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Autonomic regulation, physical activity and perceived stress in subjects with musculoskeletal pain: 24-hour ambulatory monitoring

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A B S T R A C T

The aim of the study was to investigate autonomic nervous system regulation, physical activity (PA) and perceived stress and energy during daily activities in subjects with chronic muscle pain in the neck–shoulders (trapezius myalgia) (n = 23) and symptom-free controls (n = 22). Subjects underwent 24-hour objective ambulatory monitoring of heart rate variability (HRV) and PA, and reported their perceived stress and energy in a diary. Standard HRV measures were extracted in time and frequency domains. The volume and pattern of different types of activities were quantified in terms of intensity and duration of walking, and time spent sitting, standing and lying during the 24-hour measurement. Results showed shortened inter-beat-intervals (higher heart rate) and reduced HRV in the pain group, most pronounced during sleep ($p<0.05$). For overall PA, the pain group showed increased lying time, compared to controls ($p<0.05$). A different activity pattern was found in the pain group, with reduced leisure time PA and increased PA during morning hours, in comparison with controls ($p<0.05$). Both groups demonstrated low levels of perceived stress, whereas reduced energy was observed in the pain group ($p<0.05$). In conclusion, monitoring of 24-hour HRV demonstrated diminished HRV among persons with chronic neck–shoulder pain. This reflected aberration in autonomic regulation, suggesting reduced parasympathetic activation and increased sympathetic tone as an element in maintenance of chronic muscle pain.

1. Introduction

Perceived stress is a known risk factor for muscle pain (Bongers et al., 2002; Larsson et al., 2007) due to activation of physiological stress systems (Lundberg, 2002). The autonomic nervous system (ANS) is a key stress system intrinsically involved in nociception (Benarroch, 2006).

Several studies indicate the involvement of the ANS in the development and maintenance of chronic muscle pain (Martinez-Lavin, 2007; Vierck, 2006). Generally, objective indications of ANS aberration are seen at both local and systemic levels. Chronic trapezius myalgia is associated with changes in muscle physiology, such as morphological disturbances (Larsson et al., 2001; Andersen et al., 2008) and insufficient metabolism (Sjøgaard et al., 2010), possibly related to sustained muscle activation and disturbed muscle circulation (Visser and van Dieën, 2006). Impaired blood flow in painful muscles is frequently found among subjects with trapezius myalgia, which partly seems to reflect excessive sympathetic activation (Maekawa et al., 2002; Passatore and Roatta, 2003). Results from previous studies have demonstrated impaired trapezius blood flow in patients during static contractions (Larsson et al., 1999; Hallman et al., 2011), pain stimulation with cold water (Acero et al., 1999), needle stimulation in the trapezius muscles (acupuncture) (Sandberg et al., 2005), and during computer work (Cagnie et al., 2012).

Laboratory studies which used heart rate variability (HRV) to assess autonomic regulation in widespread muscle pain, e.g. fibromyalgia (FM) indicate basal hyperactivity of the sympathetic nervous system, which may lead to hypo-reactivity to physical and mental challenges (Martinez-Lavin and Hermosillo, 2000; Okifuji and Turk, 2002). Based on heart rate and blood pressure recordings during controlled rest and in response to stress, similar findings have been revealed among subjects with localised neck–shoulder symptoms (Gockel et al., 1995). However, other authors considered these deviations too small and inconsistent to prove the role of this mechanism in neck–shoulder pain (Sjörs et al., 2009).

Assessment of autonomic function in persons with muscle pain is usually based on controlled laboratory examination. Often, these experiments use a relatively short duration of the stressors, which may not be relevant for activities that occur in daily life, resulting in poor ecological validity and difficulties in interpretation of the results.

Abbreviations: ANS, Autonomic nervous system; BMI, Body mass index; EE, Energy expenditure; HRV, Heart rate variability; FM, Fibromyalgia; HF, High frequency; IBI, Inter-beat intervals; LF, Low frequency; PA, Physical activity; PNN50, Proportion of the number of differences between successive inter-beat intervals > 50 ms; SDNN, Standard deviation of normal-to-normal inter-beat intervals; VLF, Very low frequency.

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One valuable instrument, which complements laboratory diagnostics, is ambulatory monitoring of cardiovascular characteristics — especially when considering changes in HRV in relation to physical activity (PA) and perceived stress, as these factors could have a direct influence on autonomic regulation. Moderate and vigorous PA have been associated with increased resting HRV (Rennie et al., 2003; Melanson, 2000) indicating an improved autonomic regulation in favour of parasympathetic predominance in more active individuals. Inversely, higher perceived stress at work is associated with lower parasympathetic tone (Vrijkotte et al., 2000; Chandola et al., 2008).

Only a limited number of studies have assessed ambulatory HRV in patients with chronic muscle pain (for example: Doğru et al., 2009; Haley et al., 2004; Martínez-Lavín et al., 1998), mainly focusing on widespread pain conditions such as fibromyalgia which is associated with a wide range of neurasthenic symptoms and sleep disorders. However, these studies did not objectively assess PA or included subjects with localised neck–shoulder pain. Recent studies, focusing on objective assessment of PA (Verbunt et al., 2009), indicate that persons with chronic muscle pain are less physically active than are non-symptomatic subjects (van Weering et al., 2007) in accordance to the fear-avoidance model (Vlaeyen and Linton, 2008). Although some studies have shown decreased daily activity in patients, others have revealed different patterning throughout the day, typically with patients showing lower PA levels in the evening (van Weering et al., 2009). Thus, another possible explanation, more feasible to neck–shoulder pain, suggests that reduced PA is related to fatigue rather than fear of movement (Spenkelink et al., 2002). However, it is not known whether these patterns of PA can be seen in persons with chronic neck–shoulder pain, and how it affects ANS. Therefore, characterising daily PA requires objective assessment methods that provide detailed and precise information about volume and patterns of different activity types.

The aim of the present study was to investigate differences in autonomic regulation, PA and perceived stress and energy between subjects with chronic neck–shoulder pain and healthy controls, by means of 24-hour ambulatory monitoring of HRV, PA and self-ratings. It was hypothesised that the pain group would show reduced HRV, altered pattern of physical activity and higher perceived stress compared to the control group.

2. Materials and methods

2.1. Subjects

Twenty-three subjects with chronic neck–shoulder pain and 22 non-symptomatic controls took part in the present study. They were voluntarily recruited through advertising in local newspapers, and were interviewed in order to be evaluated in relation to specific criteria for selection to the case or control group, respectively. The pain and control groups were balanced with respect to age, gender and body mass index (BMI) (Table 1). The subjects mainly consisted of office workers and teachers, which were equally distributed across groups.

Eligible subjects who reported chronic pain or muscle discomfort localised to the neck–shoulder region were physically examined by a physiotherapist. This examination included questions regarding localisation and sensation of pain and ratings of pain intensity, assessment of tender points and range of cervical axial rotation. Physical fitness (VO_{2max}) was assessed using a sub-maximal cycle ergometer test, results presented elsewhere (Hallman et al., 2011). All subjects were classified as having chronic trapezius myalgia as they reported pain, stiffness and tender points in the trapezius muscles (Larsson et al., 2007).

Inclusion criteria for the pain group were age between 20 and 50 years, perception of chronic pain, tightness of muscles and tender points during the physical examination. Chronicity of pain was defined as persistent pain for the past six consecutive weeks and for at least 6 months. The pain was to be primarily localised to the neck and shoulders, in the absence of traumatic origin. Controls had to report themselves as healthy and non-symptomatic, and they had to be between 20 and 50 years of age to participate. Exclusion criteria were as follows: traumatic damage of the musculoskeletal system, diagnosis of rheumatism, diabetes, chronic neurological and endocrinology syndromes, as well as hypertension, coronary artery diseases and substance abuse. Persons who regularly used medication known to affect ANS function or pain perception (e.g. antidepressant, benzodiazepine, anti-inflammatory and beta-blocker drugs) were excluded. Because physical activity may change due to the absence from work, subjects who reported significant amounts of sick leave (>3 days) during the past three months were also excluded.

Table 1
Subject characteristics with means and standard deviations (SD) for the pain (n = 23) and control (n = 22) groups, respectively.

Characteristics	Pain	Control	t-Test
	Mean (SD)	Mean (SD)	*p*
Age	40.5 (7.1)	41.0 (6.9)	0.79
BMI	25.2 (4.2)	24.5 (3.6)	0.53
Male (n)	2	2	
Female (n)	21	20	
Neck pain current (0–10)	2.7 (1.1)	0.04 (0.1)	<0.001
Neck pain 6 months (0–10)	3.6 (1.5)	0.1 (0.3)	<0.001
Pain duration (years)	9.5 (7.9)	–	
Time fell asleep (h: min)	23:12 (0:56)	23:07 (0:37)	0.70
Time woke up (h: min)	5:59 (0.49)	5:49 (0:43)	0.45
Sleep duration (h: min)	6:47 (0:57)	6:42 (1:00)	0.78

The participants gave their written informed consent and received written information. The study was approved by the ethics committee at Uppsala University and was carried out according to the Helsinki declaration.

2.2. Ambulatory measurements

2.2.1. Heart rate variability

A bipolar electrocardiogram was continuously recorded with the IDEEA system using a three-lead configuration. Data were collected at a 256 Hz sampling rate from pre-gelled Ag/AgC1 electrodes placed on the distal end of the sternum and bilaterally over the sixth rib. Consecutive inter-beat intervals (IBI) were calculated off line and additionally imported to Spike2 version 6.10 (Cambridge electronic design, Cambridge, UK). The IBIs were plotted as a function of time for visual inspection and semi-automatically editing to remove artefacts and ectopic beats. Data from eight subjects (controls: n = 4; Pain: n = 4) were excluded due to insufficient quality of the ECG recording.

From a total of thirty-seven subjects, IBI time series were analysed in time and frequency domains according to Task Force standards (Task Force of the European Society of cardiology and the North American Society of Pacing and Electrophysiology, 1996). For time domain-HRV, we calculated SDNN (i.e., the standard deviation of normal-to-normal intervals) and pNN50 (i.e., the proportion of number of differences between successive intervals > 50 ms). For frequency domain-HRV, Fast Fourier Transform filtering was applied on detrended data to calculate the spectral power density (ms^2) in the very low frequency range (VLF: <0.04 Hz), low frequency range (LF: 0.04–0.15 Hz) and high frequency range (HF: 0.15–0.4 Hz). The natural logarithm was applied for VLF, LF and HF to obtain normal distribution. The relation between LF and HF was expressed in normalised units (LFnorm: $LF/(LF+HF)\times 100$).

HRV variables were derived from twelve 30-minute windows placed over six pre-selected periods, i.e. during the evening (18.00–19.00; 20.00–21.00), sleep (1-hour segment with low and stable HR between 01.00 and 03.00), morning (the first hour with activity in the morning: between 04.00 and 08.00) and day (10.00–11.00; 13.00–14.00). Repeated measures ANOVA on all 30-minute segments of IBI