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ORIGINAL REPORT

PERCEIVED DISABILITY BUT NOT PAIN IS CONNECTED WITH AUTONOMIC NERVOUS FUNCTION AMONG PATIENTS WITH CHRONIC LOW BACK PAIN

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Objective: **To assess the association of cardiovascular autonomic balance with perceived functional impairment and pain among patients with chronic low back pain.**

Design: **A cross-sectional analysis of working patients with chronic low back pain.**

Patients: **Forty-six consecutive patients aged 24–45 years with chronic low back pain fulfilling the inclusion criteria. A total of 39 subjects had technically acceptable electrocardiographic recordings during periods of rest and standard provocations.**

Methods: **Perceived functional disability was assessed with the Oswestry disability index and pain with a numerical rating scale. Autonomic nervous function was assessed by measuring heart rate variability with short recordings.**

Results: **The total power of heart rate variability was lower among those with moderate perceived disability (Oswestry 20–40%) compared with those with minimal disability (Oswestry < 20%). However, heart rate variability did not differ significantly among those with numerical rating scale values ≤ 5/10 from those with values > 5/10. The power of the high-frequency component (0.15–0.4 Hz) of heart rate variability was lower among those with moderate perceived functional impairment.**

Conclusion: **A significant association existed between heart rate variability and perceived physical impairment, but not between heart rate variability and pain. Proportionally reduced high-frequency activity was found to reflect decreased parasympathetic activity or increased sympathetic activity. This resulted in sympathetic dominance among the patients with higher subjective disability. The possible clinical implications of this observation are discussed.**

Key words: disability evaluation, autonomic nervous system, low back pain, cross-sectional analysis.

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INTRODUCTION

According to Chandola et al. (1), there is a strong association between chronic stress and physiological health risks. It has been suggested that autonomic cardiovascular indices could be used in stress-related risk assessment in occupational health (2). The focus of autonomic function and health has been cardiovascular diseases; musculoskeletal syndromes have been paid much less attention. However, there are many epidemiological and other studies suggesting that there is a connection between musculoskeletal disorders and psychological risk factors such as stress, as shown by Brage et al. (4), Sudhaus et al. (5) and Waters et al. (3). It is also worth noting that interactions exist between pain sensitivity and cardiovascular control mechanisms (6).

There is also indirect evidence of the relevance of stress and musculoskeletal disorders. Randomized trials on behavioural treatment for non-specific chronic low back pain revealed moderate evidence (2 trials, 39 people) in favour of progressive relaxation having a significant positive effect on pain and behavioural outcomes (short-term only). Combined respondent-cognitive therapy and progressive relaxation therapy were effective in the short term. No significant differences were detected between behavioural treatment and exercise therapy. Whether clinicians should refer patients with chronic low back pain to behavioural treatment programmes or to active conservative treatment cannot be concluded from this review (7).

Heart rate variability (HRV) is commonly used to assess the autonomic nervous system function (8). Decreased HRV in both short-term and long-term electrocardiography (ECG) recordings has been shown to predict poor health outcomes (9, 10). In the time domain analysis of HRV the standard deviation of R-R intervals (SD of RRIs) reflects all the cyclic components of HRV. The mean of the sum of the squares of differences between adjacent R-R intervals (RMSSD) is a good estimate of the short-term components of HRV. The RMSSD is predominantly the indicator of vagally controlled heart period variation (11). Power spectral density analysis tells us how variance is distributed as a function of frequency. The total power (TP) of the HRV includes 3 main components of the spectral densities. In spectral density analyses the high-frequency band of HRV (HF) is located between frequencies 0.15 and 0.4 Hz, the low-frequency band of HRV (LF) between frequencies 0.04 and 0.15 Hz, and the very-low-frequency band of HRV (VLF) below 0.04 Hz. The HF component reflects the parasympathetic modulation of the heart rate; the LF component is controlled by both the sympathetic and the parasympathetic nervous system (12). The LF/HF relationship has been used as an indicator of the balance between sympathetic and parasympathetic regulation (13). The VLF needs longer, usually one hour or

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more, recordings to be analysed reliably and its physiological explanation is unclear.

The aim of this study was to investigate the autonomic nervous function evaluated by HRV among patients with chronic low back pain and, in particular, whether the possible imbalance is connected to the severity of perceived pain and/or perceived disability.

PATIENTS AND METHODS

Patients with chronic low back pain ($n = 220$) were recruited by a widely circulated newspaper advertisement. The inclusion criteria were: low back pain (with or without radiation to the leg); pain duration of at least 3 months; age between 24 and 45 years; and being able to participate in the study during their working day. The exclusion criteria were: weakened general condition; malignancies; ankylosing spondylitis; severe osteoporosis; severe osteoarthritis; paralysis; progressive neurological disease; haemophilia; spinal infection; previous spinal operation; vertebral fracture during the previous 6 months; severe psychiatric disease; or severe sciatica with straight leg test result below 35 degrees or with at least one recent motor deficit. Other exclusion criteria were: pregnancy; marked overweight (body mass index over 32); or simultaneous spinal rehabilitation or spinal study (14).

From the pool of 220 patients, 46 consecutive patients were enrolled in this study. One of the authors (MG) performed the autonomic nervous system function measurements. The physicians responsible for planning the autonomic nervous cardiac reflex testing and analysis (MG and HL) had no involvement with patient selection, recruitment or other clinical examinations. The patients had no illnesses or medications affecting their autonomous nervous system. The patients' basic data are shown in Table I. Of the 46 patients, 26 (56.5%) had been on sick leave during the previous year, but none for longer than one month. None of the patients had incapacitating cardiovascular problems. Of the patients, 37 (67.4%) did not report radiation of pain. Only 2 (4.3%) experienced numbness. The straight leg test was positive in 4 cases. The study protocol was approved by the hospital medical ethics review board. No monetary incentive was provided for participants.

Perceived disability was evaluated using the Oswestry low back pain disability questionnaire (15). This questionnaire is designed to assess limitations of various activities of daily living. Each of the 10 sections contains 6 statements. The scores of all sections are added together and expressed as a percentage. The patients were classified as having minimal perceived disability (< 20%) or moderate disability (20–40%). Subjective pain was evaluated by a numerical rating scale (NRS) (0–10; 0 = no pain, 10 = worst possible pain).

HRV was analysed from short (5-min) ECG recordings during controlled (11) and spontaneous quiet breathing. Deep breathing and active orthostatic tests were performed to exclude cardiac autonomic neuropathy. Data acquisition was carried out and time domain and spectral analyses were performed by use of a PC-based analysis system (CAFTS, Medikro Inc, Kuopio, Finland). The sampling frequency for biosignals was 200 Hz and the amplitude resolution 12 bits. The algorithms were based on autoregressive modelling of spectral analysis. The statistical analyses were made among the subjects ($n = 39$) with technically acceptable ECG signals and without more than one cardiac ectopic beat/min during the collecting period in both sessions.

The statistical analyses were performed by general lineal model analysis of variance (GLM Multivariate, SPSS version 14.0) with *post-hoc* Bonferroni correction. $p < 0.05$ served as the measure of statistical significance.

RESULTS

The Oswestry score was on average 19.7% (standard deviation (SD) 10.9), that for men (17.8%, SD 10.9) not differing from that for women (22.9%, SD 10.4). Half the patients (23) had a score > 20% (21–40; moderate disability) and the other half < 20%; minimal disability. The mean ages in these groups were 36.7 (SD 5.5) and 38.3 (SD 5.7) years, respectively; a difference that was not statistically significant. Seven of the patients were smokers, 3 of them had an Oswestry score of < 20% and 4 had ≥ 20%.

The mean score of NRS was 5.8 (SD 2.1), that of men (SD 5.6) not differing significantly from that of women (SD 6.2). The mean age of the 22 subjects with a maximum NRS of 5 (37.4, SD 6.0) did not differ from that of the 24 subjects with a maximum NRS greater than 5 (37.6, SD 5.3). The NRS score did not correlate significantly with the Oswestry score.

The mean systolic blood pressure was 121 mmHg (SD 12.6) and mean diastolic blood pressure 76.6 mmHg (SD 8.2), with no gender difference. The mean overall heart rate was 59.2 beats/min (SD 7.8), with no statistical difference in HR between those with a higher or lower Oswestry or NRS score.

HRV was significantly lower among those with an Oswestry score ≥ 20% than among those with a score < 20%. The results are shown in Table II. The mean SD of RRIs during sponta-

Table I. *Patient characteristics*

Characteristics	
Patients, *n*	46
Sex ratio (M:F)	29:17
Age, years, mean, (SD)	37.5 (5.6)
Occupation, *n* (%)	
Light sedentary work	31 (67)
Physically light work	10 (22)
Physically moderate or heavy work	5 (11)
Pain duration, *n* (%)	
< 1 year	5 (11)
1–5 years	12 (26)
6–10 years	15 (33)
> 10 years	14 (30)
Pain frequency, *n* (%)	
Daily	28 (61)
Weekly	8 (17)
Monthly	6 (13)
At least 3 times a year	4 (9)

Table II. *Association of heart rate variation and Oswestry score (mean, SD) among patients with chronic low back pain*

Oswestry	< 20% *n* = 18	20–40% *n* = 21	*p*
SD of RRIs, ms*	63.6 (25.2)	52 (19.9)	0.019
SD of RRIs, ms†	55.8 (19.5)	44.9 (12.3)	0.006
RMSSD, ms*	56.5 (32.5)	36.3 (8.4)	0.003
RMSSD, ms†	52.7 (31.5)	33.6 (12.9)	0.005
TP, ms^2*	4741 (3164)	2763 (2657)	0.043
TP, ms^2†	3350 (2412)	1784 (873)	0.027
HF, ms^2*	1719 (2000)	677 (574)	0.012
HF, ms^2†	981 (948)	502 (426)	0.111
LF, ms^2*	1290 (1137)	1214 (1935)	0.342
LF, ms^2†	500 (333)	405 (335)	0.097

*During spontaneous breathing. †During controlled breathing.
HRV: heart rate variability; SD of RRIs: standard deviation of R-R intervals; RMSSD: mean of the sum of the squares of differences between adjacent R-R intervals; TP: total power of HRV; HF: high-frequency band of HRV; LF: low-frequency band of HRV.

neous breathing was 63.6 ms (SD 25.2) among those with an Oswestry score < 20% ($n = 18$) and 52 ms (SD 19.9) among those with an Oswestry score ≥ 20% ($n = 21$), a significant difference ($p = 3570.019$). In addition, the mean SD of RRIs during controlled quiet breathing was significantly ($p = 0.006$) higher among those with a score < 20% (55.8 ms (SD 19.5)) than among those with a score ≥ 20% (44.9 ms (SD 12.3)).

The mean TP of HRV during spontaneous breathing among those with an Oswestry score < 20% (4741 (SD 3164)) was significantly ($p = 0.043$) higher than among those with an Oswestry score ≥ 20% (2763 (SD 2657)). A similar difference appeared in the RMSSD. The mean TP during controlled breathing was also significantly higher ($p = 0.027$) among those with a score < 20% than among those with a score ≥ 20%. The main indices of HRV (SD of RRIs, RMSSD, TP or its components in spectral analysis) did not differ among the patients with a low (≤ 5) or high (> 5) NRS score (Table III). No autonomic neuropathy was found.

DISCUSSION

HRV measures fluctuations in autonomic modulation of the heart rate. HRV was found to be lower among those with moderate disability compared with those with minimal disability. No such finding emerged when patient groups with NRS 0–5/10 were compared with those with NRS over 5/10. HRV, as measured by SD of RRIs and by RMSSD, was lower among those with a higher degree of disability. The HF component of HRV, reflecting parasympathetic modulation of the heart rate, was significantly lower among those with moderate disability. Decreased HRV can be caused either by sympathetic activation with tachycardia (which was not found in this study) or by depressed vagal activity. In this study, the chronic low back pain group with higher disability showed decreased total power and reduced activity in the HF component in autonomic balance in the short-term quiet breathing, an imbalance leading to proportionally increased sympathetic dominance. In particular, the indices of traditional time-domain parameters (RMSSD and SD of RRIs) were significantly different in the groups. In epidemiological studies these indices have been reported to predict poor general health outcomes. A continued sympathetic drive may cause a mixed profile of pain, distress and fatigue. Cardiac sympathetic activation and parasympathetic withdrawal are caused by psychological stressors (16).

Table III. *Association of heart rate variation and visual analogue score (mean, SD) among patients with chronic low back pain*

VAS	0–5/10 $n = 18$	6–10/10 $n = 21$	p
SD of RRIs, ms*	53.8 (17.5)	59.5 (26.7)	0.231
SD of RRIs, ms†	49 (13.9)	50.5 (19)	0.456
RMSSD, ms*	40.1 (17.3)	50.1 (29.2)	0.122
RMSSD, ms†	35.9 (14.3)	47 (30.6)	0.080
TP, ms^2*	3252 (2112)	4004 (3677)	0.248
TP, ms^2†	1725 (1141)	2658 (2384)	0.286
HF, ms^2*	709 (783)	1534 (1842)	0.067
HF, ms^2†	345 (481)	836 (907)	0.165
LF, ms^2*	1113 (902)	1369 (2067)	0.336
LF, ms^2†	261 (350)	459 (332)	0.355

*During spontaneous breathing. †During controlled breathing.
VAS: visual analogue scale; HRV: heart rate variability; SD of RRIs: standard deviation of R-R intervals; RMSSD: mean of the sum of the squares of differences between adjacent R-R intervals; TP: total power of HRV; HF: high-frequency band of HRV; LF: low-frequency band of HRV.

Physical exercise is widely applied for treatment and rehabilitation of patients with chronic low back pain. Based on our observations, it is evident that some patients with chronic low back pain with a clear proportionally higher sympathetic drive and lower parasympathetic drive may benefit more from relaxation and light aerobic exercises at the beginning of their rehabilitation than by hard physical exercise, in order to balance the autonomic system (17–19).

Low HRV has been connected with chronic fatigue syndrome (13) and it is a risk factor in cardiovascular diseases (8). Larger prospective studies are required in order to determine whether low HRV is involved with anxiety and distress among patients with chronic low back pain or is a risk factor for chronic low back pain or predicts outcome in low back pain. Short-term measurement of HRV during spontaneous breathing at rest has been preferred to monitor the changes in autonomic balance due to the better reproducibility (20).

Analysis of HRV is not methodologically easy, and comparing results of different commercial systems can be difficult. This somewhat hampers the clinical application of this method. However, the reproducibility of resting HRV is fairly good (21). The present study population of working patients with chronic low back pain represented quite well the majority of the chronic low back pain population, whose Oswestry score ranged from 0% to 40%, from light to moderate disability. Our observation can be considered a preliminary observation, which should be confirmed in a larger and better controlled prospective study, in which alcohol consumption, for instance, should be better controlled than it was in the present study. Alcohol consumption is known to influence HRV (22).

Perceived disability, but not pain, was combined with HRV, suggesting that perceived pain causes different levels of distress among patients with low back pain. The level of distress, pain and disability are reflected in the HRV and may cause increased sympathetic activity.

It is not the perceived pain as such, but how the patient reacts (i.e. what interpretations they give) to the pain that may be the key link between the physical and mental aspects experienced. The assessment of autonomic balance may be a useful tool in the rehabilitation of patients with chronic back pain with mild to moderate functional disability.

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