Original Clinical Research 临床论著

Ryodoraku as a tool monitoring the effects of walking exercise

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Objective: To investigate the possibility of using Ryodoraku as a tool to indicate sympathetic neuronal activity.

Methods: Twenty-two female college students were assigned to an treadmill exercise program (three times a week for six weeks), and another 25 were assigned as controls. Skin conductance levels of the subjects were measured at 24 Ryodoraku points on the wrists and the ankles, along with heart rate variability (HRV) analysis, during and after the treadmill exercise period.

Results: The six-week exercise training resulted in a significant elevation of the average electrical conductance, which returned to the pre-training level after three months of cessation of the exercise training.

Conclusion: HRV data have shown no similar changes, suggesting that Ryodoraku is a useful tool in detecting subtle, non-cardiovascular physical responses.

Keywords: Ryodoraku; galvanic skin response; heart rate; acupuncture points

A regular, moderate, and aerobic exercise may play an important role in reducing age-related cardiovascular autonomic changes and improving cardio-respiratory fitness[1]. It is widely observed that resting heart rates reduce after a period of regular exercise, but the mechanism which causes the changes is still unclear[2]. One popular hypothesis suggests that it is a combined effect of an increase in parasympathetic activity and a decrease in sympathetic activity, resulting in an improved cardiac autonomic balance[3]. Other models include a reduction in intrinsic cardiac rate[4,5], the adaptation of baroreflex sensitivity[6], and an increase in plasma nitric oxide (NO) which is a vasodilator substance that may induce vagal-related bradycardia[7,8].

To monitor autonomic activities, the noninvasive heart rate variability (HRV) measurement is becoming a gold standard in interpreting sympathovagal balance[9]. Emerging evidence, but not all, supports the theory of exercise-induced vagal activity[10-13]. Some studies found no significant changes in either high frequency (HF) or low

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frequency (LF) region[14,15], but others showed LF increased after three months of training while decreased at 6, 9 and 12 months[6]. The inconsistence may be a result of variations in experimental designs, such as the subjects (age, gender and physical fitness), and the exercise protocols (intensity, duration and frequency).

Compared to cardiovascular regulations, electrodermal activity, mainly influenced by sympathetic neuronal activity but not by the parasympathetic system, is another approach to detect psychophysiological changes[16,17]. Earlier studies have shown that a short-term endurance training could decrease the core body temperature thresholds, which improves sweating and cutaneous vasodilatory responses, suggesting an improvement of sympathetic sensitivity regulated by preoptic-anterior hypothalamus[18-20]. To our knowledge, no studies have investigated the correlation between the endurance training and the electrodermal activity.

It is widely accepted within acupuncture community that acupuncture points are areas of lower electrical impedance and higher conductance[21-23], although the reliability and reproducibility of the measurements have been questioned lately[24-27]. Based on traditional Chinese medicine philosophy and the low impedance property at meridians, Nakatani[28] had identified 12 channels of high electrical conductance on each side of the body (24 in total), and developed the Ryodoraku theory, which literally means good (ryo) conductive (do) line (raku).

The primary goal of this study was to compare the changes of electrodermal activity measured by average Ryodoraku values. This study focused on walking exercise of moderate intensity, which is subjectively determined as Borg ratings of perceived exertion (RPE) scale at either 12 or 13, equivalent to 50% to 74% of the maximal oxygen consumption (VO_{2max}) [29,30].

1 Study participants and study methods

1.1 Subjects Forty-seven college females, with an average age of 21.0±1.0, were enrolled in this study. None of the subjects had history of any cardiovascular disease, diabetes or musculoskeletal system abnormalities. Those who had an exercise habit of more than 30 min at a time for more than twice a week and with body mass index (BMI)> 24 kg/m^2 were excluded from the study. All the subjects were assessed by clinical doctors before being recruited in this study. Of the 47 participants, 22 were assigned to the exercise group and the other 25 to the control group. A signed informed consent was obtained from each participant before participating in the study. The research protocol was approved by the Institutional Review Board at Pingtung Christian Hospital in Pingtung, Taiwan, China.

1.2 Measurements The participants were asked to rest on a chair for 10 min every time before taking measurements. All measurements were operated in a temperature-controlled ((25±1) ℃) and moisture-controlled (55%±5%) room. The electrical conductances of 24 Ryodoraku points were determined using M.E.A.D. 6.0 (MedPex Enterprises Ltd., Taichung, Taiwan, China). The M.E.A.D. is basically an amperometer employing a DC voltage of 12 V with output current in the range of 0 to 200 μA. Higher values indicate higher conductances between the reference electrode, which is 35 mm in diameter and clipped on left palm and the acupuncture point measured by 10 mm diameter cotton with saturated saline solution. The 24 Ryodoraku points were measured one by one and started from the left side, following the order of LU9 (lung), PC7 (pericardium), HT7 (heart), SI5 (small intestine), TH4 (triple energizer), LI5 (large intestine), SP3 (spleen), LV3 (liver), KI4 (kidney), BL65 (bladder), GB40 (gall bladder), and ST42 (stomach). Each measurement took 2.5 s, but only values of the last 0.5 s were averaged. It normally took less than 2 min to collect the 24 measures.

Five-minute electrocardiograph data were recorded immediately after Ryodoraku measures using CheckMyHeart Handheld Heart Monitor (Dailycare Biomedical Inc., Chungli, Taiwan, China) with Ag-AgCl adhesive disposable electrodes by means of lead Ⅰ configuration (right wrist to left wrist). N-N intervals were determined by the system and manually corrected. HRV parameters were calculated using Kubios HRV 2.0 software, developed by Department of Physics, University of Kuopio, Finland. In addition to frequency-domain measures such as LF (0.04 to 0.15 Hz), HF (0.15 to 0.40 Hz), normalized LF (LFn), and normalized HF (HFn), selected time-domain indexes such as standard deviation of all N-N intervals (SDNN) and RMSSD (the square root of the mean squared differences of successive N-N intervals) were also analyzed.

1.3 Training Subjects of the exercise group were asked to exercise on treadmill three times a week, 30 min each time. Treadmill speeds were individually preset to either 12 or 13 of the RPE according to each subject's condition. The average speed was (6.2 ± 0.5) km/h, and the average RPE was 12.4±0.5. Subjects of the control group remained inactive daily lives.

Each subject reported to the laboratory every other week for an assessment. In order to avoid the potential confounding effects of circadian rhythms, participants were asked to come in around the same time of day. The laboratory was air-conditioned with temperature and moisture set at (25±1) ℃ and 55%±5%, respectively. Subjects quietly rested at a supine position for 10 min after walking in, followed by the measurement of 24 skin electrical conductances (roughly 3 min) and five-minute electrocardiograph data collection. The overall training lasted for six weeks, and ended before the summer break. Five of the 22 exercise group members were graduated and out of contact. The other 17 subjects were reached and reported to the laboratory for a follow-up measurement at the beginning of the next semester, approximately three months after the training ended.

1.4 Statistical analysis Between-subjects P values were calculated using independent t-test and within-subjects using paired t-test. The response over time was compared between exercisers and controls using repeated measures analysis of variance (ANOVA) with Levene test ($P>0.05$) checked to satisfy the sphericity assumption. Statistical analyses were performed using SPSS 12.0 for Windows (SPSS, Chicago, IL, USA).

2 Results

2.1 Baseline data Average BMIs of the study group and the control group were (19.4±1.6) kg/m^2 and (20.0±1.9) kg/m^2, respectively ($P=0.390$). Other indexes were also comparable between the two groups ($P>0.05$). Baseline characteristics are summarized in Table 1.

Table 1 Baseline characteristics of study groups

(Mean±SD)

Group	n	Age (years)	BMI (kg/m^2)	HR (beats/min)	MEC (μA)
Exercise	22	21.4±0.8	19.4±1.6	69.9±8.5	51.3±21.8
Control	25	21.0±0.9	20.0±1.9	75.2±9.7	56.9±17.6

SD: standard deviation; BMI: body mass index; HR: heart rate; MEC: meridian electrical current.

2.2 Characteristics of individuals The resting heart rate, BMI, and HRV indexes of the exercise and the control groups before and after the six-week exercise training were compared and shown in Table 2. Except for a significant decrease of BMI in the exercise group ($P<0.05$), neither between-subjects nor within-subjects differences were significant.

2.3 Ryodoraku measures The average electrical conductances of the measured 24 points increased gradually and significantly from the beginning of the study. In comparison, the control group decreased significantly in the second week, but no significant changes for the following weeks. The follow-up measurement of the 17 subjects illustrated that the effects of walking training vanished three months after the training ended. Between-subjects analyses performed by independent t-test found P values of 0.332, 0.002, 0.086, <0.001 for baseline, at the 2nd, 4th and 6th week, respectively (Figure 1). Repeated measures ANOVA further confirmed the meaningful effect of the six-week training ($P<0.001$).

To investigate whether the change in electrical conductance was due to the changes in BMI, we applied a scatterplot of the 94 pairs of BMI *vs* electrical conductance, including the pre-training and post-training measures of the 47 subjects (Figure 2). The correlation coefficient of Pearson's test was −0.023 ($P>0.05$), indicating no statistical significance.

3 Discussion

Although it is well recognized that endurance training decreases resting heart rate, explanation for this phenomenon is not conclusive. In this study, none of the HRV measures, including SDNN, RMSSD, LF and HF, were significantly different after six weeks of walking exercise training. Resting heart rate did not change in this study too, indicating no evident of cardiovascular adaptation by such a short-term training. The significant decrease in BMI, however, suggests that this training protocol may have physical effects other than effects on cardiovascular system.

We took advantage of the well-developed Ryodoraku device and used the average electrical conductance of 24 meridian points as an indicator of the sympathetic activity level. In comparison with HRV measurement, the meridian electrical conductance increased after two weeks of exercise training and remained significantly elevated until the

Table 2 Resting HR, BMI and heart rate variability indexes before and after 6-week training

(Mean±standard deviation)

Index	Exercise	Control	*P*-value (between-subjects)
Number of subjects (*n*)	22	25	
HR (beats/min)			
Before	69.9±8.5	75.2±9.7	0.054
After	71.9±9.4	74.9±9.9	0.291
P-value (within-subjects)	0.201	0.911	
BMI (kg/m^2)			
Before	19.4±1.6	20.0±1.9	0.318
After	19.2±1.4	20.0±1.9	0.103
P-value (within-subjects)	0.004*	0.718	
SDNN (ms)			
Before	47.3±17.4	44.0±14.2	0.470
After	44.1±17.6	44.5±18.2	0.948
P-value (within-subjects)	0.349	0.867	
RMSSD (ms)			
Before	46.3±25.4	40.9±16.3	0.387
After	44.7±23.9	44.4±23.9	0.963
P-value (within-subjects)	0.751	0.399	
LF (ms^2)			
Before	666±513	560±560	0.503
After	533±414	485±478	0.712
P-value (within-subjects)	0.272	0.463	
HF (ms^2)			
Before	978±104 1	766±646	0.400
After	981±107 7	937±973	0.885
P-value (within-subjects)	0.991	0.231	
HFn			
Before	54.4±17.4	58.0±16.2	0.471
After	57.3±17.5	61.8±17.3	0.386
P-value (within-subjects)	0.386	0.347	

* BMI of the exercise group was significantly lower ($P<0.01$) after the walking training. HR: heart rate; BMI: body mass index; SDNN: standard deviation of all N-N intervals; RMSSD: square root of the mean of the sum of the squares of differences between adjacent N-N intervals; LF: power in low frequency range (0.04 to 0.15 Hz); HF: power in high frequency range (0.15 to 0.4 Hz); HFn: HF power in normalized units, HF/(LF+HF).

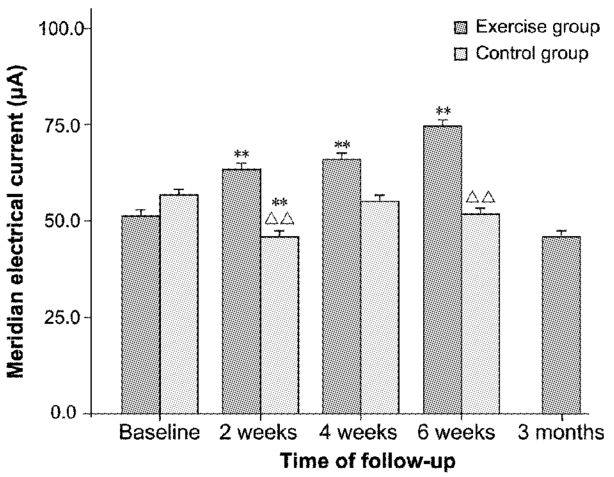

Figure 1 Electrical current of the exercise group and the control group

Data were expressed as mean±standard deviation; $n=22$ in exercise group, $n=25$ in control group, and $n=17$ in exercise group after three-month follow-up. Between-subjects significance was set at $P<0.05$. ** $P<0.01$, *vs* baseline data of respective group; △△ $P<0.01$, *vs* exercise group.

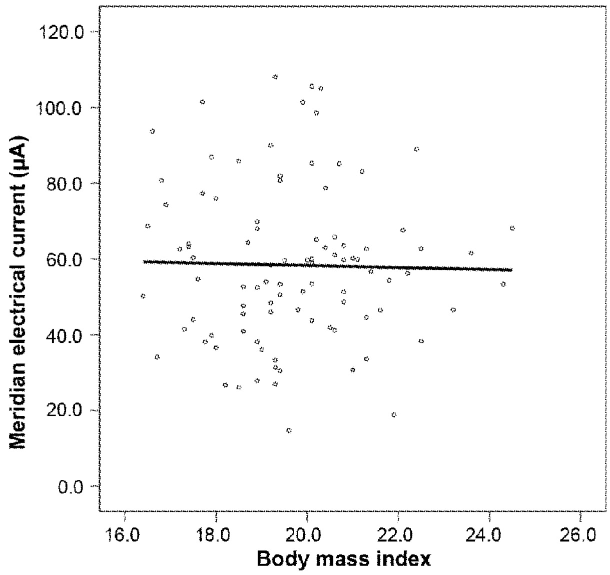

Figure 2 Scatterplot of body mass index *vs* meridian electrical current ($n=94$)

$r=-0.023$ ($P>0.05$) by Pearson's test.

training ended. Although both HRV and skin electrical conductance are widely used in measuring autonomic activations, studies have shown that other factors may also play roles so that sympathetic and parasympathetic activities interact in complex ways[31], a phenomenon known as directional fractionation[32], later integrated as the concept of "autonomic space"[33].

It has been proposed that to facilitate the rise in skeletal muscle blood flow, there might be sympathetic vasodilator nerves to skeletal muscle. Clear evidence became to emerge during the 1930s, although it is still in debate whether this sympathetically mediated vasodilatation is due to cholinergic mechanisms and NO-dependent stimulations, or it is a adrenoceptor-mediated process[34]. The observation of Ichinose *et al*[35] on improved heat loss responses in exercising women suggested the involvement of a vasodilatation process induced by a short-term endurance training. Our skin conductance study, on the other hand, supports the idea that it is a sympathetically mediated process.

The study by Weng *et al*[36] suggested that BMI and the electrical conductance of meridian points were negatively correlated, because of the poor conductance in the measured regions with higher fat tissue. To rule out the possibility that the increase of skin electrical conductance after the endurance training was due to the effect of a decrease in BMI, a correlation analysis of BMI and electrical conductance of the 47 subjects was performed. We found no significant correlation between these two variables in this study.

The follow-up measurement shows, as expected, that the effect of a short-term training on sympathetic system is reversible. In one study, it took two weeks after an 8-week aerobic training to bring the vagal activity back to the baseline level[5]. In another one, it needed eight weeks to reverse the trend of increase in sympathetic activity after 12 weeks of intensive training[37]. In comparison, our result indicated that 12 weeks were sufficient to reverse the training effect on skin conductance.

There were other limitations of this study. First, we did not take menstrual cycle into consideration. The relationship between the menstrual circle and the electrodermal activity is still not well established as existing data are conflicting[38,39]. Further studies will take this factor into consideration. Second, the assignment of study subjects into the exercise and control groups was not randomized, and our study could not rule out the potential psychological effects as the exercise group received more attentions compared to the control group which did not receive any intervention. Third, the second week of the training happened to be the midterm exam week of the college, and some subjects stayed up late the night before taking measures. It may explain the decrease in conductance of the control group in week 2.

4 Conclusion

This study found that resting skin electrical conductance which was determined by Ryodoraku, elevated after a six-week walking exercise, and returned to the baseline after the training was withdrawn. We also noticed that the elevation of the skin electrical conductance was evident in skin electrical conductance measurement only, suggesting that at least in this study, skin conductance may be more sensitive than HRV in analyzing autonomic response.

5 Competing interests

The authors declare that they have no competing interests.

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步行运动效果的良导络检测研究

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目的：探讨应用良导络仪评价交感神经活性的可能性。

方法：纳入 22 位大学女生参与运动训练，进行每周 3 次，连续 6 周的跑步机运动。另有 25 位作为不运动对照组。记录锻炼前、中、后阶段的心率变异以及手腕与脚踝上的 24 个良导络电导值后进行分析。

结果：经过 6 周锻炼后，受试者的手腕与脚踝上的 24 个良导络平均电导值显著增高。此效果在训练结束 3 个月后消失。

结论：由于此锻炼效果只在良导络仪上观察到，并未出现心率的变异数据，显示在相关心肺功能研究方面，良导络仪或许足以反映出较心率变异更为细微的交感神经系统变化。

关键词：良导络；皮电反应；心率；针刺穴位

《中西医结合学报》增设“研究方案”栏目

《中西医结合学报》开设了一个新的栏目——研究方案（Study Protocol），欢迎广大作者及读者踊跃投稿。

“研究方案（Study Protocol）”栏目主要发表已注册的临床试验的研究方案。发表临床试验的研究方案将使研究者的研究方案通过同行评议获得有价值的反馈；使读者能够将研究的最初计划与实际完成情况进行比较，从而避免发生“挑选数据”和事后修正研究目的的做法；使试验资助者及研究者知晓何种类型的试验正在进行以避免重复试验；使系统综述的作者方便获取正在进行的试验研究的资料，在一定程度上减少发表偏倚；使患者了解正在进行的试验以决定他们是否主动成为受试者。综上所述，发表临床试验的研究方案将有助于提高医学研究的水平。

在本刊发表的研究方案将是一篇可被全文引用的开放获取文章，同时还将被收录于 PubMed。本刊所接收的研究方案可以是计划中的研究或者是正在进行中的研究。如果该研究已获得相关伦理委员会审查通过并由较大规模的基金支持，则通常这类研究方案不再需要同行评议；而没有基金支持或未通过伦理审查的研究方案将需要通过同行评议才能考虑被本刊录用。作者在投稿时应该提供伦理审查和基金资助情况的证明。

随机对照试验的研究方案应遵照 CONSORT 声明的要求，并要在摘要的最后一行提供临床试验注册号。CONSORT 声明的中、英文版均可在 CONSORT 网站（http://www.consort-statement.org/）下载，其中文版也可在《中西医结合学报》网站（http://www.jcimjournal.com）下载。

在本刊发表研究方案的作者并非一定要将其后期的研究结果投稿给本刊，但本刊将十分欢迎这些后续投稿。

研究方案应提供该研究设计的假设、主要论据及方法学。研究方案的撰写应分为以下几个部分：(1)文题页；(2)结构式摘要，分背景（Background）、方法和设计（Methods and Design）、讨论（Discussion）、临床试验注册（Trial Registration）4 个部分；(3)关键词；(4)正文；(5)参考文献；(6)图表，必须有试验流程图，也可以有其他图表（附图注、表注）；(7)其他资料（如有）。

研究方案中正文的写作可以分以下几个部分：(1)背景（Background），可以包括研究背景、研究意义或前期研究（Pilot Study）、研究目的（Aims）和假设（Hypotheses）等；(2)方法（Methods），根据试验的实际情况可以包括研究设计（Study Design）、受试者（Participants）、人口学特征（Demographic Characteristics）、样本量计算（Sample Size）、纳入标准（Inclusion Criteria）、排除标准（Exclusion Criteria）、干预措施（Study Interventions）、试验场所（Settings）、随机分配方法（Randomization and Allocation）、盲法（Blinding）、知情同意（Informed Consent）、伦理委员会审查（Ethics Review）、主要结局指标（Primary Outcome Measures）、次要结局指标（Secondary Outcome Measures）、不良反应（Adverse Events）、随访（Follow-up）、数据管理和质量控制（Data Management and Quality Assurance）、统计学方法（Statistical Methods）等内容；(3)讨论（Discussion）；(4)利益冲突（Competing Interests）、作者贡献（Authors' Contributions）、致谢（Acknowledgements）及基金资助（Funding Source）等。

您的“研究方案”稿件可以用中文撰写并发表，但我们极力建议您用英文撰写并发表您的“Study Protocol”，以便让更多的国际同行知晓您的研究工作。

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