

Heart rate and heart rate variability responses to Tai Chi and jogging in Beijing and Graz

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Abstract

Background: Tai Chi is a famous training method in China, and jogging is a popular kind of exercise both in Austria and China. Nevertheless, there is little information concerning online monitoring of biosignals during both training activities in parallel. Within the last years innovative scientific monitoring tools for evaluating features of neurocardial fitness have been developed. **Aims:** The goal of this study was to demonstrate heart rate and heart rate variability analysis for the first time during Tai Chi and jogging. **Volunteers and Methods:** Continuous electrocardiographic monitoring over a period of 75 minutes was performed simultaneously in two healthy volunteers using the same type of equipment (medilog AR12 systems). Two healthy persons (both male, 49 years and 52 years, respectively), both hobby sportsmen, were monitored continuously during two resting periods before and after active sport and also during Tai Chi and jogging, respectively. **Results:** Data acquisition was performed without any technical problems in both subjects. Poincaré plots of sequential R-R intervals (beat to beat variability) show two ellipses of different shape and magnitude. During resting periods blood pressure effects can be clearly seen in one subject (jogging). The same effects, however reduced, are obvious in the other volunteer during Tai Chi. **Conclusions:** The present investigations during Tai Chi and jogging highlight the potential value of heart rate and heart rate variability monitoring even under difficult conditions. The innovative kind of analysis helps to show how well the human body reacts to sport, stress and recovery.

Keywords: Heart rate, heart rate variability, autonomic nervous system, Tai Chi, jogging, exercise.

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Introduction

Tai Chi is a traditional Chinese conditioning exercise which is performed by many people in the Eastern world. It is based mainly on slow movements, controlled breathing, and mental concentration [1]. The minimal exercise program contains between 24 and 50 different movements, the prolonged one up to 108 different kinds of movements. One exercise has a duration of about 40 minutes of active movement [2]. Tai Chi is performed alone, but the exercises are directed towards an imaginary partner, which is in contrast to Qi Gong. To each forward movement, a backward movement exists. Therefore the

slow movements resemble a fighter in slow motion (Fig. 1).

Jogging is a low to medium-intensity type of aerobic training performed by many people in the Western and Eastern world. It is one of the most popular kinds of exercise in Austria, and one does not need to explain the procedure in detail.

Both training methods yield good results regarding physical fitness and functional capacity improvement [1, 3].

At a Sino-Austrian scientific conference in Seefeld, Austria, the authors had a discussion that it is still not clear which of the two types of training leads to higher changes in heart rate (HR) and its variability (HRV), and which one is more efficient.

Thus, the aim of this preliminary pilot study was to investigate the influence of Tai Chi and jogging on HR and HRV for the first time in the two healthy volunteers under standard conditions in Beijing (WZ) and Graz (GL) respectively. The same type of monitoring equipment was used in both persons in China and Austria.



Fig. 1 Tai Chi. Training session of one of the authors (WZ) in Seefeld, Austria, in September 2010.

Materials and Methods

Heart rate and heart rate variability monitoring

Two identical HRV medilog® AR12 (Huntleigh Healthcare, Cardiff, UK, and Leupamed GmbH, Graz, Austria) systems were used for cardiac monitoring. The sampling rates of the recorders are 4096 samples per second. Therefore R-waves can be detected extremely accurately. All raw data are stored digitally on special memory cards. After removing the cards from the portable systems, the data can be read by an appropriate card reader connected with a standard computer. The dimensions of the used HRV recorder are 70 x 100 x 22 millimeters, the weight is about 95 grams with batteries [4].

Heart rate and heart rate variability data analysis

HRV is measured as the percentage change in sequential chamber complexes, so-called RR-intervals, in the ECG. The registration of HRV is performed using three electrodes on the chest. The RR-intervals in the ECG are controlled by the blood pressure control system, influenced by the hypothalamus and in particular controlled by the vagal cardiovascular center in the lower brainstem. Therefore in the clinical environment it is important to simultaneously record respiration and if possible continuous blood pressure. HRV can be quantified over time using registration of percentage changes in RR-intervals in the time domain as well as the changes in the frequency range by analysis of electrocardiographic power spectra. Parameters are

recommended by the task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [5]. Calculation of ECG power spectra is thought to provide an understanding of the effects of sympathetic and parasympathetic systems on HRV. Early work pointed out a few bands in the spectrum of HRV that could be interpreted as markers of physiological relevance. Associated mechanisms are thermoregulation which can be found in the very low frequency band, blood pressure and respiratory effects.

With the new software the HRV is analyzed and displayed in a new way to help judge the function of the autonomic nervous system [4]. Viewing this innovative kind of analysis helps to show how well the human body reacts to sport, stress and recovery [4].

Healthy volunteers

The investigations were performed with the two first authors (WZ: male, 49 years, 171 cm, 72 kg; and GL: male, 52 years, 173 cm, 75 kg), both in good physical shape, but not elite athletes. WZ has been performing Tai Chi in China for more than 20 years, almost every day for 40 minutes. GL has been jogging at least three times a week in Austria also for more than 20 years. Both subjects were free of neurological or cardiovascular disorders and were not taking any medication. The registration of the non-invasive parameters was in accordance with the Declaration of Helsinki of the World Medical Association.

Procedure

The study design used in both volunteers included the following steps: three 'Skintact Premier F-55' ECG-electrodes (Leonhard Lang GmbH, Innsbruck, Austria) were fixed on the chest. The study consisted of two resting periods (10 minutes before and about 10 minutes after exercise) and an active sport period (Tai Chi 40 minutes, jogging 50 minutes).

Results

Heart rate monitoring

Data acquisition was performed without any technical problems. The authors were able to capture data under difficult conditions (motion artefacts during Tai Chi and jogging).

The HR data from the Tai Chi session in Beijing (WZ, 49 years) over a period of about 75 minutes are shown in Figure 2a (upper panel). Both recording sessions began with a resting period (00:00) of stretching and relaxing. There are some artefacts during this period in the Tai Chi recording caused by movements of the thorax. The mean HR during this period was 94/min in the Tai Chi practitioner (Fig. 2a) and 67/min in the jogging subject (Fig. 2b). After ten minutes the training started. The mean HR increased significantly in both subjects (green line at 00:15; WZ: 121/min, GL: 146/min). Between 00:40 and 01:00 the maximum HR change took place (WZ: 132/min; GL: 150/min). The last part of the recording session shows again a resting period similar to those at the beginning.

After about 75 minutes, the recording sessions were finished in both participants.

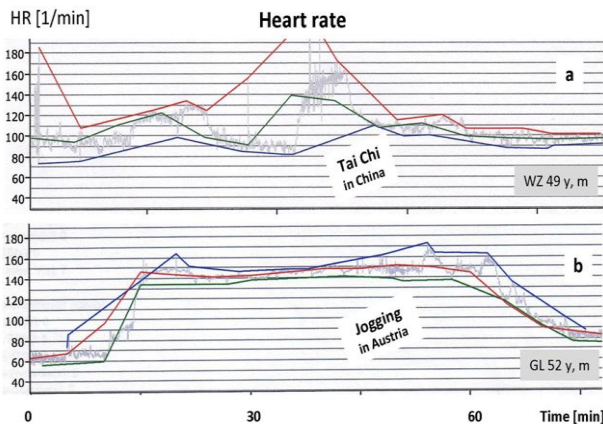


Fig. 2 Heart rate. The trend of the HR is shown in beats per minute (green: mean HR, red: max HR, blue: min HR) in the healthy volunteer performing Tai Chi (a) and the other subject during jogging (b).

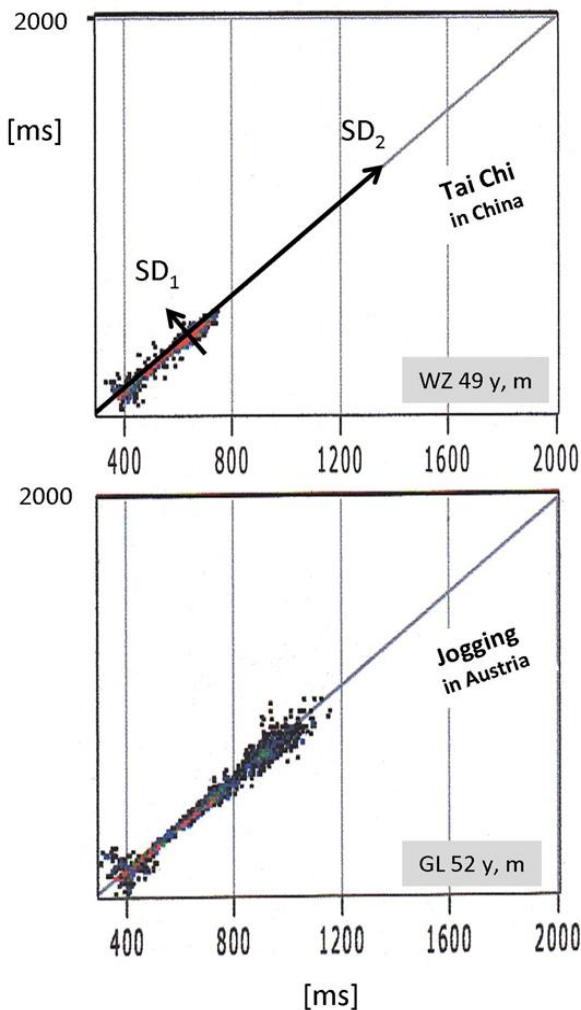


Fig. 3 Quantitative beat-to-beat analysis of RR-intervals (Poincaré plot). The results of the Tai Chi participant (a: WZ, 49 years) are directly comparable to those of the jogging participant (b: GL, 52 years). Note the different shapes of the ellipses resulting in a different total heart rate variability over the whole

measurement period.

Frequency [Hz]

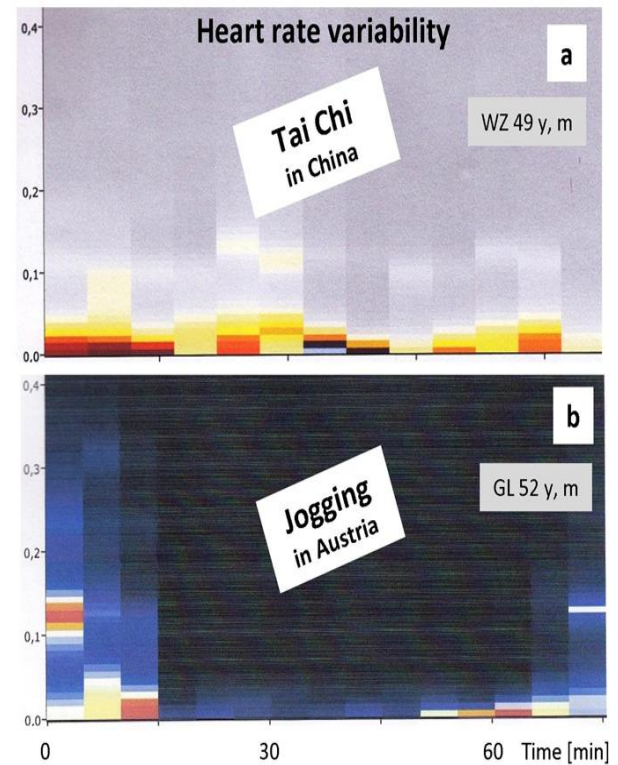


Fig. 4 ‘Fire of Life’ power frequency analyses. Heart rate variability (HRV) data (about 75 minutes) of the two participants are shown.

Heart rate variability-scatterplots

Figure 3 shows two Poincaré scattergrams, a technique taken from non-linear dynamics, in which each RR-interval is plotted as a function of the previous RR-interval. These graphical representations of cardiovascular dynamics normally result in elliptical types of shape. The ellipse is fitted onto the so-called ‘line of identity’. Standard deviation of the points perpendicular to the line of identity, denoted by SD_1 , describes short term RR variability due to the respiratory component of HRV. The standard deviation along the line of identity, denoted by SD_2 , describes long-term variability [6]. In Figure 3 (a and b) the two different persons produced two ellipses of different shape and magnitude. The jogging subject (Fig. 3b) showed a higher HRV associated with an a little bit bigger ellipse. The other subject performing Tai Chi (Fig. 3a) produced a slightly reduced ellipse in which the RR points gravitate around the mean RR and the line of identity.

Heart rate variability – frequency domain

The results of the frequency analysis of HRV of both subjects are shown in Fig. 4.

At the beginning of the recording (first resting period) only a very small influence of respiratory sinus arrhythmia (frequency range 0.35 – 0.40 Hz) is recognizable in the volunteer from Graz (Fig. 4b; left side). In addition, the

influence of blood pressure waves (frequency ~ 0.12 Hz) can be clearly observed. The frequency range < 0.05 Hz may also contain slowly changing effects from the renin angiotensin system and temperature regulation, however the time of registration is too short for analysis (5 minute intervals). During the active period (jogging) the blood pressure effects (~ 0.12 Hz) disappeared. After jogging, during the second resting period (Fig. 4b, right side) the blood pressure component of HRV analysis is prominent again. The same effects on the influence of blood pressure, however markedly reduced in the resting periods, are shown in Fig. 4a in the Tai Chi volunteer. However, in general a much higher influence can be seen in the Tai Chi subject. Not only total variability, but also specific frequency component increases (e.g. blood pressure influence) are noticeable during Tai Chi. The so-called 'Fire of Life' burns much brighter during Tai Chi than during continuous jogging which can be seen in Fig. 4 at the first glance.

Discussion

HR and HRV have been investigated in normal subjects of various age groups [7, 8] and also in different cardiovascular diseases such as acute myocardial infarction, congestive heart failure, arterial hypertension, diabetes mellitus and different autonomic dysfunctions [5]. Beside HRV power spectral analysis the so-called 'Fire of Life'TM analysis (Huntleigh Health Care, Cardiff, UK) is a totally new method of visualization of HRV, which has been described in very few scientific publications [4, 9, 10] by our research group.

Tai Chi, which is a traditional Chinese exercise, has been receiving attention also in scientific literature. The main features of Tai Chi are its flowing movements including loosening up, relaxing, and practising meditation with slow abdominal respiration [11]. Tai Chi is often taken as part of health-promotion activities or rehabilitation training, and significant mental and physical effects have been reported [12-19].

At this moment (December 2010), 670 scientific articles concerning 'Tai Chi' and 1325 papers concerning 'jogging' can be found in pubmed (www.pubmed.gov). In a recently (2010) published research article [12] the authors systematically reviewed the effects of Tai Chi on stress, anxiety, depression and mood disturbances in Eastern and Western population. Eight English and three Chinese databases were searched, and forty studies with a total of 3,817 investigated subjects were found. The authors found that Tai Chi appears to be associated with improvements in psychological well-being including reduced stress, anxiety, depression and mood disturbance, and increased self-esteem.

In our study, two persons were exemplarily investigated. The two first authors and study participants are from two different continents, and each of them performed his preferred training trial. Both are of similar age. It is interesting that even with the slow movements of the Tai

Chi training, similar maximum heart rates appeared compared to jogging. The subjects are of similar age and in a similar state of training, however the methods (Tai Chi and jogging) are completely different.

Relatively few studies have investigated the effects of exercise on HRV measures. Decreases in time and frequency domain variables are seen from rest to exercise [20, 21]. The changes in HRV indices, however, are inconsistent when exercise intensity increases and after recovery, as also our results from the Tai Chi and jogging training show.

In summary, the present pilot study of HR and HRV analysis during Tai Chi in China and jogging in Austria demonstrates a new method for the quantification of HR and HRV parameters ('Fire of Life' analysis). It shows very clearly exercise-related differences. Innovative research including artificial intelligence techniques is needed to detect subjects at risk of cardiovascular disease, so that appropriate training is possible.

Conclusion

Tai Chi and jogging exercises are both recommended to improve health in Asia and Europe, respectively. Which exercise modality offers the best results is still unclear and cannot be quantified by heart rate and its variability alone. Maybe a combination of both could yield the best results for the state of health.

Acknowledgement

Both WZ and GL carried out the data collection. GL performed the design, analysis and coordination of the scientific work and drafted the manuscript. TH was responsible for data management and transfer in China. LW organized the measurements and data analysis. All authors read and approved the final manuscript. Conflict of interest disclosures: none. The authors would like to thank Ms. Ingrid Gaischek, MSc, for her valuable support in creating figures and preparing the manuscript. The results will be presented partly at the 25th International Congress for Sports Medicine in Seefeld/Tyrol, Austria, on February 22nd, 2011. The investigations were supported by the Jubiläumsfonds of the Oesterreichische National Bank (OeNB; project 13463), the Federal Ministries of Health and of Science and Research and Eurasia Pacific Uninet (project 'Bioengineering and clinical assessment of acupuncture – a Sino-Austrian research pilot study'), and were performed within the areas 'Sustainable Health Research' and 'Neuroscience' at the Medical University of Graz.

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