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Effect of magnetopuncture on sympathetic and parasympathetic nerve activities in healthy drivers – assessment by power spectrum analysis of heart rate variability

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Abstract The object of this study was to assess the effects of magnetopuncture applied to Dazhui (DU14) point and Neiguan (PC6) points on sympathetic and parasympathetic nerve activities by power spectrum analysis of heart rate variability in healthy drivers during simulated driving. Using power spectrum analysis, the low frequency (LF) and high frequency (HF) components of heart rate variability can be calculated reflecting the sympathetic and parasympathetic activity. The 40 healthy male subjects were randomly divided into two groups: A (study group) and B (control group). All subjects were required to be well rested before the experiment. The subjects of both groups were required to perform a simulated driving task for 3 h. During the driving, magnetopunctures were applied to the DU14 and PC6 points for A while the subject performed the task for 2.5 h, and for B magnetopunctures were applied to non-acupuncture points which were 1.5 cm away from the two acupuncture points respectively over the same time. Subjective response to a questionnaire was obtained after the simulated task in the two groups. At the end of the driving task the LF component in normalized units (NU) had decreased significantly ($P < 0.05$) indicating a reduced sympathetic nerve activity and the HF component (NU) increased significantly ($P < 0.05$) indicating a increased parasympathetic nerve activity for A compared with pre-stimulation while for B no significant differences were observed. There were significant group differences in LF (NU), HF (NU) and LF:HF at the end of the driving task ($P < 0.05$). It was concluded that a modulating effect of magnetopuncture on sympathetic and parasympathetic nerve activities in healthy subjects was associated with the acupuncture points. The findings represent physiological evidence

that magnetopuncture may reduce mental fatigue in healthy drivers.

Keywords Driving fatigue · Magnetopuncture · Heart rate variability · Sympathetic activity · Parasympathetic activity

Introduction

Experimental and clinical studies suggest that differing inputs to somatic nerve fibres have a significant effect on pain as well as on autonomic functions and hormones (Andersson and Lundberg 1995). It has been found that acupuncture affects the cardiovascular system via the autonomic nervous system. In a thermography study on 19 healthy subjects, both manual and electrical acupuncture applied unilaterally to the Hegu point in the thenar muscle produced a symmetrical long-lasting warming effect indicating reduced sympathetic nerve activity. As the observed changes were symmetrical, the authors suggested a central spinal or supraspinal mediated sympathetic nerve effect rather than a peripheral effect. In addition, a short-term cooling effect induced by electrical acupuncture indicated a transient segmental increase in sympathetic nerve activity (Ernst and Lee 1985, 1986; Sugiyama et al. 1996).

The usual method of revealing the underlying modulations on beat-to-beat interval of the heart is by spectrum analysis of either R-R interval compared to interval number (tachogram) or by R-R interval plotted against elapsed time. Heart rate variability (HRV) allows an analysis of the interaction between the activities in the sympathetic and the parasympathetic nervous systems by modulation of the heart beat-to-beat interval. The HRV technique has previously been used to demonstrate the influences of different body positions, the influence of various anaesthetics on the autonomic nervous system and separate qualitative different levels of stress (Mohr et al. 2002; Lucini et al. 2002; Widmark et al. 1998). Frequency fluctuations in

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the range of 0.04–0.15 Hz (low frequency, LF) are controversially considered to be markers of sympathetic nerve activity, and high frequency (HF) fluctuations in the range of 0.15–0.40 Hz are considered markers of parasympathetic or vagal nerve activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). A reciprocal relationship exists between these two frequency domains and is similar to that characterizing the sympathovagal balance (Malliani et al. 1991).

One of the most studied acupuncture points is the Hegu point (L1 4) in the thenar muscle that is innervated by sensory and autonomic, mainly sympathetic, nerve fibres (Suter and Kistler 1994). Stimulation of the thenar muscle resulted in a significant increase in the sympathetic and the parasympathetic nerve activity during the stimulation period (Haker et al. 2000). However, the use of a needle, which can injure the tissue, is a noxious stimulation inducing pain. Other treatment variations have been developed. These include acupressure (stimulation of acupuncture points using manual pressure instead of needles), magnitopuncture (acupuncture point is influenced by magnetic fields), electroacupuncture (involving electrical stimulation through the needles), moxibustion (adding heat to the needles), and neuroelectric stimulation (delivering low-level electrical stimulation to acupuncture points through surface electrodes) (McLellan et al. 1993). While several studies have investigated the effect of acupuncture on sympathetic nerve activity, there have been few studies on the effects of magnitopuncture on the sympathetic and parasympathetic nerve activity, particularly in healthy drivers in a fatigued state during driving.

The purpose of this study was to assess the effects of magnitopuncture applied to DU14 and PC6 points on sympathetic and parasympathetic nerve activities using power spectrum analysis of HRV in healthy drivers in a fatigued state during simulated driving.

Methods

Subjects

The experiment procedures were approved by the University's Ethics Committee. To avoid the influence of sex and age on HRV, 40 healthy men aged 20–29, recruited from staff and students within the university, were scheduled to participate in the study (Table 1). The subjects were healthy and were not known to be suffering from any illnesses or taking any medication. Written informed consent was obtained from each subject before participating in the study.

Table 1 Mean (SD) characteristics of the subjects ($n=40$)

Subjects	Age (years)	Body mass (kg)	Height (cm)
Men	25.87 (2.35)	66.62 (7.40)	172.62 (3.54)

Driving simulator

The subject in the driving simulator viewed a 32 in television monitor at a distance of 2.5 m. A 3-h videotape showed a view of the road ahead, including other vehicles and roadside objects such as trees and traffic signs while driving along a scenic highway having few intersecting roads and scarcely any buildings. A speedometer was provided. To enable an indicated speed of 60 km·h⁻¹ to be maintained the accelerator pedal position was monitored. A small red light mounted in the middle of the dashboard stayed on when pedal pressure was maintained within prescribed limits.

Magnitopuncture

Magnitopuncture (Haci Five Elements Needle) is mainly a combination of two therapies, acupuncture point pressing and magnetic treatment. The magnetic tip of the magnitopuncture device was silver-plated and it could be attached to the body by negative pressure. When acupuncturing the point, the magnetic tip, having a surface magnetic field equal to 250 mT or more, made a magnetic line of force penetrate the body from 6 to 9 cm (equal to the depth of traditional acupuncture; Li-wen Guo and Ding-zhong 2002). Being non-traumatic, void of any toxic or side effects, magnitopuncture is a type of acupuncture instrument for magnetic treatment that does not prick the skin and is safe and painless.

Procedure

The 40 healthy male subjects were randomly divided into two groups, A (study group) and B (control group); each group contained 20 subjects. All subjects were required to be well rested before the experiment. They were instructed not to eat, drink or smoke during the 2 h prior to treatment. To avoid the influence of circadian fluctuations on HRV (Fauchier et al. 1998), the experiments were scheduled to be at the same time session (between 8.30 a.m. and noon). The subjects of both groups were required to perform the simulated driving task for 3 h. During driving, magnitopunctures (Haci Five Elements needle, 250mT, Haci Company Ltd) were applied to the DU14 and PC6 points in A while the subject performed the task for 2.5 h, and in B magnitopunctures were applied to non-acupuncture points situated 1.5 cm away from the two above mentioned acupuncture points during the same time (see Fig. 1). The DU14 point is located between the spinous processes of 7th cervical and 1st thoracic vertebrae and PC6 point is situated between the tendons of the palmaris longus and flexor carpi radialis muscles. The stimulation time was 30 min. The subjects were not told which point was the acupuncture point or non-acupuncture point before the experiment. Subjective responses to a questionnaire were obtained after the simulation task for both groups (Table 2).

Measurement instruments and spectrum analysis

The subject was connected to an electrocardiogram (ECG) measuring system (FDP-1, Shanghai Medical University, ver 3.01) for recording ECG signals and subsequent calculation of HRV, LF and HF components. During the whole experiment the ECG signals were collected on-line via three electrodes attached to the chest. These surface ECG signals were sampled at 250 Hz and recorded directly onto the hard disk of a computer through an A-D convertor having a resolution of 12 bits. All the data were collected in a data logger and then transferred to a computer for subsequent blind analysis. Using an autoregressive (AR) model, the power spectrum of HRV was estimated from 256 R-R intervals of the heart beat. For spectrum analysis, the following variables were calculated:

1. The LF power (NU, normalized units)
2. The HF power (NU)

Fig. 1a-b Diagram of acupuncture and non-acupuncture points. Lines represent *DU* meridian (a) and *PC* meridian (b) respectively. Specific stimulation points include both meridian points and control points (non-acupuncture points)

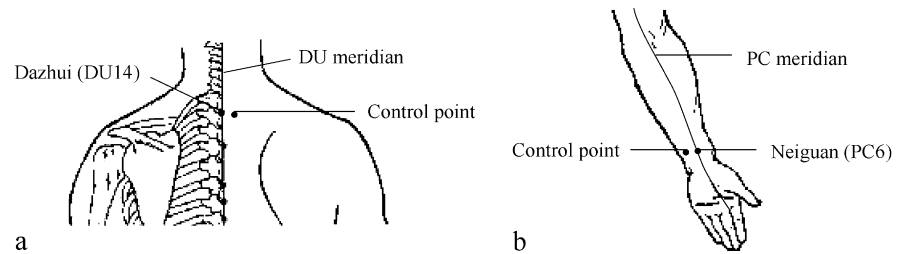


Table 2 Survey table of fatigue symptoms

No.	Signs	No.	Signs
1	Physically tired	8	Stiffness of shoulder
2	Lazy	9	Lumbago
3	Want to lie down	10	Easily distracted
4	Irritable	11	Eyestrain
5	No energy	12	Feeling sleepy
6	Mentally sluggish	13	Nausea
7	Headache	14	Trembling of hands and legs

3. The ratio of LF to HF

Each spectrum component is presented in a normalized form by dividing it by the total power (Pagani et al. 1986).

Statistical analyses

Differences between two continuous variables were compared using a two tailed Student's *t*-test. The Mann-Whitney rank-sum test was used for comparison of non-continuous parameters. Results are given as mean values (SD). A $P < 0.05$ was considered to be the level of statistical significance.

Results

HRV – LF and HF activity

Power spectrum analysis of the R-R-interval variability was performed using AR modelling. The LF component was calculated as the power within the frequency range of 0.04–0.15 Hz, and the HF component as the power within the frequency range 0.15–0.4 Hz. In Fig. 2 and Fig. 3 examples of the power spectra of 2 subjects from A and B, respectively, are shown.

The pre-task period

No statistically significant differences between the two groups were observed in LF and HF power (NU) during the pre-task period. Table 3.

The pre-stimulation period

The LF power (NU), HF power (NU) and LF:HF during the pre-stimulation period exhibited significant differences compared to the pre-task period ($P < 0.05$ or

$P < 0.01$) for both A and B. No statistically significant differences in LF and HF power (NU) during the pre-stimulation period between the two groups were observed (Table 3).

The end-task period

At the end of the driving task the LF power (NU) had decreased significantly ($P < 0.05$) indicating a reduced sympathetic nerve activity and the HF power (NU) had increased significantly ($P < 0.05$) indicating an increased parasympathetic nerve activity for A compared with pre-stimulation while for B no significant differences were observed (see Table 3). Statistically significant differences in LF (NU), HF (NU) and LF:HF between the two groups were observed at the end-task period ($P < 0.05$) (see Table 4).

Subjective evaluation

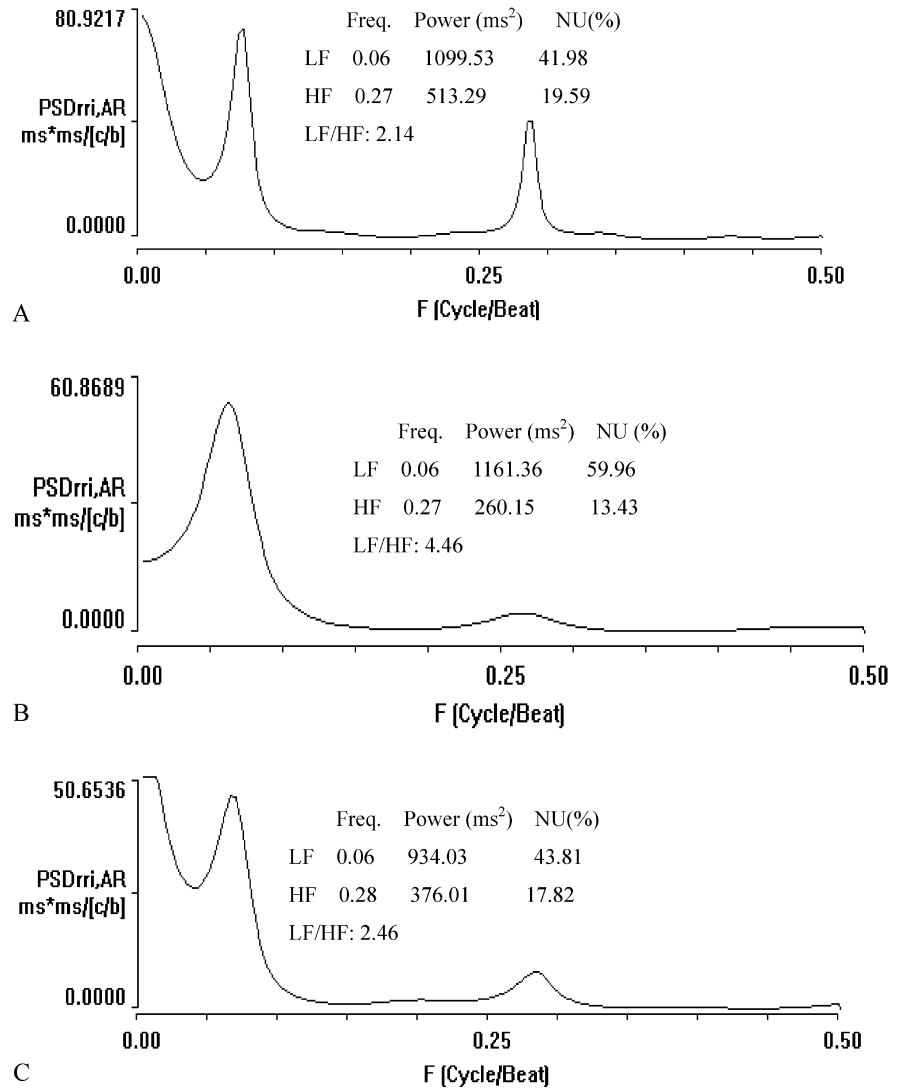
Self-reporting is the most frequently used method for assessing fatigue. It provides useful information concerning the subjective awareness of fatigue following the completion of a task. The subjective responses to the questionnaire given after the simulated task for both A and B are shown in Table 2. In Fig. 4 the comparison of main fatigue symptoms between A and B after the simulated driving task is shown. The subjective scores ranged from 1 to 7, a scale which represented no, minimally, somewhat, a little, considerably, very, and extremely. The main fatigue symptoms, such as physically tired, irritable, mentally sluggish, no energy, headache and feeling sleepy, exhibited significant differences between the two groups after the driving task ($P < 0.05$).

Discussion

Fatigue and sympathetic nerve activity

The literature has not been particularly helpful in defining the term fatigue and lacks an agreed definition. Fatigue has been defined as a state marked by reduced efficiency and a general unwillingness to work (Grandjean 1979) or a disinclination to continue performing a task, and to involve an impairment of human efficiency when work continued after the person had become

Fig. 2 Results of power spectrum density (*PSD*) computed from the heart rate variability signal by autoregressive (*AR*) modelling and spectrum decomposition in low-frequency (*LF*), and high-frequency (*HF*) components, obtained during pre-task **A**, pre-stimulation **B**, and end-task **C** for study group A. The LF power is known to increase during sympathetic enhancement, and HF power, in general the respiration-dependent part of the total variability, is a matter of the parasympathetic tone. Sympatho-vagal balance was calculated using the LF:HF power ratio. Pre-task: at the rest period of 10 min, before the driving task; pre-stimulation: at the 150~155 min period during the driving, before the stimulation; end-task: at the 175~180 min period during the driving and stimulation process



aware of their fatigued state (Brown 1994). Like pain, fatigue is a personal, emotionally rich experience, which may originate from neural (or chemical) peripheral signals, interpreted centrally, but can also be of central autochthonous origin (Davis 1995).

Cardiovascular neural regulation is the integrated response to a continuous central and peripheral interaction of inhibitory (vagal) and excitatory (sympathetic) nerve reflexes. In physiological conditions there is a dynamic closed loop interplay of these reflexes with rhythmic haemodynamic oscillations, such as those caused by respiratory and vasomotor activity. Thus, it has been proposed that power spectrum analysis of short-term fluctuations affecting heart period (R-R interval) (Pagani et al. 1986) and arterial pressure may provide an index of neural regulation and, in particular, of the balance between sympathetic and parasympathetic nerves in the modulation of cardiovascular activity (Malliani et al. 1991).

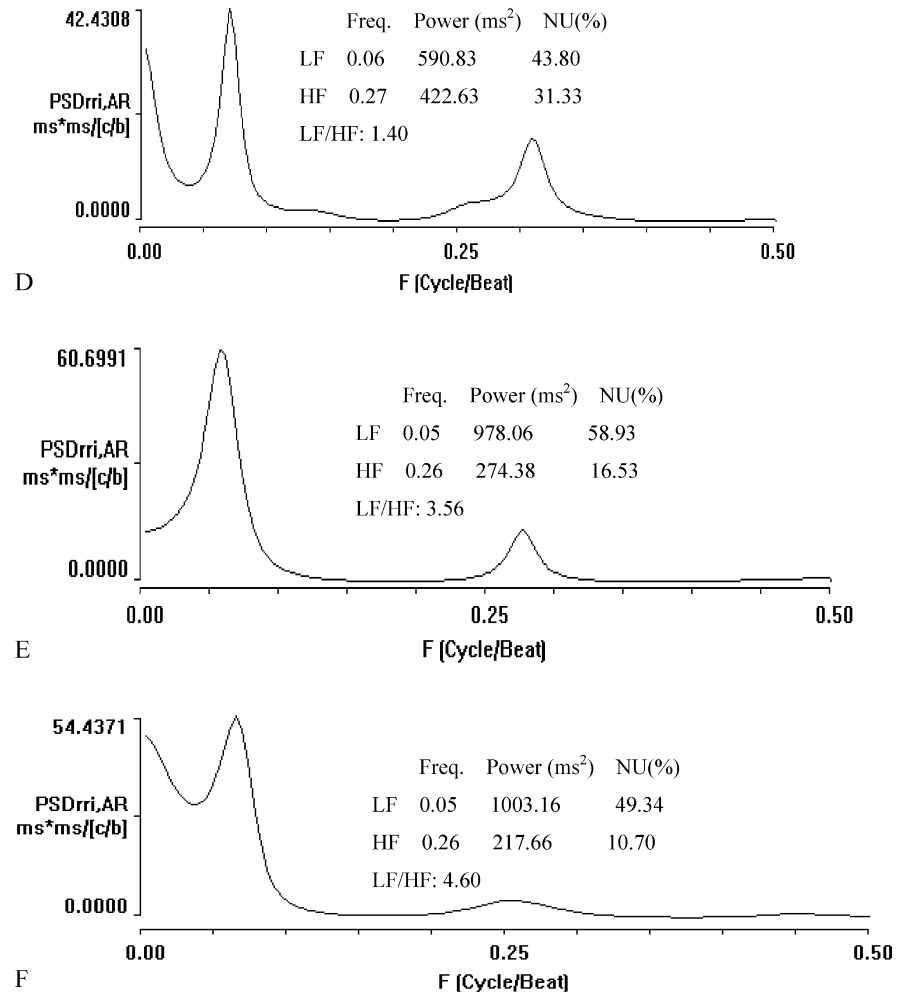
Although fatigue may be difficult to assess quantitatively, a behavioural scale from no fatigue to unbearable

(Appenzeller and Oribe 1997) has been used to consider its relationship with sympathetic nerve activity, as measured by direct intraneural recordings from sympathetic nerves in muscle (MSNA; Saito et al. 1989). A clear correlation was found between levels of fatigue sensation and MSNA, during static contraction. Several studies have shown MSNA to increase during experimental mental stress (Anderson et al. 1987).

The pre-stimulation period

Both LF power (NU) and LF:HF ratio increased significantly, and HF power (NU) decreased significantly during the pre-stimulation period compared with the pre-task period in both groups. Any shift in the relative distribution between these two major oscillatory components would mirror a parallel shift in the balance between the two autonomic outflows: accordingly the respiratory, HF, component would provide an index of vagal modulation, while the LF component would be a

Fig. 3 Results of power spectrum density (*PSD*) computed from the heart rate variability signal by autoregressive (*AR*) modelling and spectrum decomposition into low-frequency (*LF*), and high-frequency (*HF*) components, obtained during pre-task **D**, pre-stimulation **E** and end-task **F** for control group B (for details see Fig. 2)



marker of the drive to the sympathetic nerve system (Pagani et al. 1994).

According to Grandjean (1979), mental fatigue is a functional state, which graduates in one direction into sleep, and in the other direction into a relaxed, restful condition, both of which are likely to reduce attention and alertness. Although rhythms should not simply be equated to neural structures, functional states likely to be accompanied by an increase in sympathetic nerve activity are characterized by a shift of the LF:HF balance in favour of the LF component; the opposite occurs

during presumed increases of vagal activity (Malliani et al. 1991). The results indicate that sympathetic nerve activity and sympatho-vagal interaction became higher at the end of the pre-stimulation period and that the parasympathetic nerve activity was at lower level, as suggested by a clear correlation between driving time (fatigue) and activity of the autonomic nerves. Our results are in agreement with Hayashi et al. (1997) who demonstrated a lower HF power and a higher LF:HF in a very fatigued group than in a scarcely fatigued group.

Table 3 Mean (SD) values from spectrum analysis of heart rate variability (HRV) during pre-task, pre-stimulation (*pre stim*) and end-task (for details see Fig. 2) for the low frequency component (*LF*), the high frequency component (*HF*) in normalized units (*NU*) and the *LF:HF* ratio. *Group A* Study group, *Group B* control group

Group	Components	Pre-task	Pre-stim	End-task
Group A	LF (NU)	43.98 (4.21)	59.45 (5.22)*	39.81 (4.11) [□]
	HF (NU)	28.65 (3.11)	14.68 (5.53)**	20.82 (3.53) ^a
	LF:HF	1.54 (0.55)	4.05 (0.81)**	1.90 (0.52) ^a
Group B	LF (NU)	41.80 (3.12)	61.64 (6.42)*	55.26 (6.21) ^a
	HF (NU)	33.33 (3.23)	13.22 (5.61)**	10.17 (4.26)
	LF:HF	1.25 (0.61)	4.66 (0.76)**	5.43 (0.63)

** $P < 0.01$, * $P < 0.05$, Comparison of the HRV parameters between the pre-stimulation period and the pre-task period

^aComparison of the HRV parameters between the end-task and the pre-stimulation period, $P < 0.05$

Table 4 Comparison of heart rate variability parameters [mean (SD)] between the study group (A) and the control group (B) during the end-task period. For definitions see Fig. 2 and Table 3

	Group A	Group B
LF (NU)	39.81 (4.11)*	59.26 (6.21)
HF (NU)	20.82 (3.53)*	10.17 (4.26)
LF:HF	1.90 (0.52)*	5.43 (0.63)

* $P < 0.05$

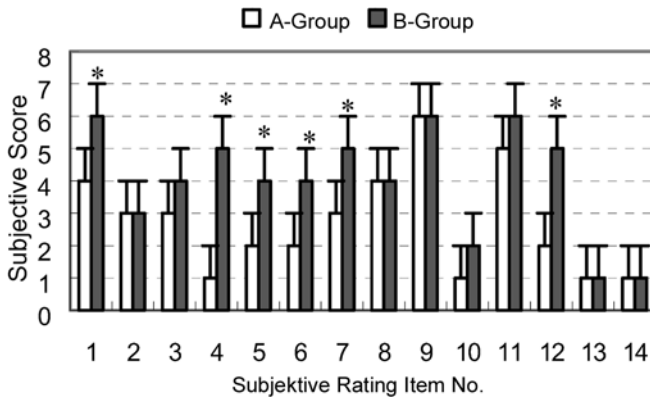


Fig. 4 Comparison of signs of subjective rating of fatigue: study group A and control group (B) * $P < 0.05$, statistical significance of difference between A and B after the simulated task

It is important to point out that spectrum analysis of R-R interval variability does not provide a direct estimate of the differential activity of either sympathetic or vagal nerves (Pagani et al. 1994), but only furnishes quantitative markers of the neural modulation of the sino-atrial node, examined in closed loop conditions. It also depends upon the continuous interaction between neural and humoral factors and the target function.

The stimulation period and post-task period

Stimulations of acupuncture points or non-acupuncture points had different influences on sympathetic and parasympathetic nerve activities during the driving process. Stimulations of the DU14 and PC6 points induced a significant decrease in the LF component of HRV reflecting sympathetic nerve activity and a significant increase in the HF component of HRV reflecting parasympathetic nerve activity at the end of the driving task period. Stimulation of non-acupuncture points did not induce such significant changes in the LF component and HF component of HRV. After the driving task the subjects in the two groups showed different responses in the subjective survey table of fatigue symptoms. The subjects of B exhibited higher subjective ratings in the main fatigue symptoms, indicating more intense feelings of fatigue.

This is an important finding as it has been indicated that stimulation of L14 resulted in a significant increase in activity of both the sympathetic and the parasympathetic nerve system during the stimulation period in

healthy subjects (Haker et al. 2000), and PC6 point acupuncture strongly inhibits the tone of the sympathetic nerve system in healthy volunteers (Abad-Alegria et al. 2001).

The rationale for using acupuncture in programmes aiming at modifying behaviours associated with *stress* and feelings of distress has been based on the untested assumption that acupuncture reduces the sympathoadrenal activity associated with arousal and stress (Knardahl et al. 1998). Some support for the assumption that somatic afferent stimulation may decrease sympathetic nerve activity comes from animal experiments. In hypertensive rats, direct electrical stimulation of the sciatic nerve produces hypoalgesia and profound reductions in arterial pressure and activity in the splanchnic sympathetic nerve lasting for several hours (Yao et al. 1982). Central opioid receptors may play a role in mediating these effects (Hoffman et al. 1990). In humans, on the other hand, no such effects of acupuncture or somatic afferent stimulation have been demonstrated.

Magnitopuncture as used in this study is mainly a combination of two therapies, acupuncture point pressing and magnetic treatment. Acupuncture points are located on the skin in areas of low electrical resistance (Reichmanis et al. 1975) and the influence of magnetic fields on the human body is closely related to acupuncture points (Ming-xia et al. 1999). So we can think of the changes of the overall autonomic features observed following magnitopuncture as being the common effect of acupuncture point pressing and magnetic treatment. We did not test the simple effects of magnetic fields per se on the overall autonomic features in this study and therefore could not evaluate their effects quantitatively.

Combined with the subjective response, possibly, the findings can explain the relaxation, calmness and reduced feelings of fatigue commonly experienced by the drivers following magnitopuncture. The findings represent physiological support for the proposal that magnitopuncture may reduce fatigue in healthy persons.

Methodological considerations

In the present study we tried to avoid any psychological and physical stress by introducing the subjects to the experiment procedure. At an initial visit all the subjects were informed about the design of the trial: in addition, in the control group, we put the magnitopunctures on non-acupuncture points. Whether on acupuncture or on non-acupuncture points, the magnitopuncture procedure would have induced the same feeling when touching the skin.

Study limitations

We did not measure directly sympathetic nerve activity, which requires invasive techniques (Pagani et al. 1997),

but only inferred sympathetic and parasympathetic nerve activity indirectly by spectrum analysis of R-R interval variability. The simple effect of magnetic fields per se on the overall autonomic functions was not tested in this study. There were also other limitations such as lack of respiratory recordings, and the use of low power statistics in this study.

Conclusion

The modulatory effect of magnitopuncture on sympathetic and parasympathetic nerve activities in healthy subjects was associated with the acupuncture points. The findings represent physiological backing for the suggestion that magnitopuncture may reduce the level of mental stress and fatigue in healthy drivers.

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References

- Abad-Alegria F, Pomaron C, Aznar C, Munoz C, Adelantado S (2001) Objective assessment of the sympatholytic action of the Nei-Kuan acupoint. *Am J Chin Med* 29:201–210
- Anderson EA, Wallin BG, Mark A (1987) Dissociation of sympathetic nerve activity in arm and leg muscle during mental stress. *Hypertension* 9:III-114–III-119
- Andersson S, Lundeberg T (1995) Acupuncture – from empiricism functional background to acupuncture effects in pain and disease. *Med Hypotheses* 45:271–281
- Appenzeller O, Oribe E (1997) The autonomic nervous system. An introduction to basic and clinical concepts. Elsevier Science, Amsterdam
- Brown I (1994) Driver fatigue. *Hum Factors* 36:298–314
- Davis JM (1995) Central and peripheral factors in fatigue. *J Sports Sci* 13:49–53
- Ernst M, Lee M (1985) Sympathetic vasomotor changes induced by manual and electrical acupuncture of the Hoku point visualized by thermography. *Pain* 21:25–39
- Ernst M, Lee M (1986) Sympathetic effects of manual and electrical cardioacu-acupuncture of the Tsusanli knee point: comparison with the Hoku hand point sympathetic effects. *Exp Neurol* 94:1–10
- Fauchier L, Babuty D, Autret ML, Poret P, Cosnay P, Fauchier JP (1998) Influence of duration and hour of recording on spectral measurements of heart rate variability. *J Auton Nerv Syst* 73:1–6
- Grandjean E (1979). Fatigue in industry. *Br J Intern Med* 36:175–186
- Haker Eva, Egekvist Henrik, Bjerring Peter (2000) Effect of sensory stimulation (acupuncture) on sympathetic and parasympathetic activities in healthy subjects. *J Auton Nerv Syst* 79:52–59
- Hayashi S, Minamitani H, Shin K (1997) Assessment of autonomic function indicators of heart rate variability aimed to assess cumulative fatigue. Annual International Conference of the IEEE Engineering in Medicine and Biology, Oct 30–Nov 2. IEEE Engineering in Medicine and Biology, Chicago, Ill., pp 300–301
- Hoffman P, Delle M, Thorén P (1990) Role of opioid receptors in the long-lasting blood-pressure depression after electric muscle stimulation in the hind leg of the rat. *Acta Physiol Scand* 140:191–198
- Knardahl S, Elam M, Olausson B, Wallin BG (1998) Sympathetic nerve activity after acupuncture in humans. *Pain* 75:19–25
- Li-wen Guo, Ding-zhong Li (2002). Testing the effect of Hacı Five Element Needle on human body using superconducting quantum interference device (in Chinese). *Biomagnetism* 1:3–5
- Lucini Daniela, Norbiato Guido, Clerici Mario et al (2002) Hemodynamic and autonomic adjustments to real life stress conditions in humans. *Hypertension* 39:184–188
- Malliani A, Pagani M, Lombardi F (1991) Cardiovascular neural regulation explored in the frequency domain. *Circulation* 84:482–492
- McLellan AT, Grossman DS, Blaine JB, Haverkos HW (1993) Acupuncture treatment for drug abuse: a technical review. *J Subst Abuse Treat* 10:569–576
- Ming-xia Guo, Di Wang, Chi Zhang (1999) The actions and mechanisms of magnetic field in medicine. *Chin J Convalesc Med* 8:13–16
- Mohr Elmar, Langbein Jan, Nürnberg Gerd (2002) Heart rate variability. A noninvasive approach to measure stress in calves and cows. *Physiol Behav* 75:251–259
- Pagani M, Lombardi F, Guzzetti S et al (1986) Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympathovagal interaction in man and conscious dog. *Circ Res* 58:178–193
- Pagani M, Lucini D, Mela GS, Langewitz W, Malliani A (1994) Sympathetic overactivity in subjects complaining of unexplained fatigue. *Clin Sci* 87:655–661
- Pagani M, Montano N, Porta A, Malliani A, Abboud FM, Birkett CL, Somers VK (1997) Relationship between spectral components of cardiovascular variabilities and direct measures of muscle sympathetic nerve activity in humans. *Circulation* 95:1441–1448
- Reichmanis M, Marino AA, Becker RO (1975) Electrical correlates of acupuncture points. *IEEE Trans Biomed Eng* 22:533–535
- Saito M, Mano T, Iwase S (1989) Sympathetic nerve activity related to local fatigue sensation during static contraction. *J Appl Physiol* 67:980–984
- Sugiyama Y, Xue Y, Mano T (1996) Transient increase in human muscle sympathetic nerve activity during manual acupuncture. *Jpn J Physiol* 45:337–345
- Suter B, Kistler A (1994) Does acupuncture influence the cardiovascular-acupuncture system via the central nervous system? *Schweiz Med Wochenschr* 124:36–38
- Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. *Circulation* 93:1043–1065
- Widmark C, Olaison J, Reftel B (1998) Spectral analysis of heart rate variability during desflurane and isoflurane anaesthesia in patients undergoing arthroscopy. *Acta Anaesthesiol Scand* 42:204–210
- Yao T, Andersson S, Thorén P (1982) Long-lasting cardiovascular depression induced by acupuncture-like stimulation of the sciatic nerve in unanaesthetized spontaneously hypertensive rats. *Brain Res* 240:77–85