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RESEARCH ARTICLE

Effect of acupuncture on heart rate variability during prolonged high-intensity training in soccer players

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Abstract

OBJECTIVE: To investigate the effects of acupuncture therapy compared with sham acupuncture on heart rate variability (HRV) in 24 elite soccer players during 4-week, high-intensity training sessions.

METHODS: The subjects were randomly divided into two groups: acupuncture group (AG) and sham acupuncture group (SG). In addition, AG had been implemented two times/week to stimulate Zusanli (ST 36), Hegu (LI 4), Shenshu (BL 23), and Chize (LU 5). While SG, had been applied to utilize a special "placebo-needle" technique on the same sites. What's more, the HRV parameters were calculated before and after interventions, respectively.

RESULTS: First, stress index (SI) had a significantly increased in SG (P = 0.031) compare pre-test with post-test, however, no significantly difference in AG (P = 0.102). Secondly, standard deviation of N-N intervals (SNDD) have enormously significantly higher in AG when comparing baseline with post therapy (P = 0.001), while, declined in SG (P = 0.827). Meanwhile, the root mean square of successive differences (RMSSD) were significant differences in AG (P = 0.023). What's more, when the high-frequency (HF) were significantly higher in AG (P = 0.047) after receiving the acupuncture therapy, the lowe-frequency (LF) power were decreased but no significant in AG and SG. Comparing with pre-experiment, the ratio of LF/HF was lower in AG, but higher in SG. Furthermore, it was significant difference when compare the post-experiment parameters of AG with SG (P = 0.015). And HF parameters have significance (P = 0.005) compare between two groups during the post-experiment.

CONCLUSION: Based on evidence, acupuncture therapy on special acupoints could strengthen the parasympathetic nervous activity and modulates the balance between parasympathetic and sympathetic activity in soccer players while they engage in high-intensity training.

Keywords: Acupuncture; Heart rate; High-intensity interval training; Autonomic nervous system; Soccer

INTRODUCTION

In the athletic field, competition becomes more and more intense, and, in generally, prolonged and high-intensity training, as well as fierce competitive season would induce insufficient recovery, fatigue accumulation, decline performance, or sports injuries. However, appropriate recovery strategies have positive significance to accelerate recovery progress and even promote

athletic performance. Selection of specific recovery techniques and strategies to minimize any residual fatigue from training and competition is one of the basic principles of training methodology.[1]

Acupuncture, one of the most essential of Traditional Chinese Medicine (TCM) technology, has been used for more than 2500 years already. The goal of acupuncture is to re-establish the balance of internal body energies, or dredge *Qi* (the circulating vital energy whose existence and properties are the basis in TCM) chances and balance *Yin* and *Yang*. Based on TCM philosophy theories, the body is considered as a delicate balance of two opposing and inseparable forces, *Yin* and *Yang*. Disease is caused by an imbalance of *Yin* and *Yang*, leading to a blockage in the flow of *Qi*.

Recently, acupuncture has been used to modulate the physical well being of various athletes. Acupuncture alleviates muscle tension, improves local blood flow, increases the pain threshold, modulates the autonomic nervous system, and readjusts the nervous-endocrine-immune systems.[2]

Heart rate variability (HRV) has used to measure the recovery from fatigue, which reflects the balance between the sympathetic nervous system and the parasympathetic nervous system.[3,4] Measuring HRV is a simple, sensitive, and non-invasive technique, which used to quantify the time intervals of beat-to-beat alteration in heart rate. What's more, acupuncture therapy has been found to change HRV and restores the imbalance of the autonomic nervous system.[5-7] However, previous studies seems to be focused on short term effects of acupuncture therapy, or non-fatigue state, or healthy man. No study reported the long-term effects of acupuncture in athletes during prolonged and high-intensity training.

Therefore, we tried to do a research about the effects of 4 weeks acupuncture intervention on HRV in soccer players during the period of high-intensity training. We also hypothesized that acupuncture therapy could improves HRV parameter of athletes who get into prolonged high-intensity training sessions. And this improvement may enhance recovery and maintain their peak performance.

MARERIALS AND METHODS

Subjects

Twenty-four male elite soccer players in East China at Political Science and Law University included though poster and randomly allocated into 2 groups: acupuncture group (AG) and sham group (SG) by a computer program using a list from the soccer coach (Figure 1). The coach and volunteers did not know which players were in the AG or SG. All of soccer players were in good health based on clinical and physical examinations, and without smoking, alcohol, history of hormone therapy, injury and acupuncture therapy during last 6 months. All subjects underwent more than 2 h 6 times/week session of high-intensity training for 4 weeks. This study was approved by the Ethical Committee of Khon Kean University, Khon Kean, 4002, Thailand (HE582343).

The baseline features of subjects were as follows (Table 1): the average age (AG *vs* SG) was (21.75 ± 1.76) *vs* (21.75 ± 1.78) years (P = 0.820), the average weight was (70.82 ± 4.83) *vs* (72.08 ± 4.99) kg (P = 0.534), the average height was (176.93 ± 6.97) *vs* (175.44 ± 4.23) cm (P = 0.535). In addition, the average duration of training experiences was (6.00 ± 1.31) *vs* (6.46 ± 1.59) years (P = 0.450). All subjects had been informed the safety efficacy and possible risks of acupuncture therapy as well as experimental protocol. The subjects were also informed of the experimental protocol and signed a consent form for participation in this experiment. The research protocol was approved from the Ethical Committee of Khon Kean University (HE582343).

The two groups were evaluated during the same time between 7:00 am and 8:00 am pre-experiment and post-experiment. The experimental room temperature was maintained at 25 ℃ and relative air humidity was between 50% and 60%. Every subject was instructed to rest for longer than 20 min before measurements, have an empty stomach, and keep in the supine position during measurements.

HRV

HRV data were collected 24 h before the experiments and 24 h after the experiments in the morning (between 7:00 am and 8:00 am). Participants were asked not to eat anything for at least 12 h and were allowed to drink some water. During the test, subjects were asked to remain supine, quiet, and without any disturbances to stabilize breathing at a frequency of 1 breath/4 s (0.25 Hz).[8] To record HRV, we used a portable blood pressure monitor (Certificate by KFDA; Bio-Sense Creative Co., Ltd., uBioMacpa, Seoul, Korea). Multiple data of HRV were calculated as follows. The stress index (SI) was calculated. Another measure of HRV was the time domain, including the standard deviation of normal-to-normal intervals (SDNN) and the root mean square of successive differences (RMSSD), which are related to exercise fatigue and recovery.[9] Additionally, the frequency domain was calculated, including low-frequency (LF; 0.04-0.15 Hz), high-frequency (HF; 0.15-0.40 Hz), and the ratio of LF/HF, which is the balance the sympathetic and parasympathetic nervous system activity.[8, 10]

Acupuncture therapy

In this study, a special "placebo-needle" had been designed by Streitberger (1998) had been utilized and changed. The sham needle tip was blunt and just touch the subject's skin and a small pricking sensation be felt. Short needles had been applied in the SG, long needles had been applied in the AG.

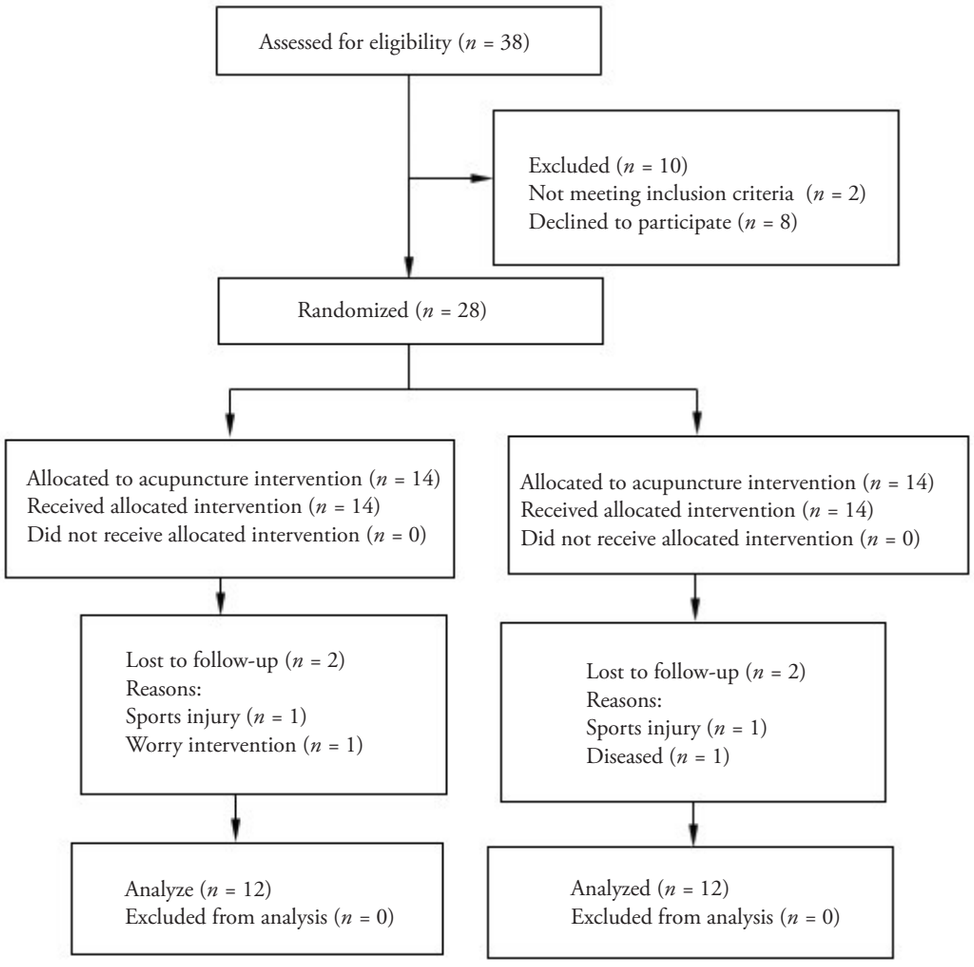

Figure 1 Flowchart of study
Two individual had lost in acupuncture group (injured and worry intervention) and two individual had lost in shame group (injured and disease).

Table 1 Baseline characteristics of the AG and SG (unpaired comparison) ($\bar{x} \pm s$)

Item	AG (n = 12)	SG (n = 12)	P value
Age (years)	21.75±1.76	21.75±1.78	0.820
Weight (kg)	70.82±4.83	72.08±4.99	0.534
Height (cm)	176.93±6.97	175.44±4.23	0.535
Training (years)	6.00±1.31	6.46±1.59	0.450
PrelnLF (ms^2)	8.12±0.54	7.94±0.58	0.453
PrelnHF (ms^2)	6.79±0.46	6.71±0.25	0.591
PreSDNN (ms)	59.65±15.33	63.09±22.03	0.662
PreRMSSD (ms)	41.57±10.75	46.57±17.15	0.403
PreSI	35.25±4.07	34.33±4.89	0.623

Notes: AG: acupuncture group; SG: shame group; pre-LF: pre-experiment natural logarithm of low-frequency spectral power; pre-lnHF: pre-experiment natural logarithm of high-frequency spectral power; pre-SDNN: pre-experiment standard deviation of normal-to-normal intervals; pre-RMSSD: pre-experiment root mean square of successive differences; pre-SI: pre-experiment stress index.

In this study, a special placebo needle was used (Figure 2).[11] Two physicians who were qualified with an acupuncture certificate, had over 10 years of experience in Shanghai First People's Hospital (graduated from the Shanghai University of Chinese Medicine), and had treated more than 1000 cases performed acupuncture in this study. In the AG, 0.25/40-mm disposable stainless steel needles (Maanshan Bond Medical Instruments Co., Ltd., Maanshan, China) were inserted into the acupoints [Zusanli (ST 36), Hegu (LI 4), Shenshu (BL 23), and Chize (LU 5)]. In the SG, we applied a special technique (placebo needle) to touch the near dermatome of same acupoints as AG. Acupuncture intervention was implemented between 8:00 pm to 9:00 pm on Monday, Wednesday, and Friday every week, for 4 weeks for a total of 12 times. The two groups

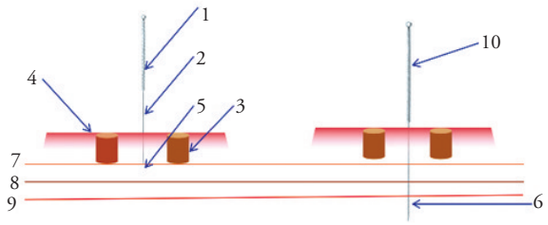

Figure 2 Schema showing a placebo needle (left) touching the skin using a blunt tip and a real needle (right)
This figure was modified from Streitberger and Kleinhenz, 1998. 1: needle handle; 2: needle corpus; 3: plastic ring; 4: plastic; 5: blunt tip; 6: sharp tip; 7: cutis; 8: subcuits; 9: muscle; 10: long needle.

were studied in different laboratories and had different acupuncturists. Before acupuncture, 75% alcohol was used to disinfect the acupoints, needles, and hands of the acupuncturists. Needles were continuously stimulated for 20 min in both groups.

Data analysis

The outcome measures are shown as mean ± standard deviations ($\bar{x} \pm s$). Two parallel group, intra-group, and inter-group comparisons were performed. The number of samples (n/group < 30) and 95% confidence levels were determined. The paired (intra-group) t-test and unpaired (inter-group) t-test were used. Data analyses were conducted with SPSS 22.0 (IBM SPSS Statistics for Mec, Version 22.0; IBM Corp., 2013, Armonk, NY, USA). The level of statistical significance was $P < 0.05$.

RESULTS

The HRV indices are shown in Table 2 (intra-group paired comparison) and in Table 3 (inter-group unpaired comparison).

Table 2 shows that SI was not significant comparing pre-experiment and post-experiment in AG (P = 0.102), lower. While SDNN have enormously significant increase (P = 0.01), and RMSSD also has significant increase (P = 0.023). In SG, SI were significantly higher compared pre-experiment with post-experiment (P = 0.031). However, SDNN and RMSSD were not significantly different post-experiment compared with pre-experiment (SDNN, P = 0.827; RMSSD, P = 0.103). Meanwhile, Table 2 also shows that as the frequency domain of HRV, lnLF and the ratio of LF/HF were no significant differences (lnLF, P = 0.365; LF/HF, P = 0.079), but lnHF were significant higher (P = 0.047) in AG. But in SG, lnLF, the ratio of LF/HF, and lnHF were no significant differences (lnLF, P = 0.435; lnHF, P = 0.051; LF/HF, P = 0.249).

What's more, no significant levels differences were found between AG and SG in any HRV measurement before therapy (SI, P = 0.654; SDNN, P = 0.662; RMSSD, P = 0.403; lnLF, P = 0.453; lnHF, P =

Table 2 Change of heart rate variability indices during intra-group paired compare means after therapy ($\bar{x} \pm s$)

Item	AG (n = 12)			SG (n = 12)		
	Pre	Post	P value	Pre	Post	P value
SI	35.25±4.07	33.25±4.42	0.102	34.41±4.95	39.94±9.23[b]	0.031
SDNN (ms)	59.65±15.33	77.81±12.56[a]	0.001	63.09±22.03	61.93±16.87	0.827
RMSSD (ms)	41.57±10.75	50.45±12.97[b]	0.023	46.57±17.15	54.82±19.22	0.103
lnLF (ms^2)	8.12±0.54	7.93±0.29	0.365	7.94±0.58	7.85±0.47	0.435
lnHF (ms^2)	6.79±0.46	7.03±0.43b	0.047	6.70±0.25	6.51±0.41	0.051
LF/HF	1.19±0.07	1.13±0.09	0.079	1.18±0.08	1.21±0.04	0.249

Notes: AG: acupuncture group; SG: sham acupuncture group; SI: stress index; SDNN: standard deviation of normal-to-normal intervals; RMSSD: root mean square of successive differences; lnLF: natural logarithm of low-frequency spectral power; lnHF: natural logarithm of high-frequency spectral power. [a]$P < 0.01$, [b]$P < 0.05$.

Table 3 Change of heart rate variability indices during inter-group unpaired compare means before and after therapy ($\bar{x} \pm s$)

Item	Pre			Post		
	AG (n = 12)	SG (n = 12)	P value	AG (n = 12)	SG (n = 12)	P value
SI	35.25±4.07	34.41±4.95	0.654	33.25±4.42	39.94±9.23[a]	0.039
SDNN (ms)	59.65±15.33	63.09±22.03	0.662	77.81±12.56	61.93±16.87[a]	0.016
RMSSD (ms)	41.57±10.75	46.57±17.18	0.403	50.45±12.96	54.82±19.22	0.522
lnLF (ms^2)	8.12±0.54	7.94±0.58	0.453	7.92±0.29	7.85±0.47	0.681
lnHF (ms^2)	6.79±0.46	6.70±0.25	0.591	7.03±0.43	6.51±0.41[b]	0.005
LF/HF	1.19±0.07	1.18±0.08	0.869	1.13±0.09	1.21±0.04[b]	0.015

Notes: AG: acupuncture group; SG: sham acupuncture group; SI: stress index; SDNN: standard deviation of normal-to-normal intervals; RMSSD: root mean square of successive differences; lnLF: natural logarithm of low-frequency spectral power; lnHF: natural logarithm of high-frequency spectral power. [a]$P < 0.05$, [b]$P < 0.01$.

0.591; LF/HF, P = 0.869) (Table 3). But the value of SI were significant lower compare AG with SG after therapy, (P = 0.039), but SDNN were significant higher compare AG with SG (P = 0.016). Meanwhile, In-HF were significant higher (P = 0.005), but LF/HF were significant lower compare AG with SG after therapy (P = 0.015).

DISCUSSION

This study aimed to assess the efficacy of acupuncture therapy to enhance recovery after high-intensity and prolonged training season. We found that the SI in the SG was significantly higher after 4 weeks of high-intensity training compared with baseline, but the SI in the AG did not significantly change and appeared to be slightly declined. This finding in the SG suggests that acupuncture therapy can decrease depression or anxiety disorders, as shown in previous studies.[22,24] A high SI makes athletes feel anxious, increases mental pressure, and induces central fatigue. Many researchers have shown that acute exercise changes the content of brain neurotransmitters, mainly including serotonin, dopamine, and noradrenalin, inducing central fatigue.[29,30] Previous studies have shown that acupuncture therapy can regulate neurotransmitters, hormones, blood lactate concentrations, creatine kinase content, and autonomic nerves to rebalance the central nervous system.[31,32] The present study showed that acupuncture therapy decreased the SI of the subjects and enhanced recovery.

The normal value of SDNN and RMSSD were thought to be the markers of physical status, and they will, in generally, decrease from rest to exercise.[33] Cervantes *et al* [27] had demonstrated RMSSD values were decreased and induce inhibition of the parasympathetic activity during precompetitive situations in swimmers. And Justin *et al* [34] found that greater parasympathetic modulation accounted for greater HRR following maximal exercise in boys versus men, and the parameters of RMSSD and SDNN were significantly higher (RMSSD, P = 0.00; SDNN; P = 0.004). The present study showed that the SDNN, RMSSD, and HF were significantly higher after 4-week acupuncture therapy compared with baseline. However, there were no significant differences in these variables in the SG. A previous study showed that appropriate exercise can increase the SDNN and RMSSD after exercise.[35] The SDNN was significantly higher in the AG compared with the SG post-experiment in the current study. However, the RMSSD was not significantly different between the groups post-experiment. Previous studies have demonstrated that long-term application of acupuncture can improve autonomic function and exercise tolerance, and reduce recovery of heart rate by 50%. Our results suggested that an increase in parasympathetic activity stimulated by acupuncture could be a mechanism for faster heart rate recovery in subjects of the AG compared with the SG.

The HF spectral component of HRV had been related to access the impact of training on status of the athlete as well as performance.[36] Aadequate training loads can improve HF power. Decreased HF power reflects insufficient recovery and fatigue, and is a marker for evaluating the training system.[37] Several previous studies showed that HF in HRV was reduced following exercise compared with baseline values.[38] Stimulation on Zusanli (ST 36) can change LF, HF, and LF/HF.[39,40] Rosann *et al* [41] had reported that acupuncture treatment is beneficial in lowering blood pressure, and this is in part due to a lowering of sympathovagal balance. The LF/HF ratio, expressing sympathovagal balance, is one of the most important physiological controls of blood pressure. Konrad *et al* [39] showed that manual stimulation of Hegu (LI 4) led to a significant increase in HF power. In our study, HF was significantly higher compared after acupuncture therapy with baseline in the AG, but HF appeared to be decreased in the SG. After 4 week high-intensity straining, the value of HF were significant higher comparing AG with SG (HF, 0.005). All these parameters (HF of AG, 7.03 ± 0.43; HF of SG, 6.51 ± 0.41) had show that acupuncture therapy could improve the HF index. HF power contributes to parasympathetic nervous activity. Therefore, acupuncture therapy can enhance parasympathetic activity. Further observation, in post therapy and sham therapy, the ratio of LF/HF has significant lower compare AG with SG (P = 0.015).

No significant changes were observed in eigher LF before to after in the two groups. But the ratio of LF/HF was decreased in AG, increased in SM. After 4 weeks therapy, HF and the LF/HF ratio were significantly higher in the AG than in the SG. These means prolonged stimulation on these acupoints is beneficial to enhance HF, but no effect on LF. In other words, acupuncture therapy changes parasympathetic and sympathetic balance should be related to improve HF. And the ratio of LF/HF decrease is one of evidence that acupuncture enhancing recovery when athletes survive in the prolonged, high-intensity training season.

Many mechanisms of acupuncture therapy may enhancing recovery have been studied. Acupuncture effects the aerobic condition, be beneficial to cardiac output, reduces arterial blood pressure and heart rate.[42, 43] Nishiio *et al* [44] suggested that the acupuncture may increase in cardiac vagal activity and decrease in cardiac sympathetic activity, and induced response decrease in heart rate. Haker *et al* [45] demonstrated that acupuncture changed activity in the sympathetic and parasympathetic nervous systems, depending on the site of stimulation and period of observation. Therefore, acupuncture therapy is a complex method for recovery in training. A combination of physiological and psychological markers may be required to determine the mechanisms of acupuncture for enhancing recovery in exercise. In the future, we plan to combine the rating of perceived exertion, physiological and immune indi-

ces to study the effect of acupuncture intervention. What's more stimulation on different acupoints, or using different pattern may induce different results. Therefore, further studies are that stimulate other acupoints and other therapy methods to enhance recovery in more athletes.

In conclusion, acupuncture that stimulates special acupoints can increase parasympathetic nervous system activity. Additionally, this acupuncture modulates the balance between parasympathetic and sympathetic activity in soccer players engaging in high-intensity training. These findings suggest that acupuncture therapy can facilitate recovery during prolonged, high-intensity training and be an effective means for recovery in training.

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