by the LL and UL (P = 0.008). However, it was not significant in the total distance (P = 0.31), in Zone 2 (p = 0.2) and in Zone 3 (P = 0.26). During the 12 sessions of the study, the LL and UL trained for 192 min in Zone 1; 96 min in Zone 2, and 54 min in Zone 3, totaling 342 min. Since there was no load distribution control in CL, the subjects trained for approximately 456 min in Zone 1; 281 min in Zone 2, and 100 min in Zone 3.
Table 3. External Training Load (ETL) Measured by the Distance in Each Training Zone in 12 Study Sessions.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Total Distance (m)</th>
<th>Zone 1 Distance (m)</th>
<th>Zone 2 Distance (m)</th>
<th>Zone 3 Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL</td>
<td>41365 ± 3390</td>
<td>25467 ± 2023</td>
<td>9065 ± 837</td>
<td>6848 ± 1182</td>
</tr>
<tr>
<td>LL</td>
<td>37295 ± 7732</td>
<td>20294 ± 3764*</td>
<td>10717 ± 2222</td>
<td>6029 ± 1250</td>
</tr>
<tr>
<td>UL</td>
<td>36683 ± 4162</td>
<td>19789 ± 2610*</td>
<td>10455 ± 1195</td>
<td>5883 ± 673</td>
</tr>
</tbody>
</table>

CL = Control Load; LL = Linear Load; UL = Undulating Load; ITL = Internal Training Load. Zone 1 = low Intensity Training <HRVT; Zone 2 = Training in HRVT; Zone 3 = High Intensity Training >HRVT. *P<0.05 in CL.

The values found for ITL were CL = 13474 ± 1059 a.u., LL = 12650 ± 1411 a.u., and UL = 12734 ± 846 a.u. No significant difference was found between groups (P = 0.57) (Figure 2).

Figure 2. Comparison of the ITL Performed by the CL, LL, and UL Groups in the 12 Sessions.

All variables showed significant differences (P<0.05) from A1 to A2 with the exception of HRrest for CL and LL and of HRVpost-exercise for CL (Table 4).
Table 4. Results of HRV and Percentage Difference from T1 to T2 in the 3 Studied Groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CL</th>
<th>Δ%</th>
<th>p</th>
<th>LL</th>
<th>Δ%</th>
<th>p</th>
<th>UL</th>
<th>Δ%</th>
<th>p</th>
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<tbody>
<tr>
<td><strong>Test 1</strong></td>
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<tr>
<td>ISWT (m)</td>
<td>850 ± 300</td>
<td>755 ± 296</td>
<td>766 ± 199</td>
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<tr>
<td>HRV rest (rMSSD)</td>
<td>28.7 ± 8.1</td>
<td>26.9 ± 5.8</td>
<td>30.4 ± 7.5</td>
<td></td>
<td></td>
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<tr>
<td>HRV post-exercise (rMSSD)</td>
<td>17.5 ± 9.0</td>
<td>15.8 ± 5.2</td>
<td>17.1 ± 4.2</td>
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<tr>
<td>HR rest (beats·min⁻¹)</td>
<td>66.8 ± 8.1</td>
<td>65.9 ± 16.2</td>
<td>63.3 ± 11.0</td>
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<tr>
<td>HRVT (km·h⁻¹)</td>
<td>5.7 ± 1.0</td>
<td>6.2 ± 1.3</td>
<td>6.0 ± 0.7</td>
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<tr>
<td><strong>Test 2</strong></td>
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<tr>
<td>ISWT (m)</td>
<td>970 ± 303*</td>
<td>14.1 0.002</td>
<td>878 ± 267*</td>
<td>16.2 0.003</td>
<td>928 ± 225*</td>
<td>21.0 &lt;0.001</td>
<td></td>
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</tr>
<tr>
<td>HRV rest (rMSSD)</td>
<td>33.8 ± 7.9*</td>
<td>17.7 0.003</td>
<td>32.8 ± 6.5*</td>
<td>22.2 0.008</td>
<td>38.8 ± 7.5*</td>
<td>27.8 &lt;0.001</td>
<td></td>
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</tr>
<tr>
<td>HRV post-exercise (rMSSD)</td>
<td>22.3 ± 4.4</td>
<td>27.7 0.112</td>
<td>20.5 ± 4.9*</td>
<td>30.0 0.008</td>
<td>25.8 ± 4.0*</td>
<td>50.5 &lt;0.001</td>
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</tr>
<tr>
<td>HR rest (beats·min⁻¹)</td>
<td>64.3 ± 9.1</td>
<td>-3.8 0.158</td>
<td>64.1 ± 14.6</td>
<td>-2.6 0.158</td>
<td>59.2 ± 10.5*</td>
<td>-6.5 0.001</td>
<td></td>
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</tr>
<tr>
<td>HRVT (km·h⁻¹)</td>
<td>7.2 ± 1.2*</td>
<td>25.2 0.016</td>
<td>7.2 ± 1.6*</td>
<td>17.4 0.001</td>
<td>8.0 ± 0.9*</td>
<td>34.1 &lt;0.001</td>
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</tbody>
</table>

CL = Control Load; LL = Linear Load; UL = Undulating Load; ISWT = Incremental shuttle Walk Test; HRV rest = Heart Rate Variability at Rest; (rMSSD) = Root Mean Square of the Successive Differences; HRV post-exercise = post-exercise Heart Rate Variability; HR rest = Heart Rate at rest; HRVT = heart rate variability threshold; *P<0.05 vs. Test 1.

Table 5 shows the effect size (ES) calculation for the ISWT, HRV rest, HRV post-exercise, HR rest, and HRVT variables in the comparison between A1 and A2. The ES was great in HRV post-exercise and in HRVT in the UL group and moderate in HRVT in the CL group. As for the other differences from A1 to A2, the effect was considered to be small or trivial.

Table 5. Effect Size for the ISWT, HRV rest, HRV post-exercise, HR rest, and HRVT Variables in the Comparison Between T1 and T2 of the CL, LL, and UL Groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CL T1 vs. T2</th>
<th>LL T1 vs. T2</th>
<th>UL T1 vs. T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISWT (m)</td>
<td>0.40 Small</td>
<td>0.41 Small</td>
<td>0.81 Large</td>
</tr>
<tr>
<td>HRV rest (rMSSD)</td>
<td>0.62 Medium</td>
<td>1.03 Large</td>
<td>1.13 Large</td>
</tr>
<tr>
<td>HRV post-exercise (rMSSD)</td>
<td>0.54 Medium</td>
<td>0.90 Large</td>
<td>2.07 Large</td>
</tr>
<tr>
<td>HR rest (beats·min⁻¹)</td>
<td>-0.31 Small</td>
<td>-0.11 Small</td>
<td>-0.37 Small</td>
</tr>
<tr>
<td>HRVT (km·h⁻¹)</td>
<td>1.43 Large</td>
<td>0.84 Large</td>
<td>2.97 Large</td>
</tr>
</tbody>
</table>

CL = Control Load; LL = Linear Load; UL = Undulating Load; ISWT = Incremental shuttle Walk Test; HRV rest = Heart Rate Variability at Rest; HRV post-exercise = post-exercise Heart Rate Variability; HR rest = Heart Rate at rest; HRVT = heart rate variability threshold; ES = Effect Size; T1 = Test 1; T2 = Test 2.
DISCUSSION

The present study investigated the chronic effect of exercise training with different ETL distributions on the HRV of healthy adult women. It was observed that regardless of the way the load was distributed, the subjects significantly improved in ISWT, HRV_{rest} and in HRVT. However, only the UL group showed significant reduction in HR_{rest} and the LL and UL showed increased HRV_{post-exercise}. In addition, the ETL in Zone 1 was higher in the CL group than in the LL and UL groups, but it did not result in higher ITL in the sum of the 12 accumulated training sessions. These findings demonstrate the importance of the organized aerobic ETL distribution to the studied population. They also show that the undulating distribution promotes greater gains in the HRV variables in comparison to the linear distribution and to the non-periodized training. Another finding indicates that the periodized ETL distribution may promote greater ITL accumulation throughout the aerobic training sessions, since the ETL of the CL group in Zone 1 was higher than that of the LL and UL groups.

Regardless of the way the load was distributed in the groups, the subjects were expected to present positive adaptations in the HRV-related variables and in the ISWT due to the herein proposed aerobic training. The 4-wk period with 12 aerobic training sessions was enough to promote significant changes in the analyzed variables except for HR_{rest} in the CL and LL and for HRV_{post-exercise} in the CL. These findings are consistent with results found in other studies, which used similar duration and training in non-athlete healthy men and women (23), men with heart failure (12), and recreational runners and triathletes (30).

The physiological adaptations generated by the aerobic training induce resting bradycardia by increasing the cardiac vagal tone and reducing the sympathetic nervous system activation, both at rest, during, and after the exercise (1). The HRVT and HRV_{rest} changes found in the CL, LL, and UL groups may be associated with lower vagal withdrawal and/or less sympathetic-adrenal activation during the progressive increase in the physical exercise intensity (16), and related to lower circulating concentrations of catecholamines, lower blood flow restriction in inactive regions of the muscles, and to the improved sensitivity of the pressor receptors and mechanoreceptors (2). These adaptations are important to increase the cardiopulmonary performance and the cardioprotective effect, and they directly lead to improved quality of life and physical fitness of people who practice physical exercises for health purposes (17).

It is worth highlighting that these adaptations depend on the magnitude and on the way ETL is distributed throughout the training period (15). According to Roschel et al. (26), the ETL control alone is not sufficient to represent the mechanical and physiological impact of a given training load on the body because subjects with similar characteristics may heterogeneously respond to the same ETL (17), thus requiring parameters for the internal control of organic responses. The study by Milanez et al. (22) demonstrated that an athlete with VO_{2 max} of 58 mL·kg^{-1}·min^{-1} presents daily ITL values 34% higher than those of an athlete with VO_{2 max} of 63 mL·kg^{-1}·min^{-1}, when they perform similar ETL.

The sum of the ITL is essential for the bodily adaptations, and the ETL prescription will determine the ITL accumulation during systematized training periods (9,19). Manzi et al. (20) conducted a study with athletes and demonstrated that 500 a.u. of ITL (TRIMPI) were necessary to justify the improved aerobic fitness in their elite players. In the case of healthy
subjects with moderate level of aerobic fitness \( \text{VO}_{2\text{peak}} \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \): \( \text{CL} = 35.4 \pm 11.4; \text{LL} = 31.8 \pm 11.2; \text{UL} = 32.2 \pm 7, 6 \), it was expected that the chronic adaptations promoted in the HRVT, ISWT, and HRVrest could also be explained by the ITL accumulation in the 12 training sessions since the herein found values were \( \text{CL} = 13474 \pm 1059 \text{ a.u.}, \text{LL} = 12650 \pm 1411 \text{ a.u.}, \) and \( \text{UL} = 12734 \pm 846 \text{ a.u.} \). Subjects with lower aerobic fitness level are more responsive to the ETL (14) magnitude. Thus, regarding the findings of the current study, just one research study on non-athletes was found in the literature (12). However, the authors (12) compared the applied aerobic training method (continuous vs. interval) and not the way the ETL was distributed, as was done in the current study.

Therefore, the results of the LL and UL groups indicate lower ETL in comparison to the CL group in training Zone 1 \( (20294 \pm 3764 \text{ m}, 19789 \pm 2610 \text{ m}, 25467 \pm 2023 \text{ m}, \) respectively). The total training time was 114 min shorter in LL and in UL than in CL (342 vs. 456 min). Despite the greater ETL in the CL group, there was no significant ITL difference in the comparison between groups (Figure 2). This finding suggests that the periodized ETL distribution may induce higher ITL in the studied population. Studies have shown that periodized training models induce greater magnitude of chronic adaptations in comparison to the non-periodized ones (8,29,30). Based on the results found in the current study, it also seems to be true to induce the ITL increase in CL and LL, despite the lower ETL. Some authors (9,13,24,26) highlighted that the ITL accumulation is related to the magnitude of the chronic adaptations, thus justifying the behavior of the HRV variables in the analyzed groups.

The undulating ETL distribution in the 12 sessions incremented the studied variables in comparison to the linear distribution and to the control load. Large effect size \( (\text{ES} = 2.07 \text{ and } 2.97) \) was found in HRV\text{post-exercise} and in HRVT, respectively, in the UL group. Fleck (8) points out that daily or weekly undulating periodization in strength training have shown better results than the linear one. Bartolomei et al. (3) recently demonstrated that the undulating variation produced greater gains in maximum strength and muscle hypertrophy in recreationally trained adult women than the block distribution of ETL. With respect to the aerobic training, few studies comparing the form of ETL distribution and chronic adaptations (30) were found, especially when it came to non-athletes (25) as is the case in the current study.

With respect to triathlon, running, cycling, and cross-country skiing athletes, the undulating distribution, which is also called polarized distribution, seems to promote greater increases in peak oxygen uptake and in ventilatory threshold than the other ETL organizational models (29,30). Indeed, the daily and weekly undulating ETL variation is mostly related to increased ventilatory threshold and peak oxygen uptake (4,29), and these variables are related to the HRVT test \( (r = 0.738) \) and ISWT \( (r = 0.856), \) respectively (7), as it was analyzed in the current study. Perez (25) demonstrated in healthy adult males that, despite the higher ETL, the increasing linear group showed no major gains in VO\text{2max}, blood pressure, and relative heart rate when it was compared to the stepped and undulating models. The results of the current study corroborate the studies by Perez (25), Stöggl and Billy (29), Suarez and Gonzalez-Rave (30) about the superiority of the undulating ETL distribution in comparison to the linear distribution with respect to the chronic adaptations of the aerobic training.

It can be inferred that the periodized ETL distribution with undulating variation promotes greater improvement in the HRV variables in healthy adult women. The training conducted with absolutely no control and planning should be avoided, given that the subjects who have
followed this form of training (CL) showed higher ETL in Zone 1 than those in groups subjected to load distribution (LL and UL). However, this does not necessarily imply a greater improvement in the monitored HRV variables. In addition, despite the higher ETL in the CL group, no ITL increase was detected in the volunteers. It shows that the periodized ETL distribution leads to increased ITL, and this is an important premise for the body to generate chronic adaptations to the aerobic training. Thus, it is noteworthy that the current study is the first to demonstrate this relationship in non-athlete healthy adult women.

The following potential limitations should be taken into consideration. This study was completed with a small number of volunteers in the CL group, since there was a sample loss of 4 subjects. Another limiting factor was the use of IPAQ to quantify the weekly physical activity level, which is done by self-report. Although it is a validated quantification method, it does not allow directly quantifying the energy expenditure of the studied subjects.

CONCLUSIONS

The results of the current study suggest that, regardless of the form of load distribution, the healthy adult women significantly improved their aerobic capacity, heart rate variability at rest, and heart rate variability threshold speed, thus indicating that the undulation distribution of the external training load promoted greater chronic adaptation in the analyzed HRV variables.

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