

INFLUENCE OF CARLSBAD THERMO-MINERAL WATER ON THE AUTONOMIC NERVOUS SYSTEM

Petr KOLISKO, Milada SÁROVÁ, Michele OLIVIANO, Jakub KREJČÍ, Petr UHLÍŘ

Abstract

The drinking cure is an essential part of Karlovy Vary spa treatment. The effect of Karlovy Vary mineral water on the autonomic nervous system has not yet been investigated. Based on case analyses, we hypothesized that the effects of the drinking cure have an effect on the functional activity of the autonomic nervous system. The prospective research study had the character of an experiment in clinical conditions.

Research file: Health women n = 15, age 40-50 years.

Methodology: Before and 30 min after the experimental sequence, the functional state of the autonomic nervous system was examined by the method of spectral analysis of heart rate variability in the ortho-clino-orthostatic position.

The experimental sequence:

- *rest sitting position (pre)*
- *drinking cure in a sitting position (application of 350 ml thermo-mineral water 50 °C)*
- *rest sitting position (post).*

The length of all monitored intervals was 300 heartbeats.

Results:

Pre-post status (30–50 minutes after the application of the drinking cure):

- *an increase in the overall activity of the autonomic nervous system*
- *an increase in activity in the sympathetic and parasympathetic frequency bands*
- *reducing the heart rate*
- *blood pressure values did not change.*

Effects during the application of the drinking cure (comparison with a rest sitting position):

- *a decrease in the overall activity of the autonomic nervous system*
- *an increase in sympathetic activity and decrease in parasympathetic activity*
- *an increase in heart rate*
- *an increase in systolic and diastolic blood pressure.*

Conclusions:

- *A prospective research study highlighted the reflexive relationships between the digestive system and the cardiovascular system. These relationships are modulated by the autonomic nervous system.*
- *Factors that influence the effect of the drinking cure in the area of the upper part of the digestive system are: the rhythm of swallowing and the temperature of the water.*
- *Factors that influence the post-effect of the drinking cure in the area of the duodenum and jejunum they probably are: high content of free carbon dioxide and bicarbonate ions in the Carls Bad thermomineral water. These factors apparently activate the motility of the intestinal tract and have an effect on systemic changes of the functional status of the autonomic nervous system.*

Keywords

Thermomineral Carls Bad water, drinking cure, spectral analyzes of heart rate variability, autonomic nervous system, gastrointestinal system.

1. INTRODUCTION

The drinking cure is an essential part of Karlovy Vary spa treatment. The effects of the Karlovy Vary thermo-mineral water are described by a number of authors (Benda, 1997; Třískala et Jandová 2019; etc.).

The effect of Karlovy Vary mineral water on the autonomic nervous system has not yet been investigated. Based on case analyses, we hypothesized that the effects of the drinking cure have an effect on the functional activity of the autonomic nervous system.

2. RESEARCH QUESTIONS

- Will there be a significant increase in the total functional activity of the autonomic nervous system (Total Power) in the interval of 30-50 minutes after the application of the drinking cure with Karlovy Vary thermo-mineral water?
- How will these changes affect the sympathetic (Spectral Power LF) and parasympathetic (Spectral Power HF) activity?
- Will there be changes in systolic and diastolic blood pressure and heart rate in the interval of 30-50 minutes after the application of drinking cure?
- Will there be changes in the total spectral power (Total Power), during the application of the drinking cure in M2T2 interval?
- Will there be changes in sympathetic (Power LF) and parasympathetic activity (Power HF) and changes in the sympathetic-vagal balance (Ratio LF/HF), during the application of the drinking treatment in M2T2 interval?
- Will there be changes in systolic and diastolic blood pressure and heart rate during the drinking course in the M2T2 interval?

3. METHODOLOGY

The prospective research study had the character of an experiment in clinical conditions.

Research file:

Healthy women, age 40-50 years, n = 15. The test subjects met the pre-determined criteria for the examination (good health, no medication or nutritional supplements, non-smokers, examination in the morning on an empty stomach, 24 hours before examination only light physical load only, etc.).

The length of individual T intervals in individual measurements M1, M2, M3 was 300 heartbeats

During the measurement, the following physiological parameters were monitored:

- the functional status of autonomic regulation of heart activity by the method of spectral analysis of heart rate variability
- blood pressure values (were monitored repeatedly 4x during each interval)
- respiratory frequency values (frequency/min.) were monitored during the entire experiment
- peripheral oxygen saturation was measured with a digital oximeter on the 2nd finger of the hand

3.1. Examination methodology

- Measurement M1- status pre. Intervals: (T1 clinostasis – T2 orthostasis – T3 2.nd clinostasis).
- Measurement M2 - status during the drinking cure. Intervals: (T1 the sitting position pre – T2 drinking cure – T3 the sitting position after. During the drinking cure (interval T2) 350 ml of termomineral water was applied, temperature 50° C).
- Measurement M3 - status after (M3 was started 30 min after the end of M2).

M3 measurement. was identical to the M1 measurement.

3.2. Instrumentation: diagnostic system Sima Media TF7; digital, calibrated Omron tonometer.

The Sima media TF7 diagnostic system enables the recording of R-R intervals and ECG in lead V5 during the measurement. Length of each measured interval (T) = 300 beats. The software of the system enables the conversion of data into numerical form in the frequency range of 0.02 – 0.5 Hz using a fast Fourier transformation and analyzes the activity of frequency bands of Very Low Frequency - VLF (0.02 – 0.05 Hz), Low frequency - LF (0.051 Hz – 0.15 Hz) and High Frequency - HF (0.151 – 0.5 Hz), which provide information on sympathetic activity (LF frequency band) and parasympathetic activity (HF frequency band). A prerequisite for the correct interpretation of results the SAHRV parameters in the LF and HF frequency bands is a spontaneous respiratory frequency > 9 respiratory cycles/min. (Kolisko, Jandová, Salinger et al, 2004; Salinger, Štěpaník, Kolisko et al, 2005).

The result of the spectral analysis of heart rate variability is a graphic and numerical log.

3.3. Variables

Manipulated independent variables throughout the experiment

- Body positions (clinostasis, ortostasis, sitting position)
- Drinking cure, interval M2T2: (350 ml. of thermo mineral water, temperature 50°C)

Observed dependent variables during the experiment (parameters of SAHRV, heart rate, blood pressure).

- Total spectral power/ms² (Total Power) in the frequency band 0.02 – 0.5 Hz.
- Spectral power of the low

frequency (Power LF/ms²) in the frequency band 0.051 – 0.15 Hz. (Sympathetic activity)

- Spectral power of the High frequency (Power HF/ms²) the frequency band 0.151 – 0.5 Hz. (Parasympathetic activity).
- Ratio LF/HF (Ratio LF/HF) – indicator of sympathovagal balance (SV Balance)
- Relative values of LF and HF. Spectral power in %, from Total Power, which express functional changes of sympathetic and vagal activity.
- Average values of the heart rate (SF/min.) in each of the measured intervals (T).
- Average values of systolic and diastolic blood pressure from 4x repeated measurements in each measured intervals(T) of the measurement M1, M2, M3.

3.4. Statistical methods used

- Fast Fourier transformation of SAHRV data into numerical form and transfer of results to Excel for statistical processing.
- The absolute values of the spectral powers (Total spectral power, spectral power VLF, LF, HF) were logarithmized.
- After analyzing the normality of data distribution, the following statistical methods were used: ANOVA, Fischer's LSD test, Kolmogor-Smirnov test, Cohen's d, to estimation of the statistical significancy. .
- As statistically significant changes, we considered changes at the statistical significance level $p < 0.050$ with the current size Cohen's $d \geq 0.50$. The measurement results were processed in the form of graphs and tables.

For the interpretation of the data – status pre (M1 measurement) and after (M3

measurement) we present in this article only the changes of monitored variables during the 2nd clinostasis (T3 interval) after orthostasis (T2 interval) during the spontaneous breathing.

Note: interval T3 (2nd clinostatic position after orthostasis) has a higher validity than interval T1 (1st clinostatic position before orthostasis).

During the drinking cure (M2 measurement): intervals M2 T1 (sitting position before); M2T2 (application of mineral water); M2T3 (sitting position post), we describe the changes of variables in all intervals.

4. RESULTS AND DISCUSSION

To simplify data interpretation, we present in tables the results with statistically significant changes * ($p < 0.050$, Cohen's $d \geq 0.50$ *) and trends (+) in selected intervals (T) in individual measurements during the experiment.

1. Comparison status before: (M1 measurement) and status after: (M3 measurement).
2. The results during the drinking cure (M2 measurement).

The monitored parameters during the measurements:

- Power LF ms^2 ; Relative Power LF % (sympathetic activity).
- Power HF ms^2 , Relative Power HF % (parasympathetic - vagus activity).
- Ratio LF/HF (sympathetic-vagal balance);
- Total Power ms^2 (total activity of the autonomic nervous system).
- Heart rate/min. (HR/min).
- Systolic, Diastolic blood pressure (BP/mm Hg).
- Frequency of the respiration (Breath/min.)

4.1. Status pre – status after (measurement M1 : M3)

Table 1: Changes of monitored SAHRV parameters characterizing functional changes of the autonomic nervous system. Supine position: status pre (M1T3 interval), status after (M3T3 interval).

Interval M1T3 pre : M3T3 after Women, age 40 - 50		
Parameter	Stat. sign.	Trend
Total Spect. Power (ms^2)	*	↑
Spect. Power VLF (ms^2)	*	↑
Spect. Power LF (ms^2)	*	↑
Spect. Power HF (ms^2)	+	↗
Ratio LF/HF (SV balance)	-	-
Relative Power VLF %	-	-
Relative Power LF %	-	-
Relative Power HF %	+	↗
HR/min	*	↓
TK Systol. (mm Hg)	-	-
TK Diastol. (mm Hg)	-	-
Breath/min	*	↓

Note: status pre – after drinking cure: M1 : M3 measurement. Beginning of the M3 measurement 30 min. after application of the drinking cure.

Comment on the results (table 1)

Comparison of M1T3 : M3T3 (Interval T3 – supine position).

In the M3T3 interval we found the following functional changes of autonomic regulation cardiac activity:

- A significant increase the total spectral power (Total Power/ ms^2). (Table 1) – See research question 2.1
- A significant increase of the spectral power (ms^2) in the VLF, LF frequency bands and a significant trend of Power HF (ms^2) increase. (Table 1). – Research question 2.2

These functional changes are related to an increase in overall ANS activity (sympathetic and parasympathetic activity). Terminal receptors of the right vagosympathetic in the area of the sinoatrial node and the right atrium have a influence to the conduction system of the heart and thus affect changes in heart rate variability. (Ganong, 1997; Silbernagel, Lang 2012, Šlejfa et al, 2007; Vojáček, Kettner 2017)

- The sympathovagal balance (Ratio LF/HF) does not change significantly.
- The ratio of relative spectral powers (Relative spectral power VLF, LF, HF in %) do not change (Table 1). See research question 2.2

This result is related to a proportional increase in the overall tone of the neurovegetative system and a reflexive relationship of reactivity between sympathetic and vagal activity. (Increasing parasympathetic activity slightly increases sympathetic activity and vice versa). (Ganong, 1997; Silbernagel and Despopoulos, 1993)

- Heart rate is significantly reduced (Table 1). – See research question 2.3.

The decrease in heart rate is apparently not directly related only to higher activity of the right vagus. (Relative Power HF and Ratio LF/HF - symphato/vagal balance do not change). The slowing of conduction through the conduction system of the heart is apparently modulated by other regulatory mechanisms as well. (Modulation of the atrioventricular node by the vagus, periodic changes in cardiac blood volume modulated by breathing, other intracardiac regulatory mechanisms (Ganong, 1997, Šlejfa et al, 2007; Vojáček, Kettner 2017). It is very likely that the sympatho-medullary system is not activated after a drinking cure.

- The values of systolic and diastolic blood pressure before - after do not change significantly. – See research question 2.3

Apparently, after the drinking cure, there is no higher activation of baroreflexes or activation of the renin-angiotensin system in the supine position.

The chemical composition of the thermal mineral water in Karlovy Vary significantly increases the motility of the intestinal tract in the area of the duodenum and jejunum. In addition to the intestinal nervous system, long autonomic reflex arcs are activated (viscerosensitive receptors of the jejunum - CNS - visceromotor pathways of sympathetic and parasympathetic nerves). (Sleisenger & Foldtrans Eds., 2006; Trojan 2003). The result is an increase in the activity of the autonomic nervous system.

A reflex increase in the activity of the autonomic nervous system after a drinking cure has a systemic character. These functional changes of the autonomic nervous system are very likely to affect other internal organs and glands innervated by the sympathetic and parasympathetic nervous system.

High content of free carbon dioxide and bicarbonate ions in the thermo-mineral Karlovy Vary water is likely to be the triggering factor for the increased motility of the duodenum and jejunum.

4.2. Status during the drinking cure (measurement M2)

Table 2 Changes of monitored parameters during the drinking cure M2 measurement (in a seated position). T1 interval- status pre, T2 interval - drinking cure.

M2T1 pre : M2T2 drinking cure		
Parameter	Stat.sign.	Trend
Total Spect. Power	*	↓
Spect. Power VLF	*	↓
Spect. Power LF	*	↑
Spect. Power HF	+	↓
Ratio LF/HF	*	↑ LF
Relative Power VLF	-	↓
Relative Power LF	*	↑
Relative Power HF	-	↓
HR/min	*	↑
TK Systol.	*	↑
TK Diastol.	*	↑
Breath/min	*	↓

Table 3 Changes of monitored parameters during the drinking cure M2 measurement (in a seated position): T1 interval- status pre, T3 interval after drinking cure.

M2T1 pre : M2T3 after drinking cure		
Parametr	Stat. sign.	Trend
Total Spect. Power	*	↑
Spect. Power VLF	*	↑
Spect. Power LF	-	-
Spect. Power HF	-	-
Ratio LF/HF	-	-
Relative Power VLF	-	↑
Relative Power LF	-	-
Relative Power HF	-	-
HR/min	*	↓
TK Systol.	-	-
TK Diastol.	-	-
Breath/min	-	-

**Comment on the results (table 2, 3).
Effect of the drinking cure.**

Comparison of changes in M2 measurement: M2T1 (seated position pre); M2T2 (drinking cure in a sitting position); M2T3 (sitting position after drinking cure).

- During the drinking cure (interval M2T2), there is a significant increase in the activity of the sympathoadrenal system. There is a increase of the Spectral Power LF (ms^2), Relative Spectral Power LF, Ratio LF/HF). (Table 2, 3). – Research question 2.5

- Increased activity of the sympatho-adrenal system is manifested in M2T2 interval by an increase in heart rate, systolic and diastolic blood pressure. (Table 2, 3) – Research question 2.6

The swallowing reflex and the temperature of the water apparently activate mechano- and thermoreceptors in the pharynx and upper part of the esophagus. This activates efferent sympathoadrenal activity.

The overall activity of the sympathetic nervous system during the drinking course prevails over the activity of the vagus, during the passage of mineral water through the cardia into the stomach. (Sleisenger & Foldtrans Eds., 2006).

- After the end of the drinking cure, the monitored parameters return to the initial level before the application of the drinking cure.

Rapid functional changes in the sympathovagal balance are apparently related to the overall sensitivity of the autonomic system of healthy persons.

Changes in sympatheticvagal balance, heart rate and blood pressure during the M2 measurement confirm the existence of reflex relationships between the swallowing reflex,- the reactivity of the autonomic nervous system - and the regulation of the cardiovascular system. (Sleisenger & Foldtrans Eds., 2006).

The origin and relationship of increased activity in the VLF frequency band (0.02 - 0.05 Hz) to sympathetic activity during the measurement M2 (interval T1 before - T2 during and T3 after the drinking cure) is unclear. It can probably be a manifestation of increased thermoregulatory activity of blood vessels after drinking thermo-mineral water.

CONCLUSIONS

- A prospective research study drew attention to the existence of reflexive relationships between the digestive and cardiovascular systems. These relationships are modulated by reflex changes in sympathetic and parasympathetic activity.
- Factors influencing the effect of the drinking cure in the area of the upper part of the digestive system are: the rhythm of swallowing and the temperature of the water.
- Factors that influence the post-effect of the drinking cure in the area of the duodenum and jejunum they probably are: high content of free carbon dioxide and bicarbonate ions in the Karlovy Vary thermomineral water. These factors apparently activate the motility of the intestinal tract and have an effect on systemic changes of the functional status of the autonomic nervous system.

6. REFERENCES

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Attachment

Case analysis:

Healthy women 42 years.

Graphical protocols of Spectral Analysis of Heart Rate Variability (SAHRV). Measurement M1, M2, M3.

Figure 1 State before drinking cure: (measurement M1) T1 – clinostasis, T2 – ortostasis; T3 – 2.nd clinostasis; T4 – 3.th clinostasis (rhythmic breathing 12 cycles/min)

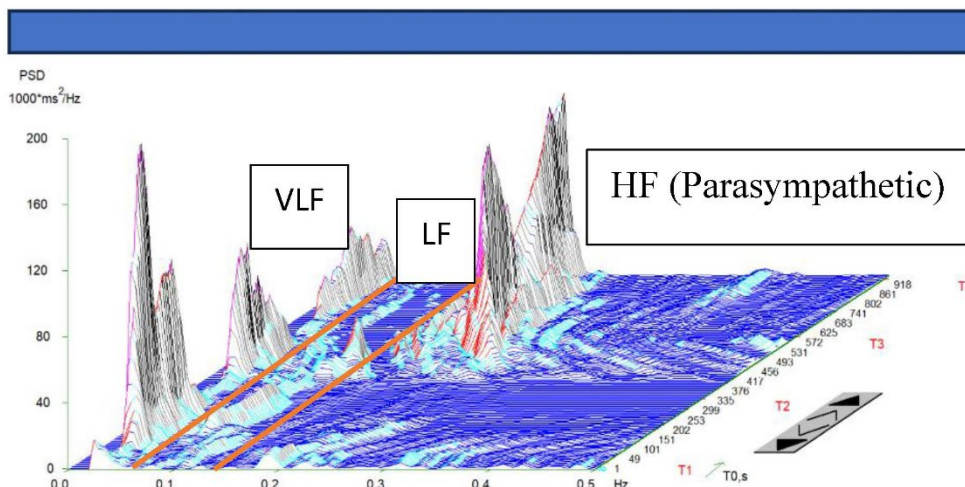


Figure 2 State during the drinking cure: measurement M2 (sitting position):
T1 – before drinking cure; T2 – drinking cure; T3 – after drinking cure

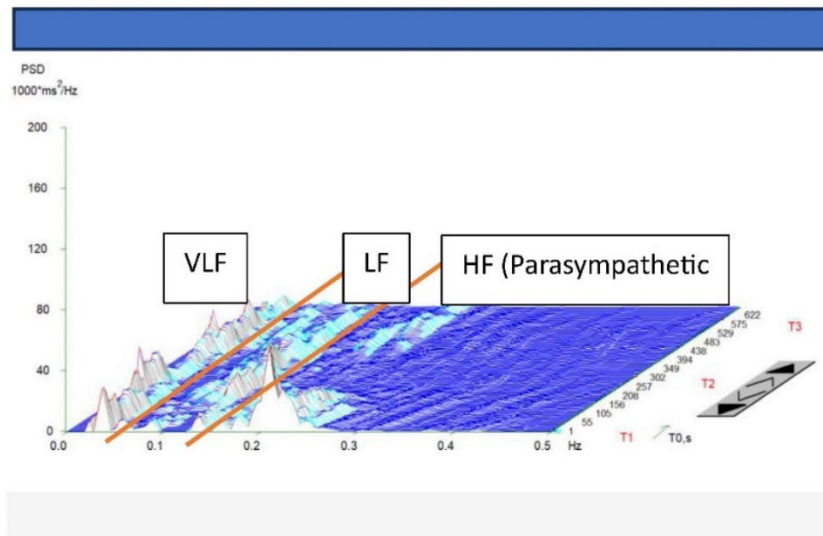
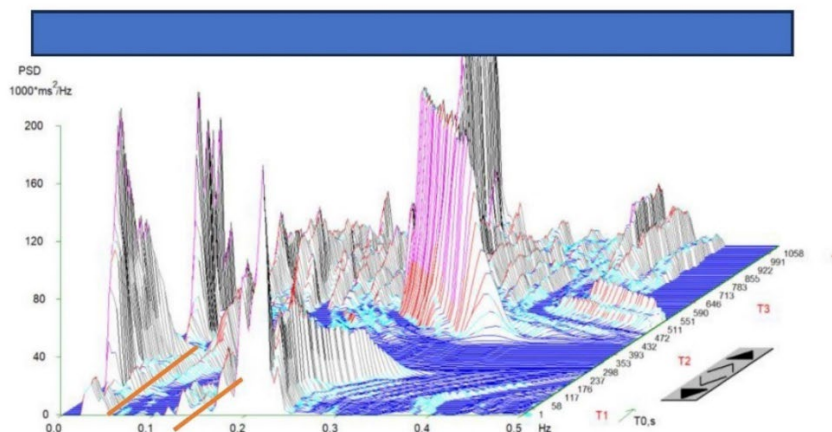


Figure 3 State 30 - 50 minutes after drinking cure (measurement M3):
T1 – clinostasis; T2 – ortostasis; T3 – 2.nd clinostasis; T4 3.th clinostasis (rhythmic breathing 12 cycles/min)



CONTACT

doc. PaedDr. Petr Kolisko, Ph.O

Palestra College of Physical Education and Sports, Prague;
Balneological clinic, Hotel Prezident, Karlovy Vary.
Karlovy Vary - Bohatice Sluneční 21

e-mail: petr.kolisko@seznam.cz

Milada Sárová

Balneology clinic, Hotel Prezident, Carls Bad

Michele Oliviano

Aquaenviro Brno

Jakub Krejčí

Faculty of Physical Culture, Palacky University Olomouc