Autonomic Response on Different Micro-Cycles of Training in Young Healthy Swimmers

Iransé Oliveira-Silva, Filipe Nobre Xavier Nunes, Edilberto Barros, Denis Diniz, Marcelo Magalhães Sales, Márcio Mota Rabelo, Rafael da Costa Sotero, Humberto de Sousa Fontoura, Grassyara Pinho Tolentino

ABSTRACT

Oliveira-Silva I, Nunes FNX, Barros EB, Diniz EBD, Sales MM, Rabelo MM, Sotero RC, Fontoura HS, Tolentino GP. Autonomic Response on Different Micro-Cycles of Training in Young Healthy Swimmers. JEPonline 2017;20(1):140-150. The aim of this study was to assess the autonomic response on different micro-cycles of training in healthy swimmers, and their relationship with physical fitness indicators. Seven swimmers with national indices underwent three training micro-cycles during the winter. Five minutes of HRV was recorded before the first daily training session. An ANOVA was applied to observe the differences between micro-cycles, and the correlation between fitness and HRV was tested. The aerobic power micro-cycle presented indicators of increased sympathetic activity compared to other micro-cycles. An absolute increase in vagal activity was observed in lactic anaerobic cycle, while the alactic anaerobic cycle showed a decrease in vagal activity compared to lactic. As to physical fitness indicators, body fat and VO2 max impacted positively on sympathetic-vagal control. The intensity of swimming training micro-cycles autonomic control is minimally noticeable after a recovery period with an apparent relationship between aerobic power training and sympathetic activity. The vagal activity is more evident during lactic anaerobic training. The results confirm that the physical fitness indicators impact the sympathetic-vagal control, especially the sympathetic activity.

Key words: HRV, Swimming, Training Micro-Cycle
INTRODUCTION

High performance is achieved in sports by observing small details (16) in the athlete’s talent, effective and well planned training, and optimal recovery, a balanced diet, and psychological factors. The control of this complex system provides balance to athletes, which in turn is perceived by the central nervous system (19). The autonomic nervous system reflects the balance of the central nervous system (10) through the sympathetic and parasympathetic branches. One way to check these changes in the system’s response is by recording heart rate variability (HRV), a simple technique, that is inexpensive and noninvasive (23,25).

It is well documented in the literature that an increase in HRV is a positive sign of adaptation to exercise, indicating a healthy individual with efficient autonomic mechanisms. (20,24). It is noteworthy that physical exercise has positive effects on the human body (8). On the other hand, the literature points out that according to the stimulus intensity and recovery time, the body may react differently resulting in situations that involve the reduction of performance (i.e., overreaching and overtraining) (3). Furthermore, the characteristic of the stimulus (i.e., aerobic or anaerobic) can generate different autonomic results (7) that tend to normalize the following day to stimulation (8). For this reason, it is important that trainers and athletes pay attention to HRV.

It is reasonably clear that gender is not a determining factor in the autonomic response or a condition for differentiation between people (13). But, the health condition of an individual (e.g., stress) greatly influences autonomic control (12,17) as a factor in the studies that examine HRV. Hence, it is important that the health status of individuals is standardized. Regarding the physical fitness of the athlete, there is evidence that shows optimal levels of body fat and VO\textsubscript{2} max are protective factors for health (8). Although each plays an important role in the control of the autonomic nervous system (17), body fat appears to have the greater influence on autonomic modulation (19).

To the best of our knowledge, there are no studies that have investigated the effects of different micro-cycles of swimming training (i.e., aerobic, anaerobic lactic, anaerobic alactic) on the autonomic modulation and its relationship with different parameters of physical fitness. Thus, the purpose of this study is to verify the autonomic response in different swimming training micro-cycles and their relationship with body fat and VO\textsubscript{2} max of athletes at the national level.

METHODS

Subjects
Seven high-performance athletes (4 men and 3 women) 17 to 26 yrs of age with no known chronic disease (such as diabetes, hypertension, cardiovascular disease, and depression) or the use of drugs that would interfere in the assessment of the athletes’ physiological variables participated in this study. All athletes have national indices and are among the best in the state. They were in preparation for national and international level competitions. All the characteristics of athletes are presented in Table 1.
Table 1. General Characteristics of Athletes Included in the Study.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>BMI</th>
<th>%BF</th>
<th>VO₂ max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>20</td>
<td>82.2</td>
<td>1.83</td>
<td>24.55</td>
<td>13.1</td>
<td>52.5</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>17</td>
<td>78.1</td>
<td>1.83</td>
<td>23.32</td>
<td>10.2</td>
<td>59.5</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>19</td>
<td>76.7</td>
<td>1.68</td>
<td>27.18</td>
<td>8.0</td>
<td>59.5</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>26</td>
<td>84.1</td>
<td>1.83</td>
<td>25.11</td>
<td>8.3</td>
<td>59.5</td>
</tr>
<tr>
<td>5</td>
<td>Female</td>
<td>18</td>
<td>57.0</td>
<td>1.70</td>
<td>19.72</td>
<td>17.0</td>
<td>45.5</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>19</td>
<td>57.4</td>
<td>1.68</td>
<td>20.34</td>
<td>21.8</td>
<td>42.0</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>20</td>
<td>59.2</td>
<td>1.70</td>
<td>20.48</td>
<td>16.1</td>
<td>45.5</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>Male</td>
<td>20 ± 3</td>
<td>80.28 ± 3.46</td>
<td>1.79 ± 0.08</td>
<td>25.04 ± 1.61</td>
<td>9.90 ± 2.35</td>
<td>57.75 ± 3.50</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>Female</td>
<td>19 ± 1</td>
<td>57.87 ± 1.17</td>
<td>1.69 ± 0.01</td>
<td>20.18 ± 0.40</td>
<td>18.30 ± 3.06</td>
<td>44.33 ± 2.02</td>
</tr>
</tbody>
</table>

Procedures

Initially, the subjects underwent a physical evaluation (1st Phase) during the first week of July between the 9 and 11 a.m. The evaluation also served to verify that the athlete met all inclusion criteria. Moreover, body composition tests were conducted to estimate the body mass index (BMI) and body fat. Then, the athletes were submitted to one 400 m performance test (v400) in an indoor 25 m pool to determine aerobic performance. The next day the athletes performed a second test to assess aerobic power on a 400 m running track. During the 2nd, 3rd, and 4th wks of July (2nd Phase) at 9 a.m., the subjects’ heart rate variability was recorded for 5 min. The ambient temperature ranged between 17 and 28°C with a relative humidity between 27 to 60%.

Body Composition

Body weight and height were measured using a calibrated scale (PL 200, Filizola, Brazil) and a stadiometer (Seca, Sanny, Brazil), respectively. Percentage body fat was estimated from skinfold measurements. Body density was calculated using the seven folds protocol as suggested by Jackson and Pollock (11). The measurements were performed by a single examiner, using a skinfold caliper (Lange, Cambridge Scientific Instruments, Cambridge, Maryland, USA). After calculating body density, it was converted to fat percentage using the equation proposed by Siri (21).

Estimate of Aerobic Power

To estimate the velocity associated with VO₂ max (vVO₂ max), two tests were applied. One in an aqueous medium, test v400, where the athlete after a preheating for 10 min in the pool at moderate intensity swam at maximum speed for a 400 m distance (v400). The total time was recorded for the distance (14), and another recording was made on the athletic track, using the "Université de Montréal Test Track" (UMTT) (15). This was done to determine the subjects’ maximal aerobic velocity (MAV) and, subsequently, an estimation of maximum oxygen consumption (VO₂ max) [VAM in km·h⁻¹ × 3.5 mL·kg⁻¹·min⁻¹]. The protocol started 7 km·h⁻¹ followed by increments of 1 km·h⁻¹ every 2 min until the subject could not maintain the velocity imposed by the cyclist that established the running pace (5). The total test time (Tₚ) was recorded (5), as well as the highest speed the athlete was able to achieve.
Heart Rate Variability
The subjects’ HRV was always recorded at 9 a.m. daily using a heart rate monitor (RS800, Polar Electro Oy, Finland), which was previously validated (27). All subjects were asked to arrive at least 20 min in advance of the water park. When they arrived, they sat motionless for 15 min. At the end of the time period, HRV was recorded for 5 min. The measurements were carried out in a space without interference or contact with other athletes or subjects.

The recorded heart rates were visually inspected and filtered manually by Polar Pro software (v 5.35.161, Polar Electro Oy, Finland) and, subsequently, analyzed by HRV Kubios (v2.0, University of Kuopio, Finland). The parameters of HRV analyzed were: (a) mean and deviation of heart rate (HR) in beats per minute; (b) mean RR interval (RR); (c) square root of the mean of successive differences between normal RR intervals (RMSSD); (d) square root of all RR intervals (SDNN); (e) variability of short-term RR intervals; (f) beat to beat plot Poincaré (SD1); (g) long-term RR interval variability; (h) Poincaré plot beat (SD2); (i) entropy sample (SampEn); and (j) short-term fractal scaling exponent for 4-11 (α1) (20,23,25).

Periodization
Three training protocols were used (micro-cycles) divided by a week. In the 1st micro-cycle, the subjects performed 13 training sessions lasting about 80 min each. The training sessions were performed on Monday, Wednesday, and Friday between 9:00 and 10:20 a.m. between 4:00 to 5:20 p.m. and from 7:00 to 8:00 p.m. Also, training took place on Tuesday and Thursday mornings between 9:00 and 10:20 a.m. and during the afternoon from 4:00 to 5:20 p.m. There was no third training session.

The morning training was exclusively in the pool (freestyle swimming). In the afternoon session, part of the training (~60 min) was performed at the pool (freestyle swimming), followed by 20 min of strength training in the weight room, which focused on developing strength and muscular endurance. The evening training sessions were conducted in the same manner of the morning sessions.

The total volume of training in the pool was 36 km·wk⁻¹. The subjects underwent 13 training sessions, where the intensities were alternating between A1 (i.e., between FC 130 to 140 beats·min⁻¹); A2 (i.e., between FC 150 to 160 beats·min⁻¹), and A3 (i.e., between FC 170 to 180 beats·min⁻¹). The athletes were subjected to a series of 50 to 400 m of freestyle swimming, with rest interval ranging from 20 to 40 sec for A1 intensity, from 40 to 60 sec for A2 intensity, and from 60 to 120 sec for A3 intensity. This training featured the study’s aerobic training cycle.

In the second micro-cycle, the training sessions had the same amount of time and were carried out on the same days and times of the first micro-cycle, except that in this period of training, the athletes also had training session on Saturday afternoon (from 4:00 to 5:20). The total volume of training in the pool was 26 km·wk⁻¹. The athletes were subjected to a series of 50 and 100 m of freestyle swimming with the intensity between 90 and 110% of the mean velocity obtained in the 400-m test (v400). This training featured the study’s lactic anaerobic training cycle.

In the third micro-cycle, 5 training sessions lasted about 80 min each, always in the morning, between 9:00 and 10:20 a.m. This training featured the study’s alactic anaerobic endurance
training cycle as well as emphasis on turns, outputs, and pace. The athletes were instructed to perform maximum efforts lasting up to 10 sec with a rest interval of 180 sec between sets.

![Figure 1. The Characterization of Swimming Training.](image)

**Statistical Analysis**

The normality and homogeneity of variance were tested using the Shapiro-Wilk and Levene tests, respectively. All data were expressed as mean, standard deviation, and limits of confidence (95%). To compare the heart rate variability values between (weeks) and within micro-cycles (day) a mixed ANOVA was used followed by the Bonferroni post hoc test. The hypothesis of sphericity was verified by the Mauchly test and, when violated the degrees of freedom were corrected by the Greenhouse-Geisser estimates. The effect size (ES) between weeks was evaluated using Cohen’s d. Pearson’s correlation coefficients were used to verify the relationships between different indicators of physical fitness (VO₂ max and body fat) and markers of time domain of heart rate variability (RMSSD and SDNN). The level of statistical significance was set at P ≤ 0.05. All data were analyzed using SPSS for Win/v. 22.0 (Statistical Package for Social Sciences, Chicago, IL, USA).

**RESULTS**

The aerobic power cycle presented higher sympathetic activity indicators compared to other micro-cycles while the two micro-cycles with anaerobic characteristic related more to the vagal activity. An absolute increase in vagal activity was observed in the lactic anaerobic cycle, while the alactic anaerobic cycle showed a decrease in vagal activity compared to lactic (Table 2).
Table 2. Comparison of the Different Indicators of Heart Rate Variability in the Three Swimming Training Micro-Cycles.

<table>
<thead>
<tr>
<th>HRV</th>
<th>Micro-Cycle 1</th>
<th>Micro-Cycle 2</th>
<th>Micro-Cycle 3</th>
<th>P</th>
<th>ES 1° x 2°</th>
<th>ES 1° x 3°</th>
<th>ES 2° x 1°</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR  (bpm)</td>
<td>80 ± 5 (75 - 85)</td>
<td>79 ± 7 (72 - 85)</td>
<td>76 ± 4 (72 - 80)</td>
<td>NS</td>
<td>0.18</td>
<td>0.88</td>
<td>0.58</td>
</tr>
<tr>
<td>RR (ms)</td>
<td>770.31 ± 46.04 (727.73 - 812.89)</td>
<td>750.88 ± 43.54 (710.61 - 791.15)</td>
<td>801.78 ± 48.34 (757.07 - 846.49)</td>
<td>0.00</td>
<td>0.65</td>
<td>0.44</td>
<td>1.11</td>
</tr>
<tr>
<td>SDNN (ms)</td>
<td>102.45 ± 17.84 (85.94 - 118.96)</td>
<td>83.49 ± 16.35 (68.36 - 98.62)</td>
<td>85.06 ± 15.73 (70.51 - 99.61)</td>
<td>0.07</td>
<td>1.15</td>
<td>1.06</td>
<td>0.12</td>
</tr>
<tr>
<td>RMSSD (ms)</td>
<td>50.26 ± 11.06 (40.02 - 60.49)</td>
<td>50.88 ± 7.03 (44.38 - 57.39)</td>
<td>48.38 ± 12.78 (36.56 - 60.20)</td>
<td>NS</td>
<td>0.06</td>
<td>0.17</td>
<td>0.24</td>
</tr>
<tr>
<td>LF (ms²)</td>
<td>3076.71 ± 1435.20 (1749.37 - 4404.05)</td>
<td>2449.82 ± 847.60 (1665.91 - 3233.72)</td>
<td>2259.28 ± 1068.08 (1271.47 - 3247.09)</td>
<td>NS</td>
<td>0.53</td>
<td>0.64</td>
<td>0.19</td>
</tr>
<tr>
<td>HF (ms²)</td>
<td>880.51 ± 395.27 (514.94 - 1246.08)</td>
<td>968.02 ± 468.14 (535.06 - 1400.99)</td>
<td>854.05 ± 519.92 (373.20 - 1334.90)</td>
<td>NS</td>
<td>0.20</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>LF/HF (ms²)</td>
<td>3.52 ± 1.52 (2.10 - 4.93)</td>
<td>3.57 ± 1.03 (2.62 - 4.53)</td>
<td>3.79 ± 0.85 (3.00 - 4.58)</td>
<td>NS</td>
<td>0.04</td>
<td>0.22</td>
<td>0.17</td>
</tr>
<tr>
<td>SD1 (ms)</td>
<td>35.64 ± 7.70 (28.51 - 42.77)</td>
<td>36.71 ± 5.01 (32.07 - 41.34)</td>
<td>34.70 ± 8.95 (26.42 - 42.98)</td>
<td>NS</td>
<td>0.16</td>
<td>0.13</td>
<td>0.29</td>
</tr>
<tr>
<td>pNN50 (ms)</td>
<td>27.46 ± 4.86 (22.95 - 31.95)</td>
<td>27.38 ± 6.77 (21.11 - 33.64)</td>
<td>24.41 ± 10.09 (15.07 - 33.75)</td>
<td>NS</td>
<td>0.00</td>
<td>0.39</td>
<td>0.36</td>
</tr>
<tr>
<td>SampEn</td>
<td>1.10 ± 0.18 (0.93 - 1.28)</td>
<td>1.31 ± 0.22 (1.10 - 1.51)</td>
<td>1.22 ± 0.18 (1.05 - 1.40)</td>
<td>NS</td>
<td>1.04</td>
<td>0.66</td>
<td>0.44</td>
</tr>
<tr>
<td>a1</td>
<td>1.38 ± 0.07 (1.31 - 1.45)</td>
<td>1.36 ± 0.05 (1.31 - 1.41)</td>
<td>1.34 ± 0.08 (1.26 - 1.42)</td>
<td>NS</td>
<td>0.33</td>
<td>0.53</td>
<td>0.30</td>
</tr>
</tbody>
</table>

HRV = heart rate variability; HR = heart rate; RR = mean R-R interval; SDNN = standard deviation of all R-R intervals; RMSSD = root mean square of successive differences between normal sinus R-R intervals; LF = low frequency component; HF = high frequency; SD1 = short-term beat-to-beat R-R variability from the Poincaré plot; pNN50 = percentage of adjacent normal R–R intervals different by greater than 50 ms; SampEn = sample entropy; a1 = detrended fluctuations of short-term fractal scaling; ES = effect size; NS = no significance

Regarding the association of autonomic indicators with physical fitness markers, the results suggest that, as expected, increased adiposity is associated with lower heart rate variability (SDNN) and, therefore, increased sympathetic nervous activity \((r = -0.76)\). Furthermore, the results indicate that higher VO\(_2\) max is associated with greater heart rate variability (SDNN), that is, higher vagal activity \((r = 0.75)\). Similarly, as to the vagal indicator of the time domain (RMSSD), it showed that higher adiposity is associated with lower vagal activity \((r = -0.36)\) and higher VO\(_2\) max values are associated with increased vagal activity \((r = 0.37)\), although the associations were weaker in comparison with the overall indicator of autonomic nervous activity (SDNN) (Figure 2).
DISCUSSION

This study aimed to analyze the effects of different micro-cycles on autonomic indicators at in swimmers at the national level. The main findings of this study indicate that micro-cycles of swimming training seem to have little influence on autonomic control. However, it is evident there is an important relationship between the autonomic nervous activity and aerobic power. The results confirm that the two indicators of physical fitness (body fat and VO$_2$ max) impact the sympathetic-vagal control, especially the sympathetic activity which tends to increase. To our knowledge, this is the first study that shows the autonomic changes because of different
swimming training cycles in experienced athletes and their relationship with physical fitness indicators.

There is no consensus in the literature on the autonomic responses induced by a specific swimming training. Duarte et al. (9) reported higher levels of vagal activity under aerobic training. On the other hand, Caruso and colleagues (6) found increased sympathetic activity induced by aerobic training, which was possibly due to the relationship described by Rossi et al. (19). They showed that body fat is the physical fitness component in swimmers that influences the autonomic activity. With these findings it seems apparent that not only the characteristic of the training leads to autonomic response, the present study adds physical fitness as well as influences autonomic modulation. However, it is emphasized that the time used for each training cycle (i.e., 3 wks) may have been limiting results. Vernillo et al. (26) showed with runners significant autonomic changes with 8 wks of training.

Another factor that deserves mention is the change in the intensity of training, which seems to have little influence on the autonomic control in accordance with the study by Azevedo et al. (1). They reported that the lack of significant difference during the phases of training may be due to the high level of VO$_2$ max of athletes, which seems to be reinforced Rossi et al. (19). In addition to this point, there is the anxiety factor that takes place with competition. Also, the sample size in the present study may have minimized the findings, although the sample was consisted of the best swimmers in the region.

Further studies are needed to investigate the relationship between body fat and ΔRMSSD. In fact, the athletes with lower body fat percentage had major changes over the 3 wks of training, which is supported in the literature (19). Thus, RMSSD is a good indicator to realize the athlete’s fatigue and, consequently, serve as a parameter for the technical prescription of training. But, at present it is not clear what the intensity of change is. It is important to note that the HRV recording method (i.e., 5 min), the subjects’ posture, the number of records, the intensity of the sessions, and the recovery period for the completion of registration the next day may have influenced the findings (4,18,28).

CONCLUSIONS

The swimming training micro-cycles exerted little change in autonomic control after the recovery period. However, there is evidence of an apparent relationship between aerobic power training and sympathetic activity while the vagal activity is more evident during the lactic anaerobic training. Body fat and VO$_2$ max influenced sympathetic-vagal control, and especially the influence of body fat on increasing sympathetic activity.

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