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Manual Respiratory Support Increases Cardiac Parasympathetic Activity in Healthy Adults

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Abstract

Purpose: *Chronic autonomic imbalance decreasing parasympathetic activity is highly correlated with several diseases and easy to implement strategies to limit this imbalance is needed. Some breathing technics are already studied aiming this vagal activity enhancement and manually supported breathing control may provide such an effect. The objective of this study was thus to investigate whether a manual respiratory support at rest, with pursed lips expiration, is effective to increase cardiac parasympathetic activity in healthy adults.*

Methods: *Twenty-four young healthy participants (22.3 ± 6.3 years old) voluntarily participated. Heart rate variability indices to determine vagal activity and breathing frequency were calculated from 5 min samples taken from a chest-belt heart rate monitor at baseline and during manual respiratory support.*

Results: *When compared to baseline, breathing frequency was significantly lower during intervention ($p<0.001$), and a significant increase in time domain ($p<0.01$), and non-linear parasympathetic indices ($p<0.01$) was observed.*

Conclusion: *Manual respiratory support produced a large decrease in breathing frequency and triggered a significantly increases of parasympathetic activity in young and healthy subjects. Thus, manual respiratory support may appear relevant to promote autonomic cardiovascular modulation in this specific population.*

Keywords: *Autonomic nervous System, Respiration, Heart Rate Variability, Physiotherapy*

Introduction

Breathing is an automatic and rhythmic act of taking air into the lungs and releasing it. A relevant characteristic of the human respiratory system is its ability to adjust breathing patterns in response to the environmental demand. However, voluntary breathing control is also possible. Slowing down one's breathing frequency can be achieved thanks to specific practices (e.g. meditation, qigong, yogic technics…) or simple respiratory exercises focussing on deep breathing with or without devices [1–3]. This may include breathing control, as part of the Active Cycle of Breathing Technique under a physiotherapist's guidance [4].

Due to the accumulating evidences showing that slow breathing techniques promote health benefits, these respiratory exercises look set to become a key component of health care in preventions [1,2,5-8]. Indeed, due to the current stressful lifestyles led by any, an increasing number of healthy people are undertaking specific activities involving slow breathing techniques to counteract this modern burden, and to aid relaxation when feeling anxious [8]. Similarly, breathing pattern interventions are largely performed in chronic diseases' management due to their health benefits, especially on the cardiovascular system (e.g. effect on resting heart rate, blood pressure…) [2,9,10].

Therefore, there is a compelling need for an objective assessment of how alterations to the breathing pattern can modify the activity of the autonomic nervous system (ANS). The sympathetic system is often seen as the "fight or flight" system whereas the parasympathetic is more the "rest and digest" system. Thus, while parasympathetic activity dramatically decreases during stress situations or some pathological conditions, it increases during rest and calm down periods [11]. Chronic autonomic dysfunction (increased sympathetic activity and decreased parasympathetic activity) plays a pivotal role in the aetiology of a number of diseases [12-17].

Several techniques of altered breathing patterns appear useful to promote favourable autonomic cardiovascular modulation. Indeed, the effects of some breathing technics on ANS activity have already been studied. For instance, yogic technics or paced breathing with devices are known to enhance vagal activity [7-9]. Therefore, techniques used in physiotherapy to teach patients breathing control are amenable to investigation. In this context, we focused on a common manual respiratory support, expiration with pursed lips, as a physiotherapist performs during the breathing control phase of the Active Cycle of Breathing Technique [4]. This Manual Respiratory Support (MRS) accompanies the breathing movements, allowing individual feedback from rhythm and depth of respiration. This approach may be more effective than automatic system as it considers individual difficulties and/or errors and may encourage subject's compliance. To the best of our knowledge, the effect of this MRS on the ANS activity has never been studied. Therefore this pilot study involves healthy individuals in order to prepare further research in patients.

ANS activity during MRS can be indirectly evaluated by heart rate variability (HRV), assessing cardiac autonomic regulation. At rest, several indices of HRV, such as standard deviation of beat to beat intervals (SDNN), indicate cardiac vagal activity [18]. Since this exploration is totally non-invasive and reliable, HRV has become more and more used in the recent decades [19-23].

The purpose of the present study was therefore to compare ANS activity between rest and MRS conditions in healthy subjects. We hypothesized that cardiac parasympathetic activity would increase during MRS.

Materials and Method

Participants

Twenty-four young healthy subjects (12 women and 12 men) were studied with a mean (± SD) age of 22.3 ± 6.3 years old, body mass index of 22.6 ± 2.1 kg.m-2 and resting heart rate of 67.7 ± 12.1 bpm. All were students in the Physiotherapy School of Besançon and were moderately active (less than 2h of physical activity per week).

They were instructed to avoid tobacco, alcohol and caffeine for at least 12h and strenuous exercise for at least 24h before the experiment. The study complied with the Declaration of Helsinki and all participants gave written informed consent.

Experimental protocol

In a temperature and hygrometry controlled room (20.2 ± 0.4°C and a relative humidity of 54.3 ± 1.2%), each subject was invited to sit in an armchair in a comfortable semi-reclined position, with their legs straightened and resting on another chair. A heart rate monitor was settled around chest, to record beat-by-beat heart rate, to assess ANS activity through HRV, and breathing frequency (Bf) during the whole procedure. Each participant was told to rest quietly for 20 min for baseline evaluation (rest). Then, a 10 min MRS procedure was applied to each participant.

Manual respiratory support procedure

A qualified physiotherapist put his/her hands on the participant's trunk. One hand was on the upper chest, under collar-bones, and the other hand on abdomen, under xiphoid process. During each inspiration, the therapist released the weight of his own arms, decreasing pressure of his hands on the trunk. During each exhalation, the therapist let his arm down, increasing pressure. This moderate pressure gradually reached a peak when the physiotherapist rested his arms entirely on the participant. Each subject was told by the physiotherapist to breathe gently, effortlessly, at their own rate and to exhale with pursed lips, making a noise like a prolonged "fff" sound.

Data collection

Beat-by-beat heart rate was continuously recorded using a heart rate monitor (t6 Suunto™ , Vantaa, Finland) which is a chest belt that automatically starts recording when receiving data . Bf was computed based on the recording [23-25].

Data analysis

The 30-min whole record of beat-by-beat heart rate was loaded onto a computer with Suunto Training Manager® Software (Vantaa, Finland). All the R-R interval values were edited initially by visual inspection to exclude undesirable beats (i.e. to ensure that each analysis for the segment was free of movement artefact and/or sharp transient in the signal due to premature beats) which accounted for less than 1% in each participant.

From each whole record, two 5-min samples [18] were selected: a rest sample and an MRS sample. These samples were then analysed with Suunto Training Manager® to record the breathing frequency (Bf, cycles/min) [25] and Kubios™ Software (Department of Physics, University of Kuopio, Finland) to perform the HRV analyses.

HRV data were analysed in time and non-linear domains. In the time domain, the mean of R-R intervals (mean RR, ms), the standard deviation of the R-R intervals (SDNN, ms), the root mean square successive difference of intervals (rMSSD, ms), and the percentage of successive difference of intervals which differ by more than 50 ms (pNN50, %) were calculated. In the non-linear domain, we focused on standard deviation of the instantaneous beat-to-beat variability of the data (SD1, ms), standard deviation of the continuous long-term R-R intervals (SD2, ms) from the Poincaré plot analysis.

At rest, all time-domain indices, also SD1 and SD2 of non-linear HRV analysis may be considered as markers of parasympathetic activity [26,27].

Statistics

All statistical analyses were performed using R software (R Development Core Team 2008. R Foundation for Statistical Computing, Vienna, Austria). All data are presented as mean ± standard deviation (SD). Inter-individual variability of the different variables was calculated as the ratio SD/mean multiplied by 100.

Normal Gaussian distribution of the data was verified by the Kolmogorov-Smirnov test goodness-of-fit test (z value <1.0). When data were skewed or heteroscedastic, they were transformed by taking their natural logarithm. Paired and unpaired differences were tested with paired and unpaired Student's t-test, respectively.

The level of significance was set at $p<0.05$. Statistical differences were expressed as standardized mean differences (Cohen effect size with Cohen's d), calculated dividing the mean difference between the two procedures by the standard deviation of the whole dataset. Thresholds were defined as: d>0.2 for small, d>0.5 for moderate and d>0.8 for large effect size (ES).

These differences were also computed as percentage of change from the resting condition. The ratio of the difference during intervention from the value at rest divided by the value at rest was calculated. For each variable the mean and SD of these ratios was multiplied by 100, giving the percentage change from the resting condition.

Pearson's correlation was performed to assess the association between continuous variables. The following criteria were adopted to interpret the magnitude of the correlation (r): < 0.1 trivial, 0.1–0.3 small, 0.3–0.5 moderate, 0.5–0.7 large, 0.7–0.9 very large, and 0.9–1.0 almost perfect.

Results

Compared to the resting condition, Bf was largely (ES=1.33; $p<0.001$) lower during MRS (13.1 ± 2.5 and 9.5 ± 1.4 cycles/min, respectively).

Mean RR was not significantly different between rest and MRS (914 ± 165 and 930 ± 123 ms, respectively; ES=0.11). On the contrary SDNN, rMSSD, pNN50, SD1 and SD2 were all significantly higher (small difference) during MRS compared to rest (Table 1).

	Rest	MRS	p	ES
SDNN (ms)	80.7 ± 31.2	97.5 ± 37.5	**	0.48 Small
rMSSD (ms)	56.6 ± 29.9	71.1 ± 37.2	**	0.42 Small
pNN50 (%)	27.4 ± 20.8	37.2 ± 17.6	***	0.50 Small
SD1 (ms)	40.1 ± 21.2	50.3 ± 26.3	**	0.42 Small
SD2 (ms)	106.1 ± 41.1	127.9± 47.3	**	0.48 Small

Mean ± SD; **; ***: significantly different at p<0.01 and p<0.001, respectively.

ES: Effect Size; MRS: Manual Respiratory Support; pNN50: Percentage of Successive Differences of Intervals which Differ by more than 50 ms; rMSSD: Root Mean Square Successive Differences of Intervals; SD1: Standard Deviation of the Instantaneous beat-to-beat variability of the data; SD2: Standard Deviation of the continuous long-term R-R intervals; SDNN: Standard Deviation of the R-R intervals.

Table 1. *Time and non-linear domain indices at rest and during MRS*

	Rest	MRS
Bf (%)	19	14.8
Mean RR (%)	18.1	13.2
SDNN (%)	38.7	38.5
rMSSD (%)	52.9	52.3
pNN50 (%)	75.8	47.2
SD1 (%)	52.9	52.3
SD2 (%)	38.8	37

Bf: Breathing Frequency; MRS: Manual Respiratory Support; pNN50: Percentage of Successive Difference of Intervals which differ by more than 50 ms; rMSSD: Root Mean Square Successive Difference of intervals; SD1: Standard Deviation of the Instantaneous beat-to-beat variability of the data; SD2: Standard Deviation of the Continuous Long-Term R-R intervals; SDNN: Standard Deviation of the R-R intervals.

Table 3. *Inter-individual variability of breathing frequency, time and non-linear domain indices at rest and during MRS (%)*

	% change ± SD
Bf	-25.6 ± 15.7
Mean RR	2.9 ± 10.5
SDNN	25.3 ± 39.7
rMSSD	32.7 ± 46.8
pNN50	108.6 ± 52.5
SD1	32.7 ± 46.8
SD2	26.5 ± 43.1

Bf: Breathing Frequency; MRS: Manual Respiratory Support; pNN50: Percentage of Successive Difference of Intervals which differ by more than 50 ms; rMSSD: Root Mean Square Successive Difference of intervals; SD1: Standard Deviation of the Instantaneous beat-to-beat variability of the data; SD2: Standard Deviation of the Continuous Long-Term R-R intervals; SDNN: Standard Deviation of the R-R intervals.

Table 3.*Percentage of change from resting condition*

Inter-individual variability at rest and during MRS and percentage of change from resting condition of each variable are presented in tables 2 and 3, respectively. rMSSD, pNN50 and SD1 presented the highest inter-individual variability while Bf and mean RR exhibited the lowest values at rest and during MRS. The greatest percentage of change from resting condition was obtained for pNN50.

While there was no significant correlation between Bf and HRV data at rest, Bf was largely associated with mean RR (r = -0.70; p<0.001), and moderately associated with rMSSD (r=-0.44; p<0.05) and SD1 (r=-0.44; p<0.05) during MRS (Figure 1).

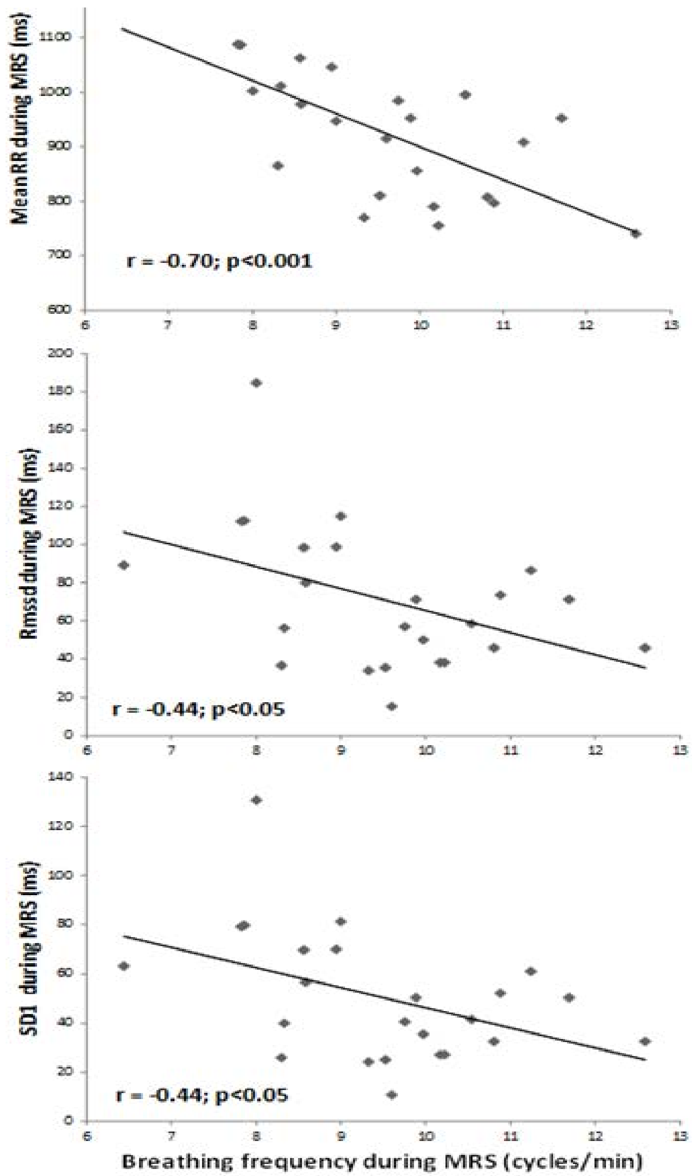

Figure 1: *Scatter graphs of correlation between Bf and mean RR, rMSSD and SD1 respectively*

Discussion

The main result of the present study was that 10 min of MRS significantly decreased breathing frequency (Bf) and altered the status of the autonomic nervous system, with an increase in parasympathetic activity.

As greater vagal activity may be associated with relaxation and recovery state, breathing control via MRS can provide such a state in the present population. Previous studies have already observed that slow-breathing practices may improve parasympathetic activity and well-being. Indeed, reducing Bf alone following a metronome breathing pacer is known to increase parasympathetic activity [9,28]. Similarly, several other respiratory exercises involving a decrease of Bf such as device-based training, biofeedback of HRV, and oriental techniques such as yoga and meditation, appear to be efficient in modifying ANS activity in a shift towards an increase in vagal tone in both healthy subjects and patients [3,29-31].

Mean RR was not significantly altered by MRS. Nevertheless, meanRR was negatively correlated to Bf during MRS, but not at rest. This means that, contrary to what happens during the resting period with spontaneous breathing, the lower the Bf during MRS, the more the heart rate is reduced. Moreover, negative correlations have also been found between Bf on one hand and rMSSD and SD1 on the other hand. This shows that beyond the mean increase of vagal indices, there is a dose-effect relationship in the context of our study (Bf during RMS ranging from 6.4 to 12.6 cycles/min). After establishing that rMSSD and SD1 are significantly greater during MRS, this correlation shows that the lower Bf during MRS, the higher the parasympathetic time domain variable rMSSD and the non-linear variable SD1 [17,32]. This could provide a further development of MRS aiming specifically Bf decrease.

MRS is a technique manually driven by a physiotherapist who exerts light pressure with hands on the trunk of the subject during each exhalation, releasing this pressure almost completely during spontaneous inspiration. Simultaneously, the subject is told to breathe gently, effortlessly, at their own rate and to exhale with pursed lips. MRS does not impose a specific Bf, which is more comfortable for the subject, and allows individual feedback on breathing rhythm and depth of respiration by physiotherapist. Taken together, these advantages may encourage regular long-term practice and compliance on the part of the subject. The Bf withdrawal induced by the MRS may be assigned to each of these techniques and/or to their combination. Indeed, manually driven breathing could be considered as a kind of touch massage, and there are evidence to support the hypothesis that massage has effects on the cardiovascular system such as reduced blood pressure and heart rate [33,34]. Similarly, exhalation with pursed lips could raise vagal tone [7]. To better understand the MRS effect on parasympathetic activity, with a view to improving recommendations and prescription, it would be relevant to study each component of the MRS separately, as well as the combination thereof, to determine their specific effect.

HRV analysis has been performed only in time and non-linear domain indexes. It is worth noting that the spectral domain was not computed in the present study. Indeed, slow breathing leads to possible mistakes in interpreting data of spectral indices. Spectral analysis aims to separate three kinds of oscillations in the whole variability of heart rate, namely the very low frequency band (VLF, from 0.003 Hz to 0.04 Hz), low frequency band (LF, form 0.04 Hz to 0.15 Hz) and high frequency band (HF, from 0.15 Hz to 0.4 Hz). This HF band is known to reflect parasympathetic cardiac regulation. However, HF oscillations are mainly produced by respiratory sinus arrhythmia (RSA), and are therefore closely linked to the subject's breathing pattern. The RSA peak of frequency is near the subject's Bf [35]. The threshold of 0.15 Hz, dividing the spectral power in LF and HF bands, is a frequency mathematically convertible into 9 cycles/min. Therefore, by spectral analysis, RSA is expected to be produced at a Bf greater than or equal to 9 cycles/min. If the subject breathes at a lower Bf, the expression of RSA switches in LF. This switch may lead to misinterpretation of spectral analysis in this condition (17,32). Moreover, if the subject lowers his Bf around 6 cycles/min (0.1 Hz), the spectral expression of RSA is added to the common LF oscillations. This addition may produce a greater total power of HRV, leading to the hypothesis of a resonance phenomenon [36].

Chronic autonomic imbalance namely increased sympathetic activity and decreased parasympathetic activity is well-known to be associated with the aetiology of several cardiovascular diseases [12-17]. The altered autonomic system could be a cause but also a marker of disease and its assessment is thus increasingly performed in preventions [37,38]. The apparent role of MRS as an active component in relaxation raises the hypothesis that routinely performed sessions of MRS without imposed frequency may lead to an increased parasympathetic activity and reduction in co-morbidities. Previously, breathing practices involving slow patterns of respiration for several sessions have been shown to induce changes in autonomic function [30,39-41]. Whether these results are consistent with chronic MRS procedure warrants further study.

Conclusion

To the best of our knowledge, this is the first study to investigate the impact of MRS procedure on vagal activity. Under the conditions of the present study, MRS manually driven by a physiotherapist led to increased parasympathetic activity in healthy young subjects. Without imposing a specific Bf, the MRS approach allows individual feedback on breathing rhythm and depth of respiration

The apparent role of MRS as an active component in relaxation raises the hypothesis that routinely performed sessions of MRS may appear relevant to promote autonomic cardiovascular modulation and to reduce co-morbidities. Whether these results are consistent with chronic MRS procedure warrants further experimentations. In addition, it would be useful to study each component of the MRS separately, as well as the combination thereof, to determine their specific effect on the autonomic nervous system.

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