The coordination of heart beat and respiration during
ergometric stress in patients with functional cardiovascular
diseases

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Summary: Patients with functional cardiovascular diseases were tested during a rectangular ergomet-
ric stress protocol for the reaction of the frequency coordination (n = 82) and the phase coordination
(n = 52) of heart beat and respiration. The ratios of the pulse and respiratory frequency converged
increasingly with the duration of the exercise, caused by a similar reaction of the respiratory rates.

Key words: heart beat respiration coordination; heart rate; ergometric stress

Introduction

During the intact phase coordination between heart and respiratory rhythm, the cardiac
rhythm is the more dominant (1, 5). In normal subjects, the incidence of phase coordination
is high at rest and decreases during stress (6, 11, 13, 14). In addition, the variance of the ratio
of pulse to respiratory frequency (P/R) decreases interindividually with exercise (6). We
investigated whether these findings could be confirmed in patients with functional cardiovas-
cular disorders (16).

Methods

Selection of patients

Ergometric recordings were analysed using protocols from 82 untrained patients (42 female, 40 male;
aged 13–69 years) with functional cardiovascular diseases. Patients with arterial hypertension and
anemia, as well as premature degeneration of the circulatory system and the respiratory tract, were
excluded.

Equipment

ECG: Three-channel recorder, Ergometer Wilken Monark, Nasal Thermistor Respiratory Sensor
(MELA Co. Ltd. Elektromedizin).

Test conditions

Since the coordination of heart and respiratory rhythm is dependent on posture (11) and physical work
usually is performed in an upright position, the ergometric test was performed not in a supine but in a
sitting position, in accordance with the 1965 IGSPE agreement, with a pedalling frequency of 50 min^{-1}.
The rectangular test protocol (9, 10, 12) was chosen in order to compare all test results with each other.
Exercise levels were performed according to Kaltenbach (8). Patients under 20 years of age were given a
testload of 1 W/kg BW; patients over 65 years were exercised with an estimated testload.
About two thirds of the patients were tested in the morning hours and the rest in the early afternoon. The seasonal distribution was nearly uniform.

**Test procedure**

After 5-min relaxation in a reclined position, the test was performed for 3 min in a supine position (pre-exercise rest), 6 min during exercise and again 5 min in a supine position (post-exercise rest). In every test minute the blood pressure and the ECG and respiratory tracings (for about 1/2 min) were recorded.

**Statistical considerations**

Only those records were evaluated, which exhibited equal respiratory cycles each minute, distinct inspiratory onset points and, in addition, a precise accompanying ECG tracing. Consequently, the heart rate (HR), the respiratory rate (RR) and the ratio of the pulse and respiratory frequency (P/R) yielded 82 curves and the phase assessments 52 curves.

The P/R was calculated to the first decimal place from the total duration of five respiratory periods. The calculation was performed logarithmically (5, 15). The cardiac cycle was subdivided into three equal segments, since within these regions maxima of coincidence were to be expected (11). Inspirations initiated within the first third of the R-R interval of the ECG were termed "systolic" (11). Furthermore, the results were tested according to the absolute phase calculation and normalized for a systolic time of 0–300 ms.

Assimilar distributions, normal distributions (using the c-transformation) and the irregularity of distributions were analysed with the chi-square test (2, 6, 11). In case a normal distribution did not exist, random testing using the Wilcoxon test was performed, otherwise a two-tailed t-test. Furthermore, the inclination towards the phase coordination was assessed using analysis of variance (AV) (4). The specific analysis of significance (p) was calculated as per Claus and Ebner (3).

**Results**

**Exercise level**

The mean level of exercise was verified by analysing the HR of the patients with a maximal testload in relation to healthy subjects, according to Sheffield: Heart rate (min\(^{-1}\)) = 220 − age (years). Following this procedure, patients in age groups between 20–69 years were exercised with 71.0–71.5 % remarkably homogeneously. Notwithstanding this moderate exercise, only 36.1% of the patients reached a steady state.

**The procedure for P/R, heart and respiratory rate (Fig. 1)**

The progress of the group is demonstrated by both mean (\(\bar{x}\)) and standard deviation (SD), the general performance of the individuals is represented by the mean of the classes with the corresponding SD, the regression (b) and correlation (r) coefficients. b and r were calculated for the pre-exercise rest by the values of X = −1 min and Y = 0 min, and for both exercise and post-exercise rest by the last values determined at rest X = 0 min and the values of Y = 1/2, 2/3 min etc. Due to a noncontinuous normal distribution, only the trend of the SD of the classes can be assessed.

Within 2 min of exercise, the mean value of the P/R of the group increased (p < 0.01), while the SD (p < 0.05) and r (p < 0.001) and b (p < 0.01) decreased. Accordingly, the average values of the P/R were convergent. The changes induced by exercise reverted during the post-exercise period.

The sequence of the mean values of the HR and RR of the group were principally equivalent. During exercise, the means of the HR of the classes were increasingly divergent, the SD of the group (p < 0.01) and of the classes (p < 0.05 and < 0.01, resp.) increased accordingly, but r and b did not change significantly. In contrast, the average values of the