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RESEARCH ARTICLE

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Stretching increases heart rate variability in healthy athletes complaining about limited muscular flexibility

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Abstract An increase in muscular flexibility, as well as a significant beneficial effect on heart rate and heart rate variability (HRV), was observed in healthy male athletes after performing a standardized 15-minute stretching-program over a period of 28 days. We believe the HRV increase to be due, at least in part, to the improved vagal and/or diminished sympathetic control. Therefore, we recommend stretching as an effective and gentle technique for health protection.

Key words heart rate variability · stretching · psycho-neuro-cardiac tone

Introduction

Autonomic nervous system (ANS) activity can be modulated through various approaches. Some drugs (e. g., beta-blocker), relaxation techniques (e. g., autogenous training) or regular sporting activities are able to reduce sympathetic and/or increase vagal tone [4, 6, 11, 18], while psychiatric disease (e. g., depression, chronic stress syndrome) as well as some other drugs (e. g., atropine, tricyclic antidepressants) may have opposite effects on ANS activity, such as increased sympathetic and/or decreased vagal tone [1, 3, 12, 16, 20].

Analysis of heart rate variability (HRV) has been established during the past few decades as a valuable tool for assessing risk factor in a variety of medical disorders including acute myocardial infarction, sudden cardiac death, and congestive heart failure [5, 8, 9, 13, 19]. Other authors have pointed out the association of HRV-related parameters with the overall health status of individuals without cardiovascular disorders [6]. HRV can be interpreted as an indicator of global psycho-physical well-being [11]. In this study, HRV was assessed as a quantifiable parameter of ANS functioning.

Stretching is a popular technique, which is easy to learn and can be performed anywhere. It may be used to reduce muscular tone and to improve flexibility [7]. Muscular stretching is known to promote physical as well as mental relaxation. However, to the best of our knowledge, the effects of muscular stretching on ANS activity have not yet been analyzed. Therefore, in a pilot study, we analyzed HRV and muscular flexibility in athletes before and after a 28-day training period.

Subjects and methods

Subjects

We recruited 15 healthy male athletes (aged 22–44 years). All of the subjects had been practicing "bodybuilding" for at least 2 hours a day and 5 times a week for more than one year. All reported good cardiovascular fitness but complained initially about "limited muscular flexibility".

Training procedure and examination conditions

Starting at day 0, all volunteers practiced a daily standardized 15-minute stretching program (of larger muscle groups) for 28 days. During this period, all subjects continued their bodybuilding training as they did before. The subjects were not allowed to smoke or to consume beverages containing caffeine for 2 hours and alcoholic beverages for 10 hours before and throughout the trial. Before taking measurements, the subjects were asked to “relax” and acclimate to the experimental setting.

Heart rate variability

Heart rate was monitored continuously for at least 25 minutes (Fig. 1) using the ambulatory heart rate monitor Polar® Vantage® with Polar® Advantage® Interface and Precision Performance® software (Polar® Electro, Kempele, Finland). The system has been described in detail elsewhere [11, 15]. Calculations of HRV parameters were assessed in two intervals, while 1) resting (sitting), and 2) during the training period, each on days 0 and 28.

We calculated 1) the root mean square of successive differences (RMSSD), 2) the number of pairs of adjacent RR intervals differing by more than 50 ms in the entire recording divided by the total number of all RR intervals (pNN50), and 3) the ratio of low to high frequency (LF/HF) derived from the spectral frequency analysis. It is generally accepted that RMSSD and pNN50 indicate vagal modulation of the heart rate [19], while the LF/HF ratio reflects sympathovagal balance. Repeated measurements of each individual subject were taken at the same time of day to avoid artificial false results resulting from circadian variations of ANS tone.

Quantification of muscular flexibility

Flexibility in large joints (e. g., shoulder, hip) was assessed to document the success of the muscular stretching training. Therefore, all subjects were investigated on day 0 and 28 and increased muscular flexibility was quantified by an overall-flexibility score. Further details are described elsewhere [7].

Statistical analysis

The quantitative variables are described using total range, mean value, and standard deviation. Differences between day 0 and day 28 were evaluated by Wilcoxon test, and they were determined to be significant if $p < 0.05$.

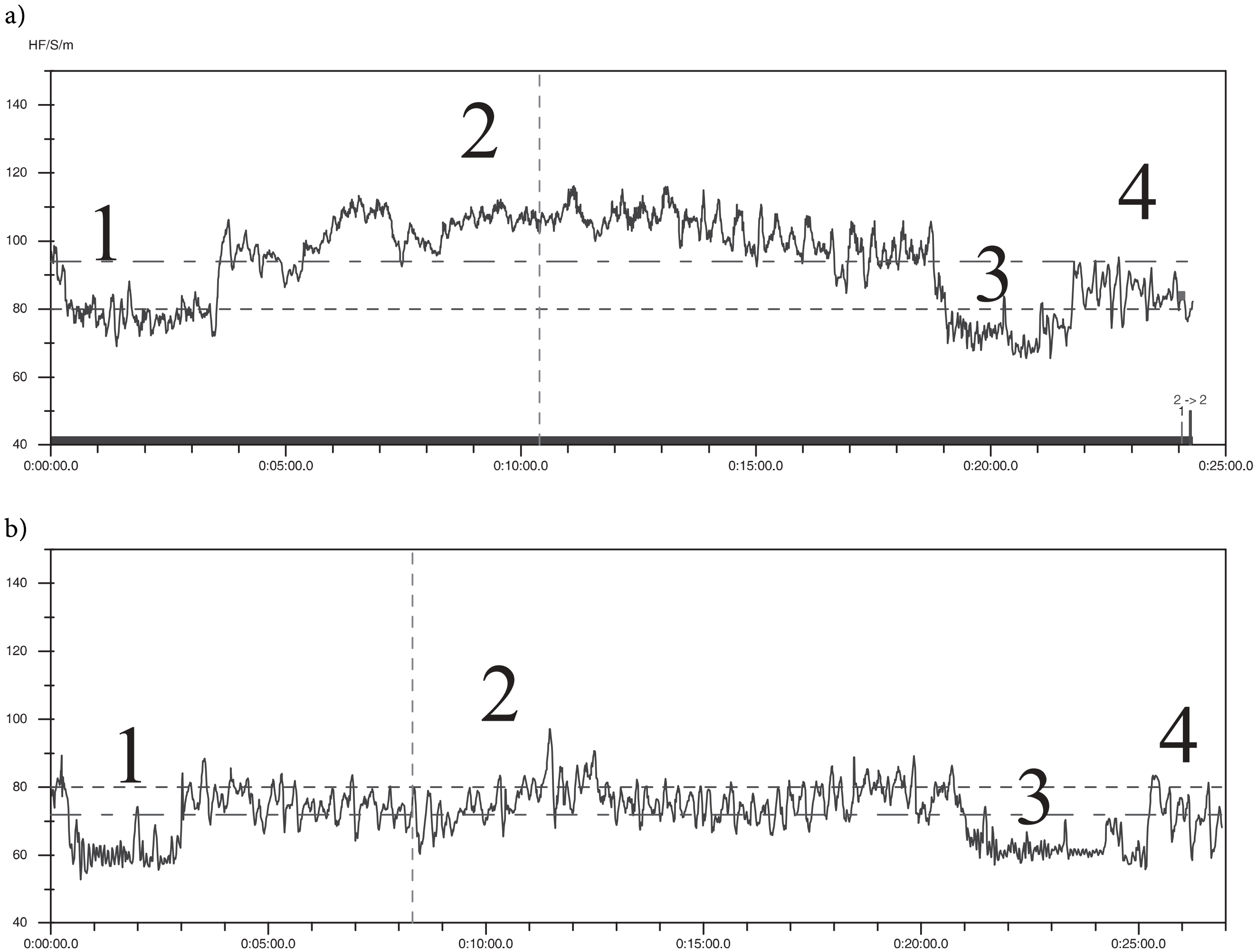

Fig. 1 Heart rate in a healthy male athlete under the conditions sitting (1), training (2), lying (3), and standing (4) on days 0 (**a**) and 28 (**b**)

Results

Comparing individual data before and after the 28-day training period, we observed a significant decrease of heart rate and LF/HF ratio and a significant increase of RMSSD and pNN50 (Table 1), indicating a switch of sympathovagal balance toward vagal dominance. In addition, the athletes achieved a significant increase of muscular flexibility (Table 1). On day 28, all subjects reported – subjectively – an increased sense of well-being.

Discussion

During the 28-day period, athletes continued their bodybuilding training (at least 10 hours a week), but they performed an additional 15 minutes of stretching per day. While the subjects initially complained about "limited muscular flexibility", they reported an distinct improvement in muscular flexibility after the 28-day period. In addition, the resting heart rate was lowered and autonomic nervous system activity appeared to be more balanced. Thus, beneficial effects on HRV may – at least in part – reflect an increased effort of vagal control and/or reduced sympathetic outflow.

During physical or mental stress (for example, during bodybuilding) muscles contract and lose their normal resting tone. Stretching allows muscles to work in a rhythmical – tonic and moving – manner, thereby releasing fixed tension and allowing muscle groups to return to their normal resting potential. This action also reduces further stress that is precipitated by pain and discomfort associated with muscular hypertension. Stretching seems to be effective in reducing muscular tension and thereby increases physical, functional, and psychosocial well-being [7]. More comprehensive than stretching, physical exercise in general has been shown to have beneficial effects on health and well-being [2, 14, 17, 18]. However, patients restricted in terms of their ability of action, and older people, are sometimes not willing or able to practice sports. Especially in these groups, stretching appears to be a gentle but efficient method to improve health and well-being. We recommend further studies, most particularly in patients suffering from psychosomatic diseases (e. g., backache, fibromyalgia, temporomandibular joint dysfunction, tension headache) or disturbances of well-being.

The bodybuilders who participated in this study had a high level of physical fitness due to their regular and extensive training load (which included rapid cycling) for at least one year. However, the subjects complained about a loss of muscular flexibility and a tendency to lowered freedom of movement. Therefore, these athletes seemed to be ideal subjects for a study of the effects of muscular stretching on ANS activity. First, these subjects were highly motivated to take part in the stretching program due to the nature of their complaints. Second, an additional 15-minute training unit should not primarily or significantly increase their cardiovascular endurance. Therefore, changes in ANS activity might be due to the stretching effects and/or due to lowered mental or physical tension. It is indicated that potential mechanisms of HRV increase might be:

- Release of vasodilative agents (e. g., EDRF) due to "stretching of vessels endothelia",
- Neuromuscular interferences reducing muscle tone, and
- General and systemic psychic-physical relaxation.

However, this study is limited by lack of a control group, and we cannot rule out that something other than stretching might have modulated ANS activity. Therefore, all of our findings should be considered as preliminary. The demonstrated positive effects on ANS activity would eventually have health-keeping and mental or physical well-being-promoting properties in patients at risk, such as cardiac patients, or in subjects seeking dis-

Table 1 HR and HRV parameters indicating vagal tone, i. e., root mean square of successive differences (RMSSD), and the number of pairs of adjacent RR intervals differing by more than 50 ms in the entire recording divided by the total number of all RR intervals (pNN50). In addition, from frequency analysis of short-term measurements (3 minutes), the ratio of low to high frequency (LF/HF) was calculated. This ratio has been suggested to mirror sympathovagal balance. Both under resting and stretching conditions, HRV increased significantly from day 0 to day 28, indicating a switch to increased vagal and reduced sympathetic outflow. Muscular flexibility improved

Mean (SD) [range]	Day 0 during resting condition	Day 28 during resting condition	Day 0 during stretching	Day 28 during stretching
HR (bpm)	79.1 (10.6) [64–99]	65.1 (12.9) $p < 0.001$ [45–90]	100.1 (14.4) [79–122]	86.3 (16.7) $p < 0.001$ [66–125]
RMSSD (ms)	25.2 (10.4) [11–41]	62.4 (26.9) $p < 0.001$ [19–120]	15.1 (7.8) [6–37]	28.7 (14.0) $p = 0.003$ [6–55]
PNN50 (%)	3.2 (3.1) [0–8]	17.3 (7.8) $p < 0.001$ [1–32]	1.1 (0.9) [0–3]	4.2 (3.2) $p = 0.002$ [0–11]
LF/HF	8.01 (5.19) [0.87–16.14]	3.44 (3.53) $p < 0.02$ [0.94–15.06]	10.69 (6.01) [2.85–25.29]	7.32 (3.76) n. s. ($p < 0.02$) [2.76–16.30]
Muscular flexibility (cm) "over-all-joints-score"	−1.3 (26.5) [−44 up to 43]	43.3 (32.8) $p < 0.001$ [−23 up to 107]	not calculated	not calculated

ease-prevention-tools. More controlled – most notably by 1) concomitance of a control group and 2) quantification of training load – studies on stretching and its effects on ANS activity should be scheduled in healthy subjects and in patients. If further studies confirm our preliminary data, stretching should be included in health care programs for the prevention and therapy of diseases.

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