Effect on HRV of archer athletes one day before competition after three different abdominal respiratory frequency

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Abstract

Purpose: To study the effect on HRV of archer athletes one day before competition after three different abdominal respiratory frequencies.

Methods: Eight elite archers performed three different respiratory frequency tests, HRV were recorded in pre-, during, and post-frequency control in frequency 16 (F16 group, n = 8), 8 (F8 group, n = 8), and 5 (F5 group, n = 8) times per minute, and hoped to find a respiratory adjust way to reduce stress. RMSSD, RR triangular index, TP, VLF, LF, HF and LF/HF were analyzed to describe the effect of respiratory frequency.

Result: The average RR separate, RR triangular index and HF showed no significant change in three respiratory frequency (P > 0.05); LF increased significantly in F16 group, but LP of F8 and F5 group increased first then reduced (P < .05); VLF rose in F8 and F5 group (P < .05, respectively), the LF/HF has the similar change as the LF in all the groups.

Conclusion: The F16 group increased equilibrium of sympathetic and pneumogastric nerve system; F8 increase excitability of sympathetic nerve; mental fatigue remission in F5.

1. Introduction

HRV (Heart Rate Variability) refers to the periodic change of heart rate within certain period of time, which is also an important index to reflect the tension and balance between sympathetic and parasympathetic nerve (vagus nerve) (Levy and Schward, 1994). HRV is a sensitive index, which reflects the fine regulating of cardiovascular system by neurohormonal factors and the regulation of cardiovascular system by autonomic nerves system. HRV has been regarded as an effective method of evaluating cardiac autonomic nerve dysfunction (Sztajzel, 2004). Under normal physiological conditions, the rhythmic change of heart is jointly controlled by sympathetic nerve and vagus nerve, making heart rhythm change in a regular and periodic way (see Fig. 1). Once being impacted by factors such illness, the heart rhythm will be out of original balance, leading to the change of heart rate and heart and cardiovascular system dysfunction (see Fig. 2), which is the physiological basis for HRV analysis (Murukawa et al., 1993). Therefore, it is of great significance to further research the influence factors of HRV. The research on influence factors of HRV has been a hot topic in recent years, wherein respiration has been proved to be one of main influencing factors (Hou and Hua, 2001). There have been relevant researches showing that abdominal breathing can effectively regulate HRV, however there have been no report clearly indicating whether respiratory frequency can influence abdominal breathing effect.

Abdominal breathing is common breath training method in traditional Chinese ideology of preserving health. It is also called breath regulating training, which means consciously extending time for breathe in and out, performing deep, slow and regular abdominal breathing, so as to realize self-regulation (Changhong and Zhong, 2011). When performing abdominal breathing, it is required to keep chest stable, regulate breath through diaphragmatic rise and fall, keep breathing deep and slow. When breathing in, the horizontal diaphragm fall and abdomen will significantly upheave; when breathing out, abdomen will be sunken. Such...
breathing method is also called “smooth breathing method” or “positive breathing method” (see Fig. 3). Since abdominal breathing can regulate the function of autonomic nervous system, improve pulmonary ventilation, and achieve sound relaxing effect, it is applied for clinical treatment of some chronic diseases (Zhang, 2003).

Abdominal breathing has a recognized effect in reducing anxiety and tension. In this research, male archer athletes of certain provincial sports team are selected as objects, who are required to conduct three different abdominal breathing frequencies from the night before team competition. Through measuring the change condition of testee’s HRV, the influences of three different abdominal breathing frequencies are compared, and the one with the highest influence on HRV is selected out, so as to provide the basis for selecting suitable approach of regulating tensity of vegetative nervous system.

2. Research design

2.1. Research object

Research objects are 8 provincial male archer athletes with the first sport grade or above. Employed athletes have similar life regulation and sports experience. They are all in healthy condition without history of taking any medicine that will affect heart capacity. Table 1 below shows the basic conditions.

2.2. Research method

2.2.1. Experimental instrument

In this experiment, POLAR RS800CX pro team from Finland is adopted as measurement tool, data is led out to computer through Polar IR transmitter and then analyzes using software of Polar ProTrainer5.

2.2.2. Test method

Test is given by three times at the night before team competition. At the first time of test, tested athletes are required to take respiratory frequency at 16 times/min (F16 group, n = 8), at the second time of test, respiratory frequency is 8 times/min (F8 group, n = 8), at the third time of test, respiratory frequency is 5 times/min (F5 group, n = 8). The tested athletes are required to wear WearLink heart rate transmission band. After checking, they are required to cross both hands and put them on abdomen, keep relax for 10 min. After that they are required to take abdominal breathing regulation under the instruction of tester, in the meantime the HRV data are collected.

2.2.3. Data interception and analysis

Tested athletes perform continuous abdominal breathing for totally 20 min. Research of data interception is based on data collected from 3 groups under normal quiet condition, including CON group (5 min data before abdominal breathing), MED group (5 min data during abdominal breathing), and LAT group (5 min data after abdominal breathing). Analysis content include times domain index: RMSSD between adjacent RR, HRV RR_triangular_index of HRV and total power (TP); frequency domain index: very low frequency component (VLF), low frequency component (LF), high frequency component (HF) and LF/HF ratio.

2.3. Statistical method

All measured results are expressed by Mean ± SD. Paired T-test is adopted to analyzed the indexes between groups of different

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Table 1

| n  | Age (year) | Height (cm) | Weight (kg) | Basic heart rate (time/min) |
|----|------------|-------------|-------------|----------------------------|
| 8  | 24.27 ± 3.32 | 173.31 ± 5.66 | 68.43 ± 12.88 | 71.27 ± 12.50 |
breathing frequencies. The significance level $P < .05$, and the insignificance level $P < .01$.

3. Results

3.1. HRV affected by abdominal breathing of 16 time/min

Comparing HRV indexes of three groups of tested athletes before, during and after taking abdominal breathing of 16 times/min, it can find that the LF value of LAT group reaches $1057.01 \pm 652.60$, which is significantly higher as compared with CON group ($412.71 \pm 236.44$) and MED group ($334.29 \pm 402.31$) ($P < .05$); However with regard to LF/HF value, MED group ($0.22 \pm 0.13$) is significantly lower than that of CON group ($P < .05$); while the LF/HF value of LAT group ($2.59 \pm 1.99$) is significantly higher than that of CON group ($P < .05$), and is significantly different from that of MED group ($P < .01$); During comparing other indexes, no significant difference has been observed ($P > .05$). These results indicate that, the sympathetic excitability is increased during abdominal breathing of 16 time/min, while tends to be normal after abdominal breathing. Therefore, it can conclude that the increase of sympathetic excitability caused by abdominal breathing is of certain continuity (see Table 2).

3.2. HRV affected by abdominal breathing of 8 time/min

Comparing indexes before during and after abdominal breathing of 8 time/min, there can be seen many differences of indexes among three groups. Regarding RMSSD value, LAT group is significantly lower than that of CON group and MED group ($P < .05$); triangle index of LAT group is significantly lower than that of CON group ($P < .05$); In terms of LF value, LAT group is significantly different from CON group and MED group ($P < .01$); The LF/HF value of MED group is significantly higher than that of CON group and LAT group ($P < .05$). No significant difference can be observed in comparison of other indexes ($P > 0.05$) (see Table 3).

3.3. HRV affected by abdominal breathing of 5 time/min

Indexes of three groups before during and after abdominal breathing of 5 time/min are shown in Table 4. It can be seen that regarding time domain indexes such as mean RR interval, RMSSD, triangle indexes, there are no significant differences. Regarding TP value, this value is significantly increased in MED group ($P < .05$), LAT group is significantly lower than that of MED group ($P < .05$), while there is no significant difference between LAT group and CON group; There is no significant difference of HF value; VLF

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### Table 2
Comparison of indexes before during and after abdominal breathing of 16 times/min ($X \pm SD, n = 8$).

| Index            | Before abdominal breathing (CON group) | During abdominal breathing (MED group) | After abdominal breathing (LAT group) |
|------------------|----------------------------------------|---------------------------------------|---------------------------------------|
| Mean RR interval | 0.90 ± 0.12                            | 0.93 ± 0.13                           | 0.95 ± 0.11                           |
| RMSSD            | 56.19 ± 17.405                          | 77.61 ± 35.06                         | 63.64 ± 29.77                         |
| Triangle index   | 0.11 ± 0.04                             | 0.13 ± 0.04                           | 0.11 ± 0.04                           |
| TP               | 1708.57 ± 437.14                        | 1769.51 ± 1090.63                     | 1860.71 ± 1050.41                     |
| VLF              | 303.57 ± 341.26                         | 229.14 ± 362.94                       | 293.71 ± 415.01                       |
| LF               | 412.71 ± 236.44                         | 334.29 ± 202.31                       | 1057.01 ± 652.60*                     |
| HF               | 692.29 ± 429.02                         | 806.14 ± 799.58                       | 612.86 ± 545.01                       |
| LF/HF            | 0.60 ± 0.89                             | 0.41 ± 0.13                           | 2.39 ± 1.99                           |

*Represent $P < .01$ when compared with CON group.

**Represent $P < .05$ when compared with MED group.

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### Table 3
Comparison of indexes before during and after abdominal breathing of 8 time/min ($X \pm SD, n = 8$).

| Index            | Before abdominal breathing (CON group) | During abdominal breathing (MED group) | After abdominal breathing (LAT group) |
|------------------|----------------------------------------|---------------------------------------|---------------------------------------|
| Mean RR interval | 0.93 ± 0.06                            | 0.96 ± 0.11                           | 0.93 ± 0.09                           |
| RMSSD            | 70.90 ± 15.28                          | 60.43 ± 17.29                         | 47.71 ± 12.32*                        |
| Triangle index   | 0.13 ± 0.03                            | 0.11 ± 0.04                           | 0.10 ± 0.02                           |
| TP               | 2004.14 ± 489.46                        | 2640.43 ± 1080.99                     | 1716.71 ± 744.07*                     |
| VLF              | 286.71 ± 610.26                         | 301.86 ± 165.09                       | 529.57 ± 324.44                       |
| LF               | 1475.86 ± 640.87                        | 2101.14 ± 901.09                      | 791.14 ± 597.52**                     |
| HF               | 648.71 ± 427.50                         | 237.43 ± 154.43                       | 396.00 ± 286.64                       |
| LF/HF            | 2.94 ± 3.06                            | 9.54 ± 7.96                           | 2.73 ± 2.86                           |

*Represent $P < .05$ when compared with CON group.

**Represent $P < .05$ when compared with MED group.

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### Table 4
Comparison of indexes before during and after abdominal breathing of 5 time/min ($X \pm SD, n = 8$).

| Index            | Before abdominal breathing (CON group) | During abdominal breathing (MED group) | After abdominal breathing (LAT group) |
|------------------|----------------------------------------|---------------------------------------|---------------------------------------|
| Mean RR interval | 0.89 ± 0.08                            | 0.91 ± 0.06                           | 0.88 ± 0.05                           |
| RMSSD            | 58.56 ± 14.58                          | 47.20 ± 8.83                          | 46.03 ± 8.35                          |
| Triangle index   | 0.10 ± 0.02                            | 0.12 ± 0.04                           | 0.10 ± 0.01                           |
| TP               | 1419.43 ± 749.57                       | 3698.29 ± 1935.99                     | 1232.71 ± 345.40*                     |
| VLF              | 396.14 ± 404.58                        | 310.43 ± 227.59                       | 452.57 ± 328.15*                      |
| LF               | 409.86 ± 464.82                        | 3419.86 ± 1750.60*                    | 297.14 ± 283.55**                     |
| HF               | 613.43 ± 273.18                        | 268.00 ± 203.64                       | 483.01 ± 327.15                       |
| LF/HF            | 0.83 ± 0.92                            | 20.85 ± 17.41                         | 0.74 ± 0.50                           |
value of LAT group is significantly higher than that of MED group (P < .05); LF value displays a large fluctuation as it can be seen that MED group is significantly higher than CON group (P < .01), LAT group is significantly lower than MED group (P < .01), however there is no significant difference between LAT group and CON group; The change rule of LF/HF is similar to that of LF, while its difference is merely significant (P < .05) (see Table 4).

4. Analysis

4.1. Effect analysis of abdominal breathing of 16 time/min on HRV

Under quiet condition, the average respiratory frequency of human body varies by age and gender. The breathing rate of normal people under quiet condition is 12~20 time/min, averaging at 16 time/min (Zhu, 2001). Compared with CON group, after consciously performing abdominal breathing (16 time/min), the heart rate of tested athlete is reduced, however there is no difference in time domain indexes such as mean RR interval, triangle index and TP value and frequency domain index such as VLF (P > .05). Analyz- ers believe that when tested athlete is at state of regular respiratory frequency, there is no significant change in overall self-adjustment capacity of autonomic nerve or in adjustment capacity of sympathetic nerve. It shows that vagus nerve tension HF first increases at the beginning stage of breathing control and then decreases at the end stage of breathing control, indicating that normal respiratory frequency is of certain effect in increasing vagus nerve tension and balancing plant nerve system. After taking abdominal breathing intervention of 16 time/min (MED group), LF value first slightly decreases and then significantly increases 5 min before intervention is finished (P < .05), accounting for 156% of that before breathing intervention under quiet condition. In addition, after taking abdominal breathing intervention of 16 time/min, the double adjusting function of sympathetic nerve and vagus nerve is significantly improved, and the capacity in regulating central excitement and inhibition is also improved, which is reflected by significantly increased LF/HF value (balance between sympathetic nerve and vagus nerve) in the late stage of breathing regulating. This shows that even though at normal breathing frequency, the balance between sympathetic nerve and vagus nerve can also be improved after certain period of conscious regulation. However from above analysis it can find that the abdominal breathing intervention of 16 time/min is of insignificant effect on HRV, but is of improving effect on the balance and double adjusting function of sympathetic and vagus nerve.

4.2. Effect analysis of abdominal breathing of 8 time/min on HRV

By taking abdominal breathing intervention of 8 time/min, all indexes of tested athlete are subjected to great change. For time domain indexes such as RMSSD, LAT is significantly lower than CON group and MED, which is the reflection of reduced vagus nerve tension; Triangle index is subjected to a continuous decrease, there is a significant difference between LAT group and CON group; TP value first increases at the early stage of intervention and then significantly decreases at the late stage of intervention; the overall value and activity of HRV is insignificantly different from that under quiet condition; In terms of frequency domain index change, HF is of no significant change; VLF increases continuously and very sharply at the late stage (P < .05); LF is in fluctuated changed, which increase at middle stage and then significantly decreases at late stage as compared with situation before breathing intervention (P < .01). The change law of LF/HF is similar to that of LF. After taking abdominal breathing intervention of 8 time/min, vagus nerve tension remained unchanged while cardiac autonomic nerve activity is improved. Athletes have higher vagus nerve tension and sympathetic excitability, and the balance between them (mutual transformation capacity) has also been enhanced. As we know heart is jointly supported by vagus nerve and sympathetic nerve. By taking abdominal breathing intervention of 8 time/min, cardiac sympathetic nerve function can be enhanced, moreover cardiac vagal function can also be enhanced (enhancement degree is lower than that of cardiac sympathetic nerve function), it is a significantly effective method to adjust cardiac sympathetic nerve by taking breathing frequency that is lower than normal breathing frequency.

4.3. Effect analysis of abdominal breathing of 5 time/min on HRV

Respiration by the rate of lower than 5 time/min is regarded slow respiration. If breathing in is in slow respiration condition, the interval between breathing in and breathing out is long, tidal volume is large, and excessive intake of oxygen may probably lead to respiratory depression. Cerebral cortex can regulate respiratory center activities at all levels under its management, can effectively regulate and control breath. We can notice that VLF in LAT group is significantly decreased, which is due to mental fatigue in certain degree (Qun, 2009). It reveals that abdominal breathing of 5 time/min may eliminate mental fatigue. However LF/HF value is fluctuated, because when tested athlete is taking conscious control of breathe to reduce breathing frequency and deepen breathing depth, it will inevitably lead to certain degree of mental and muscle tension, and thus increasing sympathetic excitability. The increase of LF is related to factors such as baroreceptor, fluctuation of blood pressure, temperature control, peripheral vessel diastolic excitability, and angiotensin. However as compared with situation before breathing control, the composite regulating function of sympathetic nerve and vagus nerve has not been significantly changed, and sympathetic nervous system tension remains as the same level as that under quiet condition.

Under above three different abdominal respiratory frequencies, triangle index and HF index have not been significantly changed, which indicates that the change degree of heart rate is low and regulating level of cardiac vagus nerve remains stable under these respiratory frequencies; VLF and LF is in significant fluctuation, from which we can know that the composite adjusting function of sympathetic nerve and vagus nerve is also fluctuated, however it overall view, the fluctuation can be controlled by breathing intervention. LF/HF is generally decreased at the late stage of breathing intervention, indicating that cardiac sympathetic excitability is at low level. Archer athletes have stronger intensity and duration of sympathetic nerve and vagus nerve excitement than normal people does, and in particular the parasympathetic adjusting functions of archer athletes are even stronger (Jing et al., 2009). Before competition, no matter what abdominal breathing frequency is taken as adjusting method, it is always of effect to HRV function. 16 time/min of abdominal breathing can generally improve the balance between sympathetic and vagus nerve, 8 time/min of abdominal breathing is mainly effective in improving cardiac sympathetic nerve excitability, and 5 time/min of abdominal breathing is more effective in eliminating mental fatigue.

5. Conclusions

(1) Compared with normal breathing condition, 16 time/min of abdominal breathing can generally improve the balance between sympathetic and vagus nerve, 8 time/min of
abdominal breathing is mainly effective in improving cardiac sympathetic nerve excitability, and 5 time/min of abdominal breathing can eliminate mental fatigue in certain degree.

(2) Before team competition, 8 time/min abdominal breathing intervention has a better effect on relieving nerve than that of 16 time/min and 5 time/min abdominal breathing.

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