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BIOPSYCHOSOCIAL WELLBEING AND ITS RELATIONSHIP WITH GEOMAGNETIC FIELD FLUCTUATIONS IN LITHUANIA

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LIETUVOS SVEIKATOS MOKSLŲ UNIVERSITETAS

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BIOPSICHOSOCIALINĖ GEROVĖ IR JOS RYŠYS SU GEOMAGNETINIO LAUKO SVYRAVIMAIS LIETUVOJE

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ABBREVIATIONS

ANS	–	autonomic nervous system
GMA	–	geomagnetic activity
GMF	–	geomagnetic field
HRV	–	heart rate variability
SR	–	Schumann resonances
WHO	–	World Health Organization

DEFINITIONS OF MAIN TERMS

Biopsychosocial wellbeing – a systematic approach to health, perceiving it as being influenced by biological, psychological, and social factors and their complex interactions. While traditional biomedical fields in medicine focus on pathophysiology and other biological aspects of disease, the biopsychosocial approach emphasizes the importance of understanding human health and illness at a broader level, covering full context of everyday phenomena that an individual faces.

Geomagnetic activity – phenomenon comprising several geophysical processes. Solar wind is a stream of energetically charged particles emanating from the Sun, and the geomagnetic field protects the Earth by deflecting most of the charged particles. Geomagnetic field changes over time and extends from the Earth's inner core to where it meets the solar wind. The solar wind is responsible for the Earth's overall magnetosphere (the sphere protecting the Earth). Fluctuations in its speed, density, direction, and other features strongly affect the Earth's local space environment and technological, biological and ecological systems on the Earth [123, 133, 184]. In this work, the term geomagnetic activity will be used to address fluctuations in the geomagnetic field.

Health – Health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or disability [72].

Mental health – a state of wellbeing in which an individual realizes his or her own abilities, can cope with casual stresses of life, can work productively and is able to contribute to his or her community [83, 121]. The concept also covers a condition that promotes optimum physical, intellectual, emotional development of an individual, emotional and spiritual resilience, in which an individual can experience joy and tolerate pain, disappointment and sadness. Overall, it is a positive feeling of kindness, which acts as a ground for believing in your own and others' dignity and value.

Schumann resonances – low frequency electromagnetic fluctuations, which are closely related to human physiologic processes [28, 147].

Social wellbeing – a state that consists of the following five dimensions:

- Social acceptance (ability to accept others as they are);
- Social actualization (positive comfort level with society);
- Social contribution (a feeling that one has a contribution to make to the society he/she belongs to);
- Social coherence (understanding the social world as predictable and comprehensible);
- Social integration (feeling as a part of the community) [84].

Wellbeing – a multidimensional concept, comprising an individual's personal view and experience in such life areas as overall life satisfaction, work, health and other fields. It combines various different emotions – positive and negative – converting them into a general subjective feeling.

INTRODUCTION

Actuality of the research

Back in 60s, German physicist Winfried O. Schumann identified and started investigating the features of geomagnetic field (GMF) fluctuations that occur in the cavity between the surface of the Earth and the ionosphere. The resonances that have been identified are low frequency electromagnetic fluctuations which are closely related to human physiologic processes [28, 147]. Investigations of interactions between human and geophysical environment were started. Numerous studies have investigated the correlations between incidents of myocardial infarctions, high blood pressure, newborns' gender, monthly deaths, etc. and disturbances in GMF [107, 108, 165, 166].

It has become clear that interactions between geomagnetic activity (GMA) and our physiology are especially strong and that GMA can modulate electroencephalogram activity. This means that GMA can have a direct influence on our sympathetic and parasympathetic activity in our body. However, the lack of more specific and longitudinal studies makes it difficult to set a clearer understanding of geophysical environment impact on human health and, what is especially important, to propose possible methods of how geophysical parameters could be implemented in human health improvement.

Another important aspect in this field is to understand the differences between global and local GMF. There are quite a number of research studies about global GMA, but our local GMA in Lithuania was not possible to be measured due to lack of necessary devices. Because a GMA detecting device was installed in Lithuania in 2014, there are possibilities to obtain more accurate data and conduct studies linking GMA and live organisms' health in Lithuania. Lithuanian researchers have had this possibility since 2014, when HeartMath Institute (California, USA) financed and installed a sensitive magnetometer, detecting local GMA fluctuations. Due to this magnetometer, there is a possibility to perform various studies researching links between GMA and different biopsychosocial components (development and progression of non-communicable diseases, changes in the incidents of suicidal events, interrelationship quality and various processes, etc.).

This magnetometer became the fifth magnetometer among the global network of now six existing magnetometers worldwide. It will not only allow us to observe and assess local GMA processes that may be significant in Lithuanian population health context, but also to cooperate with researchers where the other five magnetometers are located (USA, Saudi Arabia, Canada, New Zealand, and South Africa). For effective data comparison at the global level, there is a consistent cooperation with scientists at the HeartMath

Institute, and other researchers and experts in Macedonia, Latvia, Saudi Arabia, and United Kingdom.

Also, the obtained results of the research allow scientists and future studies to pay more attention to the psychoemotional state of a person, rather than merely concentrating on physical health indicators and/or objective measurements of a health status.

Novelty of the research

Since 2014 when the aforementioned magnetometer was installed in the territory of Lithuania, a team of scientists and specialists capable of understanding and processing big capacity data was selected. Along with this, preparations began to conduct the study described in this dissertation. This study is the first research in Lithuania using the data from the magnetometer in Lithuania, and it is the first study examining the relationship between local GMA and health parameters among young adults in Lithuania. A collaborating team of mathematicians has developed new analysis methods, enabling us to examine various characteristics of GMA and their relationships with different health parameters.

Within the global context of studies in this field, our research employs not only objective, but also subjective health assessment methods, adding more significance to self-evaluated health indicators. Also, the research emphasizes a person's psychoemotional state and its significance in terms of one's sensitivity to geophysical environmental phenomena. Finally, to the best of our knowledge, this is the first study that incorporates psychological data in the context of physiological synchronization to other group members and with the Earth's magnetic field fluctuations.

Practical significance

A better understanding of the way GMA can influence human health parameters, especially deepening knowledge about the significance of Schumann resonances (SR) and its different frequencies and intensities, can help to better explain various health related phenomena (development of diseases, deaths, etc.), their causes and dynamics. Moreover, it can help to anticipate and forecast some of their progression, as well as to help plan and take preventive actions, in order to improve the population's health and prevent critical health impairments. Also, results of the research bring better understanding of how the emotional state of a person impacts his/her sensitivity to geophysical environmental disturbances, making it important to pay the society's attention to maintaining one's psychoemotional state in a more relaxed and harmonious condition.

Author's contribution

The author coordinated and implemented all stages of the dissertation preparation: prepared the dissertation plan; prepared all necessary documents for the Kaunas Regional Ethics Committee for Biomedical Investigations and obtained a permit to conduct the research; examined the health parameters of recruited participants of the study; performed the analysis of the gathered data and summarized the obtained results. The author published the results of the study in peer-reviewed scientific publications, referenced and indexed in database Thomson Reuters Web of Knowledge. Research findings have been presented in national and international scientific conferences and are also presented in this dissertation.

1. AIM AND OBJECTIVES

Aim – to determine the relationship between young adults' biopsychosocial wellbeing and local GMF fluctuations in Lithuania.

Objectives:

1. To evaluate local GMF fluctuations parameters in Lithuania;
2. To assess adults' biopsychosocial wellbeing and health parameters;
3. To estimate the associations between biopsychosocial wellbeing and health parameters and local GMF fluctuations in Lithuania.

2. LITERATURE REVIEW

Search for scientific literature was performed in Lithuanian and English languages in *Pubmed*, *Google Scholar*, Lithuanian university of health sciences electronic publication databases, also in researchers network Research Gate. The following keywords and additional words were used during the search: *psychophysiological health, biopsychosocial wellbeing, physical health, psychological health, psychological wellbeing, mental health, social health, social wellbeing, geomagnetic activity, geomagnetic fluctuations and health, Eart*h's *magnetic field, geophysical activity*.

2.1. Health and biopsychosocial wellbeing

The young adult years are considered to be the healthy years of the life span, yet data about health statistics and overall health status at this age are contradictory and suggest that there are various health related factors that pervert the assumptions about good health during this life span [189]. Current health status and subjective wellbeing of a person is an important and significant indicator for analyzing and predicting his/her immediate future health changes and healthcare needs [139]. Evaluating and determining health status is an important process in researching various processes in human life, therefore, health is a frequent subject of research in social, psychological and other fields of science.

In 1977 George L. Engel proposed a biopsychosocial approach towards understanding health assessment [44]. He claimed that addressing symptoms and perceiving overall human health only based on bodily concepts, such as pathophysiology of diseases and derangement of tissues or organs, is a reductionist and unscientific approach. Although a challenging model to implement in practice [19], the biopsychosocial approach represents science and humanism in health care practice. Researchers Hari Kusnanto et al. [91] notice that applying this model in health care, provides awareness on the interactions among biological, psychological, sociocultural, and spiritual factors. After a thorough analysis, the authors also stress that the biopsychosocial model is particularly useful to deal with chronic diseases and ill-defined illnesses to which patients response uniquely [91].

Assessment of health status and wellbeing is a complex phenomenon, consisting of both subjective and objective components. Merely objective data, recording actual knowledge and facts about illnesses, disorders, morbidity, etc., do not reflect the full status of health, as the health status of a person is conveyed also by social, psychological factors and subjective attitudes towards his/her health [194]. Objective and subjective aspects of wellbeing are also discussed by Artūras Gataūlinas [51], who claims that if objective factors of wellbeing might be linked to the development of market relations, the emergence of subjective factors should be linked to the perception that wellbeing is reflected not merely by income and wealth, but rather by interaction with the surrounding environment. Moreover, there are numerous *objecttive* circumstances to which each individual responds *specifically* [51].

Subjectively assessed health includes both subjective assumptions and actual knowledge of the individual's health condition. A person's subjective assessment of his/her health status is most often determined by biomedical, functional and emotional components [79, 139]. Studies conducted by many scientific researchers [71, 118, 139] emphasize that it is the subjective rather than the objective assessment of health status that is a particularly important and significant prognostic indicator.

The theory of salutogenesis, presented by Aaron Antanovsky [6], which focuses not on the etymology of illnesses, but on ways how to improve and maintain good health and wellbeing, claims that maintaining good health is a continuous process, very much depending on the capacity to use an individual's inner resources available, such as the *sense of coherence*. Antanovsky found that despite various traumatic life events, some people describe their health as better than others. After thorough scientific studies, he came to a conclusion that a very important factor for perceiving one's health and overall wellbeing is the sense of coherence, which comprises three components – comprehensibility, meaningfulness and manageability [7]. Bengt Lindström and Monica Eriksson [100] explain these terms adding that they describe an individual's ability to assess and understand a situation he or she is in; to find a meaning to move forward in a health promoting direction; and having the capacity to do so.

It has become clear that the sense of inner coherence can affect health in many ways. It is especially worth mentioning that it may affect the perception of pain and may protect against depression [32]. A strong sense of coherence is an important indicator of prognoses for health status, as it helps one mobilize resources to cope with stressors and manage tension successfully [124].

With the current view that health is not just an absence of disease or negative experience, interest in wellbeing has increased over the last few decades. Existing theoretical [182] and empirical [68] studies have shown evidence that wellbeing is a multidimensional concept that cannot be captured if not addressed holistically. McKinley Health Center at the University of Illinois widened the definition of health by adding that it comprises physical, intellectual, emotional, social, spiritual, and environmental wellbeing. Authors Justina Kaliatkaitė and Laima Bulotaitė [78] also claim that good wellbeing is impossible to achieve if perceived as fragmented, ignoring unity of the whole. Personal wellbeing, according to the authors, cannot consist of one element as it must reflect both cognitive and emotional components. In other words, subjective personal wellbeing comprises an individual's personal view and experience in such life areas as overall life satisfaction, work, health and other work related processes.

The current approach towards subjective wellbeing emphasizes the emotional state of a person. Three elements that subjectively determine perceived wellbeing, as discussed by Gintautas Šilinskas and Rita Žukauskienė [155], are the following:

- overall life satisfaction;
- positive emotionality;
- negative emotionality.

As the mentioned authors additionally explain, subjective wellbeing manifests as a phenomenon combining different emotions – both positive and negative – which are converted into a general subjective feeling.

Based on observations by Šilinskas and Žukauskienė [155], it could be summarized that a high level of subjectively perceived wellbeing is achievable for those individuals who tend not to experience negative emotions, are able to maintain positive emotions in most of the life events and situations, and also who have opportunities and skills to realize their potential and who are not encumbered by social problems.

The need to explore wellbeing is also relevant for its practical application – disease prevention through strengthening health and wellbeing is in many ways beneficial, including economic elements. Thorough research has evidently shown that wellbeing is not determined by the same factors that cause diseases. This has helped to shape a broader understanding that deepening the knowledge of wellbeing can lead to much wider and more significant results than just addressing and treating illnesses that have already occurred. It has become clear that identifying and strengthening factors that have a positive influence on health and wellbeing can help strengthen the health at the individual, organizational and societal levels [17, 69]. Perhaps for this reason the construct of wellbeing received a lot of attention in the European social survey (2013), which in its final module presented the following scheme of the composition of wellbeing (Fig. 2.1.1).

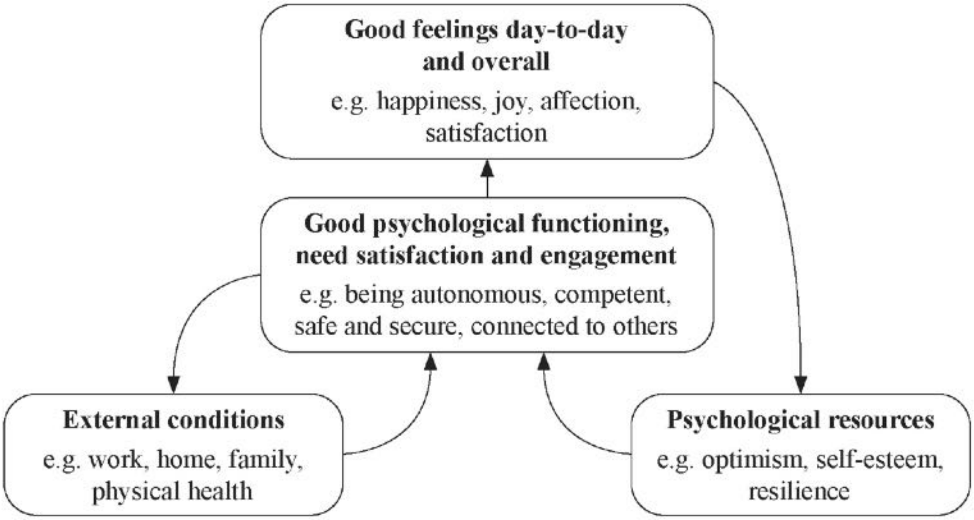


Fig. 2.1.1. *The dynamic model of wellbeing [48]*

Several years after the European Social Survey Round 6, the authors who assessed the data of the survey [76] further explored and analyzed the concept of personal and social wellbeing. Using a combination of theoretical models and statistical analysis, they identified and distinguished six key dimensions of wellbeing, made up of 35 items within the Personal and Social Wellbeing Module. Those dimensions are the following:

1. Evaluative wellbeing, which covers individuals' overall estimations of how well their life is going, including feeling satisfied with life and feeling happy overall.
2. Emotional wellbeing, which includes positive day-to-day feelings such as happiness and enjoyment of life, and lack of negative feelings such as anxiety and depression.
3. Functioning, which includes feelings of autonomy, competence, engagement, meaning and purpose, self-esteem, optimism and resilience.
4. Vitality, which includes sleeping well, feeling energized and feeling able to face the challenges that life presents.
5. Community wellbeing, which is concerned with an individual's feelings about the community in which they live, including trust in other people, feeling supported by members of the community, and experiencing a sense of neighborliness.
6. Supportive relationships, which relate to individuals' feeling that there are people in their lives who offer support, companionship, appreciation, and with whom intimate matters can be discussed.

There are many different definitions of health and wellbeing in scientific literature, but most often researchers are following the World Health Organization's (WHO) concept of health, according to which, health is not just the absence of disease or disability, but also full physical, mental and social wellbeing [194, p. 26]. In order to carry out a comprehensive, biopsychosocially-based review of health parameters, health aspects are further discussed namely by distinguishing them into the three areas described in the next subchapters – physical, mental and social. The biopsychosocial approach, contrary to traditional biomedical models in medicine, systematically perceives health as being influenced by biological, psychological and social factors and their complex interactions, and emphasizes the importance of understanding human health and illness at a broader level, not just limiting to merely biologic cell level [44].

Summarizing the addressed scientific researches and discussions of their findings, several key points can be pointed out:

- Overall health status and wellbeing of a person is a complex phenomenon, consisting of both subjective and objective components. Many researchers agree that it is the subjective rather than the objective assessment of health status that is a particularly important and significant prognostic indicator;
- A person's subjective assessment of his/her health status is most often determined by biomedical, functional and emotional components;
- Modern understanding and view towards overall health is shifting from a focus on identification and treatment of diseases and disorders to a more promising salutogenic attitude that is based on development and maintenance of good health. The theory of salutegenesis stresses that maintaining good health is a continuous process, very much depending on the use of an individual's inner resources available, such as the *sense of coherence*, meaning that by modulating one's emotional state and training specific personality traits and capabilities, an individual can influence their overall health condition.

2.1.1. Physical health and wellbeing

In 1929 Walter Cannon introduced the concept of homeostasis, after which the study of physiology has been based on the principle that all cells, tissues, and organs maintain a static or constant "steady-state" condition in their internal environment. However, with the introduction and development of signal processing techniques that can acquire continuous time series data from various physiologic processes such as heart rate, blood pressure, and nerve activity, it has become apparent that biological processes vary in a complex and nonlinear way, even during the "steady-state" conditions. These observations have led to the current understanding that healthy physiologic functioning is a consequence of continuous, dynamic interactions between multiple neural, hormonal, and mechanical control systems that perform at both local and central levels. For example, it has been proven that normal resting sinus rhythm of the heart is highly irregular during steady-state conditions rather than being monotonous and regular, which was the widespread notion for many years up to now [150].

In order to better understand what factors influence physical health and physiologic functioning, let us first start with a very significant element that an individual faces every day – his/her social surroundings. It has already been scientifically proven that for humans, deficits in social relationships such as social isolation or low social support can lead to chronic activation of immune, neuroendocrine, and metabolic systems, leading to cardiovascular, neoplastic, and other diseases [188, 192]. Developing and maintaining quality social connections play a vital role in protecting physical and overall health. A recent study found that socially embedded adults experience fewer disease risks, and that there is a significant causal link between social connections and reduced hypertension and obesity [189]. Previous non-experimental studies using observational data have found significant associations between social relationship indicators, such as social integration and support, with indicators of inflammation [188, 192] and metabolic dysfunction [188, 190].

A study conducted by Xueqing Yang et al. [189] strengthened the support for causal links between social relationships and physical functioning by finding from their results that particular social network and support characterristics may have great influences on overall health. The authors found that the relationship between social integration and better physical functioning, as well as lower clinically significant disease risks, is exceptionally strong and evident. Moreover, the study showed that the subjective perception of the quality of social network was the factor that strengthened the impact on some physiological markers. This means that it is the subjectively perceived quality of social relationships rather than the quantity or density of one's social network that better explains the link between social ties and overall health [189].

The clinical importance of heart rate variability (HRV) was noted as far back as 1965 when it was found that fetal distress is preceded by alterations in HRV before any changes occur in heart rate itself [65]. Low HRV has since been confirmed as a strong, independent predictor of future health problems and as a correlate of all-cause mortality [38, 177]. Reduced HRV is also observed in patients with autonomic dysfunction, including anxiety, depression, asthma, and sudden infant death [3, 23, 31, 53, 95, 96].

HRV declines with age [179] and aging often involves nervous system changes, like loss of neurons in the brain and spinal cord, which may degrade signal transmission [74] and reduce regulatory capacity. Reduced regulatory capacity may contribute to functional gastrointestinal disorders, inflammation, and hypertension [52].

HRV is also an indicator of psychological resiliency and behavioral flexibility, reflecting the individual's capacity to adapt effectively to changing social or environmental demands and challenges [15]. More recently, several studies have shown an association between higher levels of resting HRV and performance on cognitive performance tasks requiring the use of executive functions [173] and that HRV, especially HRV-coherence, can be increased in order to produce improvements in cognitive function as well as a wide range of clinical outcomes, including reduced health care costs [5, 10, 94, 95, 106].

Seasonality is an important factor, worth mentioning in the context of physical health analysis, especially when observing heart activity. The season differences regarding heart failure admissions to hospitals and mortality are observed: most ischemic heart disease and stroke related deaths occur in the winter (especially – February) months, traffic accidents victims are most common at the late autumn-start of winter, and suicidal cases are more observed during summer time (June-July) [166]. Authors Martin Cowie [35] and John J. McMurray et al. [116] also note that winter months can be distinguished for heart failure exacerbation in regard to such possible stimulators for cardiovascular system responses as lower temperatures, comorbidities, changes in diet, social problems, etc. [35, 116].

Gender differences are also observed when analyzing seasonality in the context of physical processes – in women seasonality of death is more common than in men [165]. Gender differences in heart failure exacerbation can be a component explaining longevity differences in male and female longevity in most industrialized countries [163].

Physical disease or malaise has a widespread effect that draws into all areas of life, however, overall health does not merely or – even to most extent – depend on the assessment of physical health status. For instance, a study conducted by Xiang J. Lin [99] showed that 43% of patients whose physical health condition was poor, evaluated their overall health and life quality as good. This is only one example that shows that health and health-related quality of health is a very complex phenomenon, being influenced by many different factors.

Despite the fact that medicine has developed methods for how to objectively assess an individual's physical health, it is well known that lifestyle and health determinants that influence the way of living have significantly higher impacts for physical health and longevity than medicine. It has long been proven that maintaining good physical health can also help significantly improve mental health [152]. In general, when discussing physical health and wellbeing, it is inevitable to pay attention to physical activity as a significant factor for improving and maintaining good physical and overall health state.

Physical activity is typically described as any type of body movement when due to muscle contraction, the amount of energy used is higher than being at rest [47]. Various scientific research analyzing the influence of physical activity on different organ systems, claim that medium intensity physical activity corresponding to the functional condition and capabilities of the organism has a significant positive effect on our health [134]. More and more evidence-based research is emerging that proves the evident benefits of regular physical activity not only for health in general, but also for the development of different chronic non-infectious disease. The importance of physical activity is perhaps one of the reasons why WHO has come up with very specific recommendations for physical activity for different age groups (Table 2.1.1.1). Unfortunately, according to WHO [55], 23% of adults and 81% of adolescents (aged 11–17 years) do not meet the WHO global recommendations on physical activity for health.

Table 2.1.1.1. *Recommendations for physical activity [47]*

Age group	Recommendations
Healthy adults aged 18–65	Not less than 30 minutes of medium intensity physical activity 5 days per week or not less than 20 minutes of very high intensity physical activity 3 days per week. Physical exertion is considered sufficient if uninterrupted physical activity lasts at least 10 minutes each time; medium intensity stages can be interchanged with high intensity stages. Furthermore, physical activity enhancing muscle strength and endurance should be also added in two or three days per week.

Several summary points on physical health are:

- Biological processes in the body vary in a complex and nonlinear way, determined by specific complexity regularities.
- Modern understanding of physiology has developed to a broader level including perception that healthy physiologic functioning is a consequence of continuous, dynamic interactions between multiple

neural, hormonal, and mechanical control systems that perform at both local and central levels.

- Social connections, their development and maintenance are significant for protecting good physical health – socially embedded adults express fewer disease risks.
- Seasonality impacts on physical health parameters and gender differences are observed and appear to be significant factors worth paying attention to when addressing physical health.
- Appropriate lifestyle remains a crucial element for good physical health. Regular physical activity is distinguished as a very important component of overall lifestyle that has a significant influence on physical and overall health.

There are many scientific publications showing that physical activity does not only help improve physical health, but it is also a very strong factor for developing and maintaining good mental health and wellbeing [29, 37]. We will further discuss physical activity in more detail in the next subchapter on mental health and wellbeing.

2.1.2. Mental health and wellbeing

Mental health is a state of wellbeing in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to contribute to his or her community [83, 121]. According to the Lithuanian Republic Ministry of Education and Science, mental health is a condition that promotes optimum physical, intellectual, emotional development of an individual and that does not hinder the development of other individuals [170]. According to the WHO, mental health is emotional and spiritual resilience, in which an individual can experience joy and tolerate pain, disappointment and sadness. It is a positive feeling of kindness, which acts as a ground for believing in one's own and others' dignity and value.

Another definition of mental health includes a positive emotional and spiritual state, the ability to feel and be one's self among other people, the ability to express one's self creating pleasure for one's self and others, and the ability to make one's own decisions and be responsible for them [170].

In its description of mental health, WHO stresses the state of wellbeing, which enables an individual to understand his/her own skills, manage stress, work productively and fruitfully, and contribute to the community he/she belongs to [120]. Apparently, mental health, according to the WHO, is defined through the state of wellbeing. Perhaps this has led to the tendency nowadays to include the concept of psychological wellbeing when addressing mental health issues. This practice is well approved by pioneers of *Positive*

Psychology. They claim that earlier psychologists were only interested in misfortunes, mental disorders and psychological difficulties that people were experiencing, giving too little attention to a healthy individual and prosperous society. Treatment and psychological intervention do not prevent mental health problems, therefore, it is important to pay most of the attention not to the risk factors, but to the subjectively perceived state of the individual, as this subjective perception of one's health and wellbeing can help anticipate the expression of disease or good health in the future [2, 149].

Mental health is one of the WHO's priority questions. In its Mental Health Action Plan 2013–2020 WHO formulated specific strategies for European Union member countries and national and foreign partners oriented towards strengthening mental health and preventing disorders. Among many aspects, it also highlights the need to create healthy living and working conditions, including implementation of evidence-based stress management strategies into public and private sectors [119].

The concept of good health encompasses the assurance of the dignified life of an individual and the principle of self-realization. According to the Lithuanian Republic Ministry of Education and Science, the following factors are important for good mental health and wellbeing (Table 2.1.2.1).

Table 2.1.2.1. *Factors affecting psychological health [169]*

Social	Biological	Psychological
• Social and economic status • Poverty • Technological changes • Media • Violence • Wars • Natural disasters • Racism • Unemployment rate	• Age • Gender • Genetic predisposition • Lifestyle • Severe somatic diseases	• Relationship with parents and other carers during childhood • Relationship with peers and other individuals • Relationship with the environment • Work and learning load

In the field of science, psychological (or mental) wellbeing is a relatively new and promising term and research area. This field of science focuses not on the search for flaws, but on factors that help a person prosper, realize one's potential and feel good in general. Although the roots of the primary psychological wellbeing are already found in philosophical reflections on happiness in the works of ancient Greek philosophers, this area of science is gaining more and more attention from scientists and politicians [138]. Research into psychological wellbeing has become particularly relevant in terms of the economic performance of the healthcare system, the increase in life expectancy, and so on [181].

Psychological wellbeing includes both positive and negative psychological factors. The positive part is the possession of a goal in life, positive emotions, life satisfaction, happiness, and optimism. The negative part is a high level of negative emotions [17]. It is believed that a happy person often experiences positive emotions and rarely negative emotions and is generally happy with his/her life [127].

Good psychological functioning is considered to be the basis for everyday and overall wellbeing. It is mostly related to the internal resources of the individual, which ensure not only the instant good feeling, but also provides potential for a long-term wellbeing support.

Scientific research has shown close relations between good psychological state and some personality trait, for instance, optimism [36]. Authors Ian Brissette, Matthews F. Scheier and Charles S. Carver [21] also show that individuals who look at the world from the optimistic point of view are better in coping with stress than those who are full of pessimistic thoughts and estimations.

Often, scientific literature suggests even broader interpretations of psychological wellbeing, involving not only positive emotions (happiness or satisfaction) but also trust, interest and good functioning, expressed through the control of one's life, goal-setting and the existence of social relationships [68, 181].

It is not entirely clear what constitutes a construct of psychological wellbeing. However, there is a consensus that personal and environmental factors play a role in this. For example, partial psychological wellbeing depends on parenting style, genetic factors, personality traits, environmental conditions and culture [1, 67]. There is debate among scientists about whether environmental conditions affect a person's psychological wellbeing. However, it is emphasized that unpleasant life events are less important than the psychological perception and interpretation of those events [68]. Here it is also important to pay attention to cultural differences that lead to different interpretations of different events / factors. Scientists who researched them and compared the results of the US and Japanese people found that there are significant differences in how different factors between the populations of these two countries are perceived and evaluated [80].

Nowadays, when discussing mental health, much attention is given to understanding and preventing depression, which is a leading cause of non-fatal disease burden worldwide, with a lifetime prevalence of 9% among European adult men and 17% among European adult women [136]. Almost two decades ago, WHO had already predicted that by the end of 2020, depression would become the second largest cause for disability worldwide [187]. Mental health disorders became more and more common, and their expressed symptoms have an increasing impact on health. Depressive disorder erodes quality of life, reduces productivity and is an obstacle to the fulfilment of social and familial roles. As a consequence, depression has become a leading cause of disability worldwide.

From an economic point of view, prevention of the emergence and progression of depression may offer good value for money when it helps to both avoid suffering, treatment costs, caregiver burden, and the costs that stem from productivity losses. Economic evidence indicates that depression prevention in adults is cost-effective especially when offered in a self-help format with minimal guidance from a therapist. It may even be cost saving from a societal perspective when the cost offsets due to changes in productivity are accounted for. Preventive e-health interventions are a case in point; they have potential to become cost-effective as they do not rely on scarce resources such as therapists' time, but rather promote self-management and are scalable, thus bringing down the marginal per-patient costs in a significant way [136].

One of the healing methods that scientists have proved to be effective in the context of mental health and disorders, is physical activity, which has both prophylactic and curative effect on treatment of mental disorders.

A physically passive lifestyle that lasts for at least 8 years (maximum of about 30 years) is significantly related to later clinically-expressed depression [22]. Various forms of physical activity can help significantly reduce the symptoms of severe and moderate depression [93]. Four independent studies have found that physical activity is an appropriate and effective component of psychotherapy treatment for depression [126].

A physically active lifestyle can also be effective when treating mental disorders such as generalized anxiety syndrome, various phobias, panic attacks and stress coping [130]. It is observed that physically active individuals have fewer complaints regarding feeling anxious or experiencing symptoms of emotional stress than physically passive individuals [73]. In general, when having difficulties dealing with any form of stress management, physical activity can be included into the treatment strategies as being significantly effective. It helps to reduce a short-term psychological reaction to an instant psychosocial stress factor by normalizing arterial blood pressure, changing muscle tone or modifying psychological factors. All these processes help achieve a faster recovery after the experienced stress [180].

Higher levels of physical activity are significantly linked with subjectively perceived better psychological wellbeing, higher joy of life, better mood, more positive emotions and better quality of life. Moreover, it also helps to shape a more positive self-perception, which is observed in all age groups. Positive self-perception has a direct and independent relationship with mental health parameters [180].

Summarizing the benefits of physical activity on mental health, it could be said that physical activity enables individuals to feel better and feel better about themselves. Longitudinal studies have shown that such people feel happier and are more satisfied with their lives [16]. This impact is observed in all age groups independently of socio-economic status or health condition.

Another necessary component for mental health analysis is social interrelationships which are especially important and play a big role in everyday life. There is consistent evidence that maintaining good quality social relationships (with family members, friends and in the work environment) has great beneficial effects on psychological health and wellbeing [14], while social isolation, a feel of loneliness and lack of close social ties are associated with poorer health and even increased mortality risks [64]. A study conducted by Ziggi I. Santini [143] has also supported previous statements by finding that poor social relationships have a significant impact on mental health [143].

One of the closest and usually most significant social relationships are with one's current family members. Family status, according to a number of researchers, can have a huge impact on psychological wellbeing. The results of a series of studies have shown that the psychological wellbeing of married people is higher than that of single individuals [101, 115, 156, 161]. Supposedly, married individuals are more likely to experience more satisfaction and self-expression in their lives, however, they have less autonomy [115]. It is noted that those married and living together, and those not formally married, evaluate their psychological wellbeing equally well. However, lonely, widowed and divorced people consider this construct much worse than married ones. Another important tendency was observed: the relationship between marital status and psychological wellbeing depends on gender. Male widows and lonely men consider their psychological wellbeing as worse than female widows and single women [151]. Many studies have shown that married couples or couples living together have fewer symptoms of depression than lonely people [146]. Having a partner is especially important for older men compared to women [77]. It can be concluded that marriage for men can act as a protective factor against the development of symptoms of depression.

Naturally, socio-economic factors also play a big role in psychological wellbeing. Particularly, strong psychological wellbeing is associated with social wellbeing, namely – social activity and social support [82]. Authors Brissette, Scheier and Carver [21] also highlight the importance of social relations when discussing psychological health and subjective personal and social wellbeing.

However, there are also contradictory findings from studies analyzing links between the components of psychological and social wellbeing. Some authors found that in case of high psychological wellbeing, there was low social wellbeing. Therefore, it is recommended that both of these factors are considered as related but distinct parts of the individual's wellbeing [151].

After all, many studies, including longitudinal ones, confirm the link between social wellbeing and psychological wellbeing, even considering socio-demographic terms [156, 183, 193]. As social wellbeing is considered by most researchers as an essential component of overall wellbeing and health, we will discuss it further in more detail in the next subchapter.

Summarizing the subchapter, it is worth pointing out that good psychological functioning is considered to be the basis for everyday and overall wellbeing, and it ensures not only the instant good feeling, but also provides potential for a long-term wellbeing support. Among many factors that influence the state of mental health, some of the most important are quality social relationships and regular physical activity, the latter, according to scientific researches, having not only prophylactic, but even a curative effect on treatment of various mental disorders.

2.1.3. Social wellbeing

One of the characteristics of human society, distinguishing it from other species, is that individuals are interrelated through social relationships. A study conducted by Joëlle Kivits et al. [88] showed that there are certain social factors that determine social health and wellbeing. Their study results revealed 4 social components that contribute to health-related quality of life and social wellbeing: living with a romantic partner, level of obtained education, professional status and net household income, regardless of age and gender. High quality social participation and overall social life is such a fundamental human need, that it has been shown in many research studies that the lack of social connections increases the odds of death by at least 50% [64, 102]. Despite the ongoing, fast technological progress that provides people with more and more different tools and ways to connect with each other, loneliness and social isolation are an ever-growing complex challenge in the society worldwide, with Julia Beaumont [9] reporting that 59% of adults aged over 52 say they feel lonely often.

The concept of loneliness can be defined as the perceived sense of isolation [61]. When defining this concept, it is important to distinguish the feeling of loneliness and being alone, as these terms sound similar, however, have different emotional and functional aspects. Being alone does not by default mean being lonely – voluntary loneliness can be a positive thing and those who live alone can be seen as "self-reliant problem solvers, respectful of other people's privacy" [43]. The English Longitudinal Study of Ageing found that 2 in every 5 individuals who lived alone reported hardly ever or never feeling lonely [9]. It is observed that feelings of loneliness are more prevalent among those groups of people who are single, widowed, divorced or separated, economically inactive, living in rented accommodation or in debt [9, 117].

It has been proposed that in the course of human evolution, loneliness has not always been associated with negative aspects, but rather has served as an adaptive function, fostering connection and reconnection with others, ensuring one's safety and long-term survival. Increasingly, more and more researchers tend to recognize loneliness as being a significant social determinant of health. In late childhood and early adolescence, experiencing loneliness may result in impaired sleep, expressed symptoms of depression, and poorer general health. These same effects are observed across the lifespan [61]. It is agreed by many researchers that loneliness is a threat to health, with evidence that it is a significant risk factor for a wide range of mental and physical health problems, including depression, high blood pressure, sleep problems and reduced immunity [62, 103, 131]. Loneliness is often associated with emotional stress and health problems, therefore, it is considered to be closely connected to overall wellbeing [157].

The opposite indicator of loneliness – involvement in social activities – is one of the significant ways of how to help improve or maintain good cognitive abilities, which, in turn, plays a big role in the overall assessment of the individual's wellbeing. Comparing cognitive abilities between those individuals who are socially active (work, are taking classes, volunteer, are engaged in charity activities, help their relatives, take part in religious or political organizations' activities, belong to various sport or other kind of clubs with other people) and those of low social activity, the former express better quality in cognitive functions [30, 45]. Some researchers even claim that high social activity and social wellbeing are perhaps one of the most significant factors for maintaining a good mental health and retarding the process of cognitive impairment [59].

As a person grows up and matures (in different levels – physical, emotional, spiritual), his/her environment changes. In time, a person sets short-term and long-term goals, experiences playing different social roles both in and outside the family. Significance of social roles and their development in the course of life is an important aspect to address when discussing social wellbeing. Social roles change and develop due to various usual life events – marriage, child birth, career changes, etc. Assumed or assigned roles often affect an individual's behaviors, his/her expectations towards himself and towards others. Psychologist Antanas Suslavičius points out the obvious significance of social roles and highlights that an individual interprets and perceives roles based on his/her personal views and background. The society, however, presents certain models and perceptions, orienting towards understanding of what should a person in a specific role do and how he/she should be acting. Different understanding of the role is a precondition for conflict. Thus, misinterpreted roles or ignoring and not playing the assigned role in an appropriate way may result in internal or external conflicts (with oneself or others).

Around the age of 25–30 a person reaches physical maturity – the most productive period in life. This period is accompanied by ongoing psychological maturation, spiritual development, change in personal values and provisions, adaptation to various environmental factors and events, etc. Science of Developmental Psychology claims that it is the age of young adulthood, when an individual has to make two very important decisions or directions in his/her life, related to marriage and career. Both of these questions are extremely complicated, complex and require much efforts, sometimes even inner struggling. These decisions may drastically change the individual's social roles and influence the burden of expectations assigned to him/her. However, speaking about marital status, researchers share different insights and findings, reaching no consensus about whether married people experience higher social wellbeing. Some studies [141, 151] showed evident links between marital status and subjective social wellbeing, however, another study [125] did not find any significant relationships and concluded that marriage, according to the study's findings, does not provide advantages in social life and wellbeing. A proposed explanation for different findings about the perception of marriage and its impact on social wellbeing is that perhaps it is very much depending on cultural features in different countries [141].

It becomes obvious, from what has been discussed, that most of the social wellbeing components are related to interactions with other people and the quality of social relationships. The term social relationships covers a wide variety of aspects related to the proximal and distal social environment. Distal social environment includes the broader social structure of opportunities for social integration (e.g. cultural, labor market, etc.) and its quality [13, 81].

Two most commonly addressed sociological concepts that analyze proximal factors of social relationships are social networks and social support [13]. The concept of social networks describe the size, density, frequency and duration of social contacts, whereas social support emphasizes the functional aspects and their significance regarding providing instrumental, emotional or informational resources [24]. Important additional aspects concern the quality of and satisfaction with social support received and, what is important to note, the distinction between perceived and received support.

Defining the relationship between engagement in social networks and health outcome, it turns out that social networks are related to depression [175]. Partially, social networks are found to be important for the feeling of gaining social support. However, extensive networks may not necessarily be supportive and, on the contrary, members of social networks may be a source of stress or even severe interpersonal conflicts [178].

On the one hand, young adulthood is a period when adults are naturally involved in participation of multiple social networks associated with the actual circumstances during this life period, including those at work, in their community, with children and other parents, etc. Supposedly, social integration is not a discriminating issue during this lifetime period for most of young adults. On the other hand, these multiple social connections during this time are potentially stressful in nature and may generate additional unwanted tension [189]. Prior research found that it is this period of life that is, compared to other stages of life, mostly characterized by multiple role conflicts across different social domains [34].

Moving forward with the most influential areas of social life, it is important to address the working environment. Various scientific studies found a significant link between job satisfaction and social wellbeing. Those with higher job satisfaction, according to the study conducted by Maryam Shoorvazi et al. [153], had higher levels of social wellbeing. Another study [49], examining the level of social wellbeing and job satisfaction among teachers, found obvious significant statistical relationship between these two variables. The findings of that research were in agreement with Larson Theory, which describes social wellbeing as the individual's evaluation of the quality of his/her relationships with family members, others, and social groups. The author claimed that social wellbeing scale measurements are significant in describing the individual's overall wellbeing, especially concerning those aspects that indicate his/her satisfaction or dissatisfaction with life and social environment, and, additionally, it also includes the individual's internal responses, i.e. emotion, thinking, and behavior [92].

Leila Rastgoo et al. [137] found in their research that there is a significant relationship between psychosocial health parameters and job performance among the nurses working in Ardabil hospitals. In fact, their study revealed even broader results concerning more areas of social life – individuals who have a high level of social wellbeing have better abilities to be successful in coping with the challenges when playing major social roles, and they tend to live in families with higher emotional and financial stability and integration. Moreover, those individuals are more effective in taking active participation in collective activities, and, remarkably, are more compatible with social norms [137].

Another question that interests scientists when analyzing social well-being is whether there exist specific personality components that can determine or predict an individual's quality and satisfaction of social interactions. Authors Brissette, Scheier and Carver [21] in their research distinguish such personality trait as social optimism which, according to them, enables a person to feel part of the community or society in general. As the authors claim in their study, an individual by default is already a part of some community and that he/she thinks not only about his/her own future, but also about the community's future, cherishing hopes and expectations regarding future wellbeing. The main outcome of these findings is that each individual, whether it is conscious or not, carries inside a wish to strive not only for personal wellbeing, but also for the wellbeing and prosperity of the society, country and the whole world.

Another author Audronė Telešienė [172] also addressed social optimism, defining it as a personality trait, explaining how an individual evaluates in general the future of the community or society to which he/she belongs and/or the whole world. In the table below are two statements that were used in the European Social Survey [48] and the percentage of respondents that agreed or disagreed with the statements. Disagreement reflects optimism; agreement reflects pessimism.

Table 2.1.3.1. *Social optimism among Lithuanian inhabitants [172]*

Question	Agreed	Disagreed
For most of the Lithuanians, life is getting worse	65.3%	8.6%
Considering what is happening in the world nowadays, I find it hard to cherish hopes for the future of the world	43.1%	17.1%

As it is obvious from the table above, the level of social optimism in Lithuania is relatively low. The majority of respondents (65.3%) believe that for the most of the Lithuanians, life is getting gradually worse, and that they find it difficult to cherish positive hopes regarding the future of the world.

Another set of data regarding indicators of social wellbeing among Lithuanians is shown in Table 2.1.3.2, which represents the findings from a thorough analysis conducted in the frame of European Social Survey [48].

Table 2.1.3.2. *Average standardized scores on six wellbeing dimensions, by country [48]*

	Evaluative wellbeing	Emotional wellbeing	Functioning	Community wellbeing	Supportive relationships	Vitality
Denmark	0.68	0.36	0.32	0.10	0.30	0.05
Norway	0.53	0.39	0.19	0.23	0.25	0.02
Switzerland	0.52	0.16	0.21	0.14	0.23	0.17
Iceland	0.51	0.28	0.19	0.42	0.19	0.05
Finland	0.51	0.22	0.16	–0.03	0.10	–0.06
Netherlands	0.46	0.20	0.16	0.04	0.16	–0.04
Sweden	0.41	0.24	0.13	0.15	0.22	0.00
Israel	0.31	0.04	0.17	0.03	0.07	0.11
Germany	0.31	0.18	0.18	0.08	0.24	0.10
Belgium	0.26	0.04	0.07	–0.02	0.01	–0.06
United Kingdom	0.23	0.11	0.07	–0.02	0.05	–0.07
Spain	0.16	–0.04	–0.02	0.06	0.07	–0.14
Poland	0.11	0.00	0.10	–0.08	0.09	0.02
Slovenia	0.08	0.27	0.10	–0.01	0.08	0.06
Cyprus	0.07	–0.05	0.07	–0.14	0.16	0.12
Ireland	0.03	0.23	0.12	0.19	0.00	0.09
France	–0.01	–0.01	0.04	–0.06	0.09	0.07
Italy	–0.06	–0.16	–0.01	–0.06	–0.14	–0.06
Slovakia	–0.12	0.03	–0.14	–0.01	–0.15	0.03
Czech Republic	–0.14	–0.01	–0.17	–0.14	–0.24	–0.03
Estonia	–0.17	–0.06	–0.01	–0.08	–0.09	0.06
Kosovo	–0.21	–0.17	0.14	0.16	–0.06	0.07
Portugal	–0.31	–0.07	–0.09	0.01	–0.10	0.15
Lithuania	–0.36	–0.28	–0.17	–0.12	–0.12	–0.12
Albania	–0.38	–0.37	0.01	–0.14	–0.10	–0.05
Russian Federation	–0.40	–0.23	–0.83	–0.45	–0.33	–0.04
Hungary	–0.49	–0.30	–0.14	0.21	–0.16	–0.18
Ukraine	–0.55	–0.23	–0.18	–0.04	–0.25	–0.04
Bulgaria	–0.88	–0.24	–0.17	–0.08	0.06	0.03

As we see in Table 2.1.3.2, the countries are sorted from highest to lowest according to the evaluative wellbeing dimension. Lithuania appears in the lower part of the list, meaning that the analyzed six wellbeing dimensions (evaluative wellbeing, emotional wellbeing, functioning, community well-being, supportive relationships, and vitality) are in a relatively poor condition, compared to other European countries.

To summarize the subchapter, it is important to note that the area of social interactions is significant in terms of an individual's feeling as being part of the community. It has been proved that the lack of social connections increases the odds of death by at least 50%, therefore, this field is important to pay attention to, not only in the frame of public health parameters, but also in the context of economic wellbeing and overall factors of the society's wellbeing. Despite the ongoing fast technological progress that provides people with more and more tools and ways how to connect to each other, loneliness and social isolation are an ever-growing complex challenge in the society worldwide, with statistics portraying that 59% of adults aged over 52 say they feel lonely often. Involvement in social activities helps also to improve or maintain good cognitive abilities, which, in turn, play a big role in the overall assessment of the individual's wellbeing and functioning.

2.2. Geomagnetic activity and human health

Solar wind is a stream of energetic charged particles emanating from the Sun, and the geomagnetic field protects the Earth by deflecting most of the charged particles. GMF changes over time and extends from the Earth's inner core to where it meets the solar wind. Fluctuations in its speed, density, direction, and other features strongly affect Earth's local space environment and technological, biological and ecological systems on the Earth [123, 133, 184].

As the National Oceanic and Atmospheric Administration describes, daily magnetic field activity fluctuations arise from current systems caused by regular solar radiation changes. Other irregular current systems affect magnetic field changes caused by several factors: the interaction of the solar wind with the magnetosphere; by the magnetosphere itself; by the interactions between the magnetosphere and ionosphere; and by the ionosphere itself [127]. In order to describe fluctuations in the GMF caused by the mentioned irregular systems, the following magnetic activity indices were designed:

- The ***K-index*** was first introduced by J. Bartels in 1938 and consists of a single-digit 0 thru 9 for each 3-hour interval of the universal time day (UT). It is a quasi-logarithmic local index of the geomagnetic activity at the given location and time compared to a calm day curve. Each magnetometer measures the maximum deviation of the horizontal component of the magnetic field at its location and reports this. The global *Kp-index* is then determined with an algorithm that results in the mean standardized *K-index* from 13 ground-based magnetometers around the world. The *Kp-index* ranges from 0 to 9 where a value of 0 means very little geomagnetic activity and a value of 9 means extreme geomagnetic storming.

- Since K-scale relationship to magnetometer variations is non-linear, it is not capable of producing the average of a set of K-indices. Instead, every 3-hour K-value is converted back into a linear scale called the a-index. The average from 8 daily a-values provides the ***Ap-index*** of a certain day. Days with high levels of geomagnetic activity have a higher daily Ap-value. [127].

Another geomagnetic activity related indicator is *R sunspot*, which is used to describe spots on the sun's surface. The relative number R is used to measure sunspot activity, and the value of R attempts to account for the fact that sunspots tend to appear in groups. The numeric expression of R is based on subjective manual determination on a daily basis [128].

Finally, another indicator in terms of the global geomagnetic activity is ***f10.7 index***, which is one of the longest running records of the solar activity. The *F10.7 index* originates from the chromosphere and corona of the solar atmosphere. This index correlates well with the sunspot number as well as a number of UltraViolet and visible solar irradiance records. Also, it has proven very valuable in specifying and forecasting space weather [127].

In addition to the global geomagnetic and space weather indicators, it is important to mention a German physicist Schuman, who, back in 60s, identified and started investigating the features of GMF fluctuations that occur, namely in the cavity between the surface of the Earth and the ionosphere. The resonances that have been identified are low frequency electromagnetic fluctuations which are closely related to human physiologic processes [146]. Electromagnetic impulses, like those from global lightening flashes (the world's thunderstorm activity) fill the Earth-ionosphere cavity and excite the Schumann resonances. Resonances can be observed at around 7.8, 14, 20, 26, 33, 39 and 45 Hz. The observation of Schumann resonances can provide valuable information about solar activity, world thunderstorm activity, the Earth-ionosphere cavity, climatic changes and human health indicators.The human brain is a very sensitive electromagnetic organ, therefore, changes in GMA and SR intensities have significant impact on alterations in brain-wave and neurohormone responses. Belov et al. [12] have confirmed this by identifying obvious alterations in EEG rhythms.

The first SR frequency with local maximum of power, is approximately 7.83 hertz (Hz), with a (day/night) variation of around ±0.5 Hz. The other higher local maximum powers are at frequencies ~14, 20, 26, 33, 39 and 45 Hz, all of which closely overlay with Alpha (8–12 Hz), Beta (12–30 Hz) and Gamma (30–100 Hz) brain waves, detected in the electrical activity of the brain (EEG). An example of Schuman resonance data is depicted in Fig. 2.2.1.

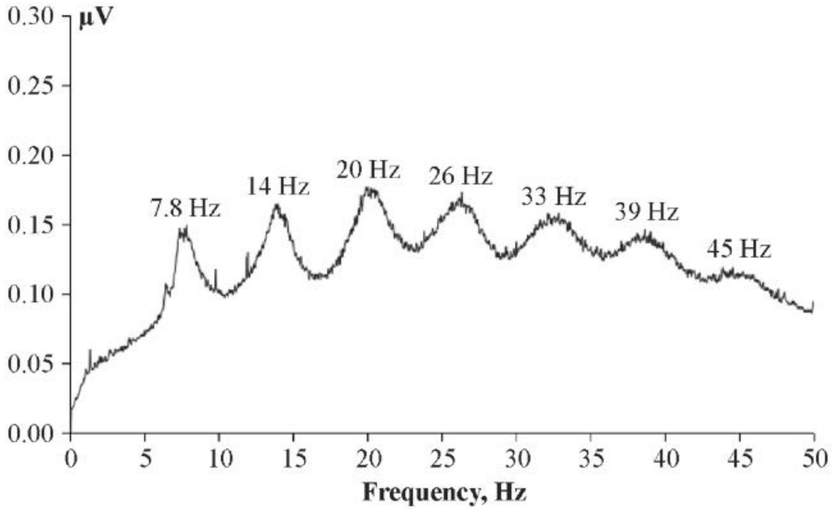


Fig. 2.2.1. *An example of Schuman resonance data recorded from the magnetometer in Boulder Creek, California [111]*

The similarity of EEG with the SRs was recognized early on, and the ability for the EEG rhythms to synchronize with SR activity was later observed by König [89]. A study conducted by Sergey V. Pobachenko et al. [135] showed that during a daily cycle, variations in the EEG are similar to changes in the SR.

Neil Cherry [28] presents a theory arguing that because brain waves and SR share the same frequency range, resonant absorption of the SR signals by the human brain is possible. It is also proposed that every living organism on the earth has a specific sensitivity to the strength and frequency of GMF fluctuations [4, 98]. Heliobiology is the branch of science that deals with the impact of solar activity and related effects on living organisms (sometimes also referred to as cosmobiology and/or astrobiology). Studies linking geophysical environment activity level and the human psychophysiological health state show that a subset of the population is predisposed to adverse health due to geomagnetic variations and extremely high as well as extremely low values of GMA seem to have adverse health effects [132]. Recent studies showed that both weak and strong GMF disturbances are linked to negative health outcomes [60, 70]. A question regarding the optimal strength of the GMF for maintaining a good health still remains open.

Since modern equipment detecting GMF fluctuations enables researchers to capture and identify different frequency waves, it is meaningful to briefly distinguish and describe each of the frequency range's main health aspects. Annette Deyhle, a researcher at the HeartMath Institute [39], briefly describes the five stages of the waves:

- *Delta* waves are observed during a deep dreamless sleep or unconsciousness;
- *Theta* waves occur at a first stage of sleep and during deep meditation. It has been linked to creativity, fantasizing, and is believed to reflect activity from the limbic system and increased activity in anxiety, behavioral activation and inhibition;
- *Alpha* waves reflect that major rhythm found in a normal state, relaxed adult. It has been linked to overall mental and body/mind coordination, calmness, alertness and learning; when being in Alpha rhythm, a person experiences a pleasant wellbeing, calm and smooth thinking, and positive attitude. Lack of this rhythm can lead to expressed signals of stress, concern, brain activity disorders and indications for various diseases;
- *Beta* waves are mostly associated with active processing, stress, concern and anxiety. This rhythm is observed during normal waking consciousness and outward attention. Being in a state of Beta rhythm mostly causes higher levels of released stress hormones;
- *Gamma* waves are associated with waking states and can occur when we are simultaneously processing information in both brain hemispheres. It can be also associated with hyperactivity, panic, fright, tension and peak intellectual performance.

After the initial observations by Schumann and his colleagues, many studies followed, examining a broad range of physiological, psychological and behavioral changes associated with changes in geomagnetic and solar activity. It is commonly recognized that geophysical factors may promote social unrest by influencing the mental state of people [171]. A number of studies have shown that geomagnetic and solar influences affect human behavioral and health outcomes, the nervous and cardiovascular systems being the most clearly impacted [50, 86, 104]. Increased rates of violence, crime, revolutions, frequency of terrorist attacks also have been linked to GMF disturbances [59, 122, 158]. In 2001, other researchers [87] found that the majority of crimes of serial maniacs in USA and Russia coincided with the increases in GMA. Another study, using data on suicide terroristic attacks in Israel, Iraq and Afghanistan (1,062 cases during 1994–2008), found that certain patterns of GMA features were similar in all countries studied and typically accompanied such acts. Surprisingly, an increase in GMA was significant ($p<0.0001$) on the day of an attack and on the day following the attack [56].

All of the above-mentioned geophysical environment features can affect human health, wellbeing and behaviors both directly and indirectly, depending on different factors, including current health status and maturity of the individuals. Increases in solar radio flux, cosmic rays and SR power were all found to be associated with increased HRV and parasympathetic activity. A link with the autonomic nervous system (ANS) was also found and it appeared to respond quickly to changes in cosmic rays, SR power and the solar radio flux [108]. Relationship between geophysical factors and human health is also apparent not only on the just mentioned physical level, but also on a larger societal scale. An increase in these geophysical factors are associated with increased social unrest [122], motivation [159] and human flourishing [46].

Looking at the links between geophysical activity factors and human health, it is important to consider what level these links appear in more detail. Rollin McCraty et al. [104] conducted a 31-day study, where they examined synchronization of human ANS rhythms with GMA and found that correlation between changes in solar acitivity and GMA and changes in human nervous system activity is evident. This correlation appears to be a result of not just a response to, but also a synchronization with the time-varying magnetic fields. A likely explanation for that relationship and influence might be that the human nervous system resonantly couples with geomagnetic frequencies (Alpha waves) or ultra-low frequency standing waves (Delta and Theta waves) that overlap with human physiological rhythms [104].

The interactions between autonomic neural activity, blood pressure, respiration and higher-level control centers in the brain produce both short and longer-term rhythms in HRV measurements [112]. HRV is typically used as an indicator of ANS function and dynamics. HRV can also be described as an indicator of functional status of interdependent regulatory systems that operate to help a person to adapt to environmental and psychological challenges [150].

Research examining HRV measures have flourished in recent decades [112, 114, 173]. Many studies have demonstrated a link between GMA and incidents of coronary disease and myocardial infarction and significant decreases in HRV during magnetic storms were identified [20, 33, 40, 104]. Also, the relationship between higher number of myocardial infarction and changes in the local GMF high frequencies (Gamma waves) was observed [75].

In a study conducted in 1998 [42], low-frequency geomagnetic rhythms were compared with EEG rhythms, blood pressure, heart rate, and reaction times. The study results showed that the oscillations in both heart and brain patterns changed simultaneously with the changes in GMA. Kevin S. Saroka and Michael A. Persingerb [145] examined the relationship between human EEG and GMF and found a close interaction between cerebral cortical activity and local GMF, confirming a direct GMF impact on human emotions. Experiments conducted by Tatyana Zenchenko et al. [195] examined healthy individuals' heart rates at rest and compared them with low-frequency variations between 0.5–3.0 MHz in the GMF. The researchers found that in two-thirds of the experiments, there was a synchronization between the heart rhythms and the rhythms in the GMF that occurred between 4 and 30 minute-long periods.

Eliyahu Stoupel et al. [164] have showed that GMA, accompanied by high cosmic ray activity (neutron activity), is significantly linked to a rise in more medical emergencies and the total numbers of daily deaths. Anticipatory reactions, occurring several days before the onset of a magnetic storm, have also been observed, with significant alterations in various participants' physiological health parameters including blood pressure, HRV, heart rate, etc. [40, 41, 85, 104].

In another study performed by Stoupel [168], low GMA was associated with more sudden deaths, some increase in electrical heart instability number of ventricular and supraventricular extra systoles and higher rate of ventricular tachycardia. Tachysystolic sudden cardiac death (related to ventricular tachycardia and ventricular fibrillation) is significantly more often observed in conditions accompanied by higher cosmic ray (neutron) activity and lower GMA [167]. GMA level was also found to be negatively correlated with the monthly occurrence of pregnancy-induced hypertension [168].

As HRV was described as an indicator of ANS, one of the conclusions that the described in his findings propose is that daily ANS activity reacts to changes in geomagnetic and solar activity and that its responses are initiated at different times after the changes in GMA and persist over different lengths of time. Also important is that different individuals respond differently to those changes [4, 85].

Research in the field of heliobiology [132], over a period of approximately 30-years came to the following conclusions, defining relationship between health effects and geomagnetic disturbances:

- Geomagnetic disturbances have a greater effect on humans at higher geomagnetic latitudes.
- Unusually high values of GMA have an effect on human cardiovascular health.
- Unusually low values of GMA seem to have a negative effect on human health.
- About 10–15% of people are significantly negatively affected by geomagnetic disturbances.
- HRV is negatively correlated with geomagnetic variations.

After reviewing all the mentioned findings which reveal a very complex relationship between environmental geophysical factors and human health, there might be a question whether it would be better for living organisms to be isolated from GMA? A study investigating healthy subjects who were isolated from the GMF and who were compared to a control group, showed a significant increase of 17% in capillary blood flow and average reduction of 2 mmHg in diastolic blood pressure [57]. A few studies examining animal health have shown a pronounced effect of hypo-magnetic fields on their cardiovascular system. The serious anomalies in the development of the cardiovascular system have been revealed in the experiments on Japanese quail embryos [176]. Another study was conducted by NASA Laboratory with four healthy young adults selected for service in the Navy. They were exposed during 10 days in “zero magnetic field” (the magnetic field did not exceeded 50 nT), after which an influence of hypo-magnetic conditions on the certain cognitive tests in comparison to the control unexposed group was detected. However, differences in blood pressure and heart rate during the study were not statistically significant [11].

To summarize the discussed peculiarities on GMA and health outcomes, we should first define certain stable features of GMA, which are the following:

- GMF changes over time and extends from Earth’s inner core to where it meets the solar wind.
- The solar wind is responsible for the overall Earth’s magnetosphere (the sphere protecting the Earth). Fluctuations in its speed, density, direction, and other features strongly affect Earth’s local space environment and technological, biological and ecological systems.
- Every living organism on Earth has a specific sensitivity to the strength and frequency of GMF fluctuations.

Many different factors play a mediating role in the influence of GMA on different health parameters. Some of these factors include the condition of health status, HRV functioning, even the quality of interpersonal relationships. All the discussed findings reveal a very complex relationship between environmental geophysical factors and human health.

It can be concluded that geophysical environment is evidently linked to human health in different levels and different patterns, affecting human behavioral and health outcomes, the nervous and cardiovascular systems being especially impacted. Obviously, this relationship is affected by many factors, including maturity of a person, quality of interpersonal relationships, current state of one's health, and many more. Also, this relationship is complex, occurring not only in observed time intervals, but also as a synchronization process.

3. MATERIAL AND METHODS

3.1. Procedure and study sample

For optimal and reasonable research design, consultations and pieces of advice were obtained from the HeartMath Institute research department, which has a long-term experience in studying the GMA related factors. In order to thoroughly examine the GMA related health factors, a two-phase study was conducted (further – *Study 1* and *Study 2*). On 23 December, 2015, Kaunas Regional Ethics Committee for Biomedical Investigations granted the permission for our research (no. BE-2-51) (Annex 1).

For the ***Study 1***, 20 participants were recruited. The main objective of this study was to assess the synchronization between the HRV time series of each participant and the magnetic field data. This information was then used to construct clusters of participants within the group based on the estimated synchronization between their HRV and the magnetic field. Finally, to examine whether an emotional state has an effect on synchronization with GMA.

The mean age of the 20 participants in the *Study 1* was 23.3 (SD 0.6) years, consisting of 16 females and 4 males. All participants were medical students from the Lithuanian University of Health Sciences. All participants underwent daily 24-hour ambulatory HRV recordings during a two-week period between 26 February and 12 March, 2015. Prior to the start of the study, each participant received instructions on attaching, starting, and stopping the recorders when necessary (for instance, when taking a shower). Participants were instructed to stop the recorder each morning after waking up as they started the day, and allowed up to 50 minutes to shower or bathe before reattaching the recorder and starting the new day's recording. *Ambu Blue Sensor VL* microporous breathable disposable electrodes were used for all of the recordings. The electrodes were placed in a modified V5[1] position. To minimize skin irritation over the two weeks, participants were encouraged to locate the electrodes around three different positions near the V5 electrode sites. All of the HRV recordings were downloaded from the File Transfer Protocol site to a computer workstation and analyzed using the numerical computing environment *DADiSP 6.7*. The local time stamps in the HRV recordings were converted to Coordinated Universal Time (UTC) to enable

[1] For measuring the potentials close to the heart, an American cardiologist Frank Norman Wilson introduced the precordial leads (chest leads) in 1944 [187]. These leads, V1–V6, are located over the left chest. The points V1 and V2 are located at the fourth intercostal space on the right and left side of the sternum; V4 is located in the fifth intercostal space at the midclavicular line; V3 is located between the points V2 and V4; V5 is located at the same horizontal level as V4 but on the anterior axillary line; V6 is at the same horizonal level as V4 but at the midline [187].

synchronization between the five locations that took part in the study and the magnetic field data sets.

In addition to the gathered HRV data, each person's quality of interactions between each other within the participating group during the two-week study period were assessed. At the end of each day each participant was asked to make a list of other participating individuals who they had interacted with that day (if any) and rate whether the interaction had positively (+1) or negatively (−1) affected their state that day.

In the middle of this two-week period, on 5 March, the group participated in a 15-minute coherence technique, in order to analyze whether their inner psycho-emotional state can influence personal relationship with GMF fluctuations.

There was a broad range of scientists and specialists from different fields of science working together in this study, including specialists from applied mathematics, geophysics, cardiology, psychology, etc. New mathematical methods were developed during the analysis of this study and innovative algorithms were constructed for the computation of geometrical synchronization [174].

It is worth mentioning that the *Study 1* was performed in 5 countries globally at the same time each of which were locations where the local magnetometers had been installed (Canada, Lithuania, New Zealand, Saudi Arabia and the USA).

Results from the *Study 1* raised a hypothesis that local geomagnetic field strength fluctuations may have an impact on individuals' health and wellbeing, therefore, *Study 2* was designed with a larger sample.

After the implementation of *Study 1*, it was decided that a two-week observational period is optimal when observing GMF fluctuations. The results obtained in the Study 1 raised a hypothesis that GMF fluctuations may have impact on individuals' health and wellbeing, therefore *Study 2* was planned. For the Study 2, it was decided to gather self-reported data about participants' health and wellbeing parameters.

Study 2 was conducted during 2016 by organizing five waves, each of which lasted 14 consecutive days (Fig. 3.1.1). After collecting the necessary data from the study participants after all five waves, the accurate local GMF data, according to the dates when each study wave took place, was received. GMF data was received by each of the study date's average score, and also by accurate score of each hour of the days when the study took place.

Fig. 3.1.1. *Conducted study waves by date and number of subjects*

It was decided to examine young adults aged 18–39 years residing in the city of Kaunas (Lithuania). The study participants were recruited using the convenience sampling, collaborating with various companies and organizations that agreed to take part in the study. During the meeting with each recruited group of participants, each participant was personally given an envelope with the study questionnaires for 14 days (Annex 2). Participants were informed about the study's aim, process and the right to withdraw their participation at any time upon one's will. In addition, during the instruction meeting with the study participants, the candidates were informed about the minimum and maximum age required for the study. The questionnaires with respondents' age outside the age range of this study, were not further processed into the study database and were eliminated from further analysis. A total of 264 participants' data were included into the final study database. Each study participant filled out the questionnaire 14 days in a row, once per day. All five study waves included unique participants, meaning that each participant of the study took part only in one of the five organized waves. All participants had to indicate the exact time each day they were filling in the questionnaires. Participants were asked, if possible, to fill out the questionnaires during the first part of the day.

The minimum required sample size for the study was calculated based on the general population aged 18–39 years, residing in Kaunas city. The population size was based on data from Statistics Lithuania about Kaunas city population aged 18–39 years, which in total comprised 90,806 persons. This was considered as the target population, and further sample size calculations were based on the formula for proportions below [144, p. 23]:

$$n = \frac{z^2 \times p \times (1-p)}{\left(1 - \frac{1}{N}\right) \times \Delta^2 + \frac{z^2 \times p \times (1-p)}{N}}$$

In our case, the N = 90,806, z = 1.96, p = 0.20 (based on pilot observations), and Δ = 0.05. This ends in the minimum sample size of n = 246.

Table 3.1.1 presents the main characteristics of the *Study 2* participants. As seen in the table, the majority of the study sample were females (70%), and over 70% of the participants were 19–29 years old. Regarding their family status, the majority (66.5%) of the participants were not married at the time of the study, and over half of the total sample (53.4%) indicated having obtained secondary education. In total, 63% of the participants reported no regular physical activity in their everyday lifestyle.

Table 3.1.1. *Main characteristics of the Study 2 sample*

Characteristic	Group	n	%
Gender	Male	79	30.0
	Female	184	70.0
Age	19–29 years	187	70.8
	30–39 years	77	29.2
Family status	Not married	175	66.5
	Married	55	20.9
	Divorced	16	6.1
	Lives with a partner	17	6.5
Education	Primary	1	0.4
	Secondary	140	53.4
	Vocational	18	6.9
	Non-university level higher	12	4.6
	Bachelor's degree	40	15.3
	Master's degree	46	17.6
	Higher than master's degree	5	1.9
Physical activity	Regular	91	37.0
	Not regular	155	63.0
Weight	69.3 ± 15.4 kg		
Height	173.4 ± 9.1 cm		
Body mass index	22.9 ± 3.8		

3.2. Assessment tools

Geomagnetic field (*Study 1* and *Study 2*)

The local GMF intensity was measured using the magnetometer located in Lithuania which is a part of the Global Coherence Monitoring Network [109]. The place for the magnetometer installation was chosen in the territory of The Institute of Animal Science of Lithuanian University of Health Sciences, located in Baisogala (Radviliskis district). Two magnetic field detectors (Zonge Engineering ANT-4) at the site are positioned in the north-south and east-west axes to detect local time-varying magnetic field strengths (sensitivity 1 pT) over a wide frequency range (0.01–65 Hz) while maintaining a flat frequency response. The data acquisition infrastructure captures, then stamps the global positioning system time, and transmits the data to the common server. Processes recorded by every magnetometer in the network are continuously sampled at a rate of 130 Hz.

The magnetometer values are uploaded to the central server at the end of each hour, and the time required for the upload is about one minute. So, the magnetometer data contains one-minute-long periods of missing data for each hour. Hourly data files are downloaded to a personal computer (PC) workstation for post-processing where each hourly data file was transformed into consecutive 30 s long segments. The power spectral density (PSD) was calculated for each segment. All PSD segments for each hour were then averaged together. The sum of the PSD in the frequency range from 0–66 Hz was calculated for each hour in the study period.

The data from the magnetometers is able to be differentiated across six different frequency ranges: 0–3.5 Hz, 3.5–7 Hz, 7–15 Hz, 15–32 Hz, 32–66 Hz, and 0–66 Hz, which makes it possible to conduct different analyses by examining different aspects of each of the frequency ranges. Mean power of local magnetic field fluctuations in Lithuania, measured in pT in five different frequency ranges, overlaps between the Schumann resonance and EEG frequency ranges.

An example of magnetic field intensity series is shown in Fig. 3.2.1.

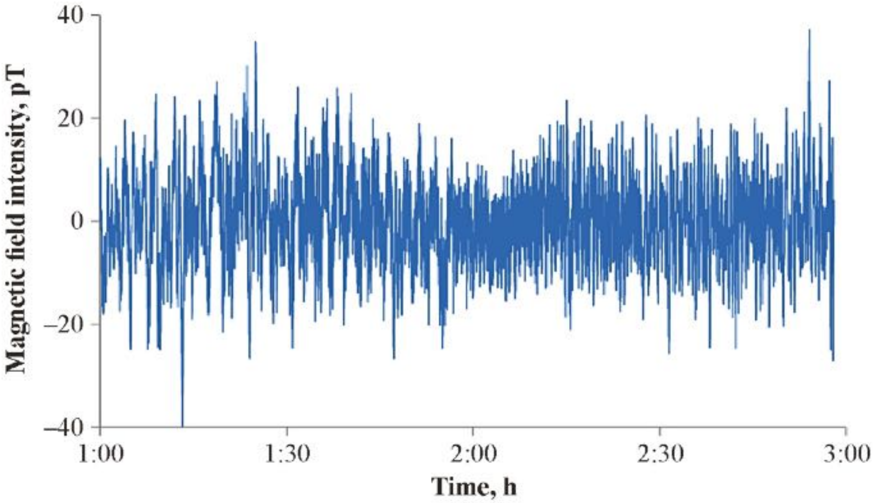


Fig. 3.2.1. *An example of the local magnetic field intensity data (measured in Lithuania during the time period between 2015/02/26 01:00:01 and 2015/02/26 03:00:01)*

An example of the spectrogram $S(\theta, \omega)$ of the magnetic field signal depicted in Fig. 3.2.1 for $\Delta\theta = 4$ *hours*, $\omega \in [0; 52]$ *Hz* is displayed in Fig. 3.2.2.

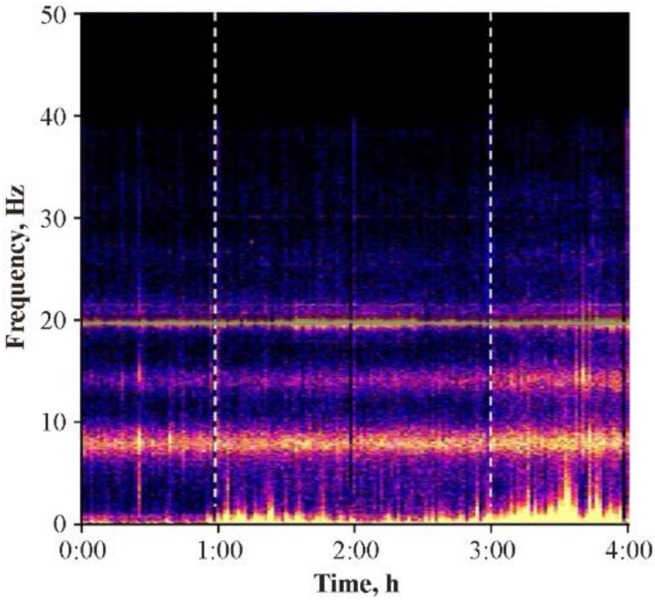


Fig. 3.2.2. *An example of the spectrogram for the magnetic field data presented in Fig. 3.2.1. Frequency resolution is* $\frac{1}{4096}$, $\Delta\theta = 4$ *hours*, $\Delta\omega = 52$ *Hz*, $\omega \in [0; 52]$ *Hz*

Under the permission of HeartMath Institute, Lithuanian magnetometer data are constantly supervised and handled by mathematicians at Kaunas University of Technology, with which Lithuanian University of Health Sciences signed a cooperation agreement together with HeartMath Institute in 2014, and in 2020 it has been officially extended for the next five years.

Heart Lock-In Technique (*Study 1*)

In order to examine whether inner state of an individual is associated with geomagnetic field fluctuations, the Heart Lock-In® coherence technique was performed during the *Study 1*. On March 5th, the group of the study participated in the Heart Lock-In Technique for a 15-minute period. The Heart Lock-In Technique, introduced in 1992, focuses on building the capacity to sustain heartfelt positive emotions. Because it helps to instate or lock in new patterns, the Heart Lock-In Technique is considered an emotional restructuring technique. The technique has been shown to increase coherence in an individual's heart rhythms.

The Heart Lock-In Technique is generally practiced for five to fifteen minutes at a time, although longer sessions may also be used. The steps of the Heart Lock-In are:

- Step 1: Focus your attention in the area of the heart. Imagine your breath is flowing in and out of your heart or chest area, breathing a little slower and deeper than usual.
- Step 2: Activate and sustain a regenerative feeling such as appreciation, care or compassion.
- Step 3: Radiate that renewing feeling to yourself and others [110].

Use of this technique is typically accompanied by feelings of peace, harmony, and sense of inner warmth, and is often an effective means to relieve accumulated stress and negative feelings [113].

HeartMath is a registered trademark of Quantum Intech, Inc.

HRV data collection *(Study 1)*

HRV is a noninvasive measure that reflects activity and dynamics of ANS. All participants of the *Study 1* underwent daily 24-hour ambulatory HRV recordings during a two-week study period (Bodyguard2, Firstbeat Technologies Ltd., Jyväskylä, Finland). The HRV recorder calculates the RR interval (time interval between two consecutive heartbeats) from the electrocardiogram sampled at 1000 Hz. The RR interval data were stored locally in the device memory, and downloaded to a computer workstation at the completion of the study. All of the HRV recordings were downloaded from a file transfer protocol site to a computer workstation and analyzed using the numerical computing environment *DADiSP 6.7*. Inter-Beat-Intervals (IBI) greater or less than 30% of the mean of the previous four intervals were considered artifacts, and were excluded from further analysis.

Daily recordings were processed in consecutive 5-minute segments in accordance with the standards established by the HRV Task Force. An example of a regular (equidistant) time series of time intervals between heart-beats is shown in Fig. 3.2.3.

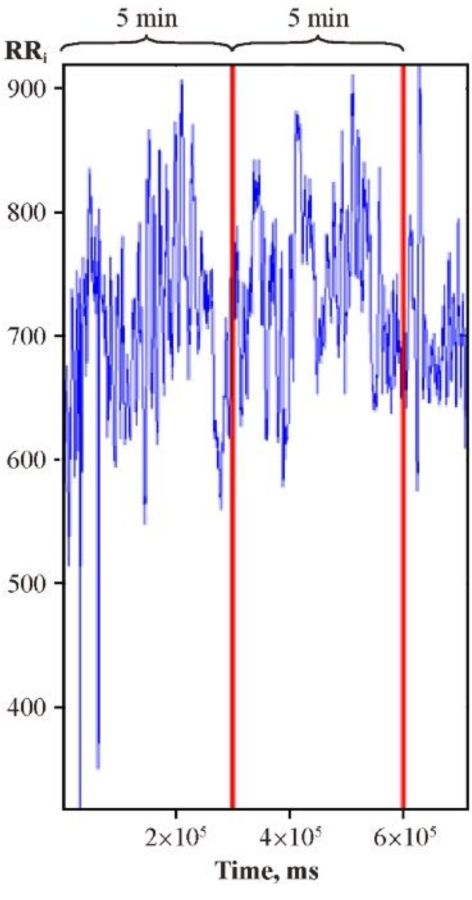


Fig. 3.2.3. *An example of a regular (equidistant) time series of time intervals between heartbeats*

Any 5-minute segment with >10% of the IBIs either missing or removed in editing were excluded from the analysis. The local time stamps in the HRV recordings were converted to Coordinated Universal Time (UTC) to enable synchronization between the five locations globally and magnetic field data sets [105].

12-Item Short Form Survey (SF-12) (*Study 2*)

SF-12 has been extensively used as a valid measure of self-reported health-related quality of life in a variety of population groups [66]. The original survey was developed from the Medical Outcomes Study (MOS), a multi-year study of patients with chronic conditions, resulting in a 36-item Short-Form Health Survey SF-36 [184]. The SF-12v2®covers the same eight health domains as the SF-36 with substantially fewer questions, making it a more practical research tool for many investigators who must restrict survey length. The eight health domains are the following:

- General health;
- Physical functioning;
- Role physical;
- Body pain;
- Vitality;
- Social functioning;
- Role emotional;
- Mental health.

The instrument has been validated across a number of populations [18, 25–27, 142], including adults population in Kaunas city [90] – the same city where the discussed main study of this dissertation was conducted. It is noteworthy that the mentioned study examined 25–84-year-old adults, showing that the methodology is applicable to both younger and older individuals. Many scientific researches have confirmed the survey's sensitivity to observing individuals' mental and physical changes.

The questionnaire consists of twelve items that measure the aforementioned eight health domains to assess physical and mental health. Physical health-related domains include:

- General health (1 item);
- Physical functioning (2 items);
- Role physical (2 items);
- Bodily pain (1 item).

Mental health-related scales include:

- Vitality (1 item);
- Social functioning (1 item);
- Role emotional (2 items);
- Mental health (2 items).

Answers to the questions are scored. To calculate the physical and mental health-related scores we used the QualityMetric Health Outcomes Scoring Software 4.5. The software applies a norm-based scoring algorithm empirically derived from the data of a US general population survey, where a mean of 50 and a standard deviation of 10 are recommended in order to facilitate cross-cultural comparison of results. The possible scores for the physical and mental health-related scales can range from 0 (the worst) to 100 (the best). Scores are calibrated in a way that 50 reflects the average score or norm. A higher total score indicates a better subjectively evaluated health state [185].

SF-12® is a registered trademark of *Medical Outcomes Trust* and all survey users are required a formal licensure by *QualityMetric Incorporated*. After signing a non-commercial license agreement, *QualityMetric Incorporated* shared a validated questionnaire form in Lithuanian language. The translation and validation process was supervised and certified by *Health Research Associates* in 2012.

Subjective health dimensions (*Study 2*)

In addition to SF-12 questions, the subjects were asked to provide their answers to four questions regarding their physical vitality, emotional vitality, social connectedness and overall wellbeing. These questions were constructed cooperating with the HeartMath Institute research director Rollin McCraty. The constructed questions were:

Physical Vitality – what is the current level of your physical energy?

Emotional Vitality – what are you feeling right now?

Social Connectedness – what is the current quality of your social relationships?

Overall Wellbeing – how do you feel about your life right now?

For the used Lithuanian version in the study, see Annex 2.

Subjects had to assess each of the questions by Likert scale from 1 to 5. A higher total score of 14 study days reflects better subjectively evaluated health indicator.

The internal consistency of these items in the study sample was $\alpha = 0.852$.

Additional information *(Study 2)*

Subjects of the study were also asked to fill in information about their marital status, age, weight, height, education level, gender and physical activity.

3.3. Data analysis

Study 1

Computation of the synchronization of HRV and GMF

In order to estimate the synchronization between the HRV time series of each participant during the initial study and the GMF fluctuations, the following steps were implemented:

1. The power of the local GMF was computed using Algorithm A:
   - Compute the spectrogram $S(\theta, \omega)$, as described in [174].
   - Crop the spectrogram $S = \min\{S; S_{crop}\}$ in order to eliminate intermittent chaotic outbreaks in the measured data due to manmade noise, lightening, etc.
   - Apply the Gaussian median filter of dimensions 3×3 for the reduction of noise.
   - Compute the signal power as $P = \sum_{\omega=\omega_{min}}^{\omega_{max}} \left(\frac{1}{\Delta\theta} \sum_{t=t_0}^{t_1} S(t, \omega) \right)$.

Following the described algorithm, the signal power time series is the sum of the values of the spectrogram corresponding to the specified frequency and time intervals.

2. A straightforward Algorithm B was applied for the computation of the area of the embedded attractor based on the direct assessment of the geometric area occupied by the set of points of the trajectory matrix in the state space:
   - Compute the center of the mass of the points comprising the attractor. Move the origin of the state space to the center of the mass;
   - Divide the state space of the attractor into the slices with equal central angles of a circle centered on the origin. The number of slices depends on the number of points in the observation window of the time series;
   - Set the radius of each slice to the maximal distance between a point belonging to that slice and the origin;
   - Compute the area of the attractor S_τ as the sum of areas of all slices.

3. The Algorithm C was constructed for the estimation of geometrical synchronization between two time series:
   - Divide signals X and Y into T observation windows of size m (m should be large enough to enable the reconstruction of a meaningful attractor in the state space):
     $(X_1, \dots, X_m), (X_{m+1}, \dots, X_{2m}), \dots, (X_{n-m+1}, X_n)$;
     $(Y_1, \dots, Y_m), (Y_{m+1}, \dots, Y_{2m}), \dots, (Y_{n-m+1}, Y_n)$.
   - Compute optimal time lags for each observation window for both time series using Algorithm B. This information reduction algorithm allows identification of similarities between attractors reconstructed from different time series from the geometrical point of view. The variation of optimal time lags reconstructed for a pair of time series is used for the quantification of the generalized geometrical synchronization between those time series;
   - Calculate the vector of absolute differences between obtained optimal time lags for each observation window:
     $\tau_{*j}^{(X,Y)} = \left|\tau_{*j}^{(X)} - \tau_{*j}^{(Y)}\right| \ (j = \overline{1,T})$.
   - In order to identify the slow dynamics reflecting averaged changes in absolute differences between optimal time lags for each data signal, divide the vector of absolute differences into $F = \frac{T}{h}$ segments: $\left[\tau_{*(h\cdot(i-1)+1)}^{(X,Y)}, \dots, \tau_{*(h\cdot i)}^{(X,Y)}\right] \ (i = \overline{1,F})$. The number of points h in each segment should be large enough to produce a meaningful averaging.
   - Calculate the mean absolute difference $\bar{\tau}_i^{(X,Y)} = \frac{1}{h}\sum_{j=1}^{h} \tau_{*(h\cdot(i-1)+j)}^{(X,Y)} \ (i = \overline{1,F})$ between optimal time lags for each segment. The obtained vector of mean absolute differences $A^{(X,Y)} = \left[\bar{\tau}_1^{(X,Y)} \bar{\tau}_2^{(X,Y)} \dots \bar{\tau}_F^{(X,Y)}\right]$ is defined as a measure representing the geometrical synchronization between data signals X, Y.

More detailed procedure of the construction and implementation of the computational method, as well as the process of validation is thoroughly described in [174].

Identification of clusters in the group based on the similarity/ synchronization between participants' HRV and GMA

In order to identify clusterization of the study group of 20 people based on synchronization of their HRV with fluctuations in GMA (these fluctuations are reflected by the power of the local magnetic field data), the below procedure was implemented.

Suppose a set of time series $X^{(k)} = (X_1^{(k)}, \ldots, X_n^{(k)}), k = \overline{1, K}$ and a master time series $M = (M_1, \ldots, M_n)$ are given. The objective of the following procedure is to compare and clusterize time series $X^{(k)}$ $(k = \overline{1, K})$ based on their synchronization in respect to the master time series M. The steps of **Algorithm D** read:

1. Compute the vector of mean absolute differences $A^{(X^{(k)},M)} = [\bar{\tau}_1^{(X^{(k)},M)} \ldots \bar{\tau}_F^{(X^{(k)},M)}]$, describing the relationship between $X^{(k)}$ and M as described in **Algorithm C**, for each $X^{(k)}, k = \overline{1, K}$.
2. Calculate the Euclidean distance (the measure used to estimate the geometrical similarity of two data vectors) which represents the similarity between all K data signals, using the following formula:
$$\left\| A^{(X^{(i)},M)} - A^{(X^{(j)},M)} \right\|_2 = \\ = \sqrt{\left(\bar{\tau}_1^{(X^{(i)},M)} - \bar{\tau}_1^{(X^{(j)},M)}\right)^2 + \cdots + \left(\bar{\tau}_F^{(X^{(i)},M)} - \bar{\tau}_F^{(X^{(j)},M)}\right)^2}, \\ i, j = \overline{1, K}.$$

The above equation yields the symmetric matrix of Euclidean distances.

3. Construct a dendrogram plot (UPGMA) [159], using the obtained matrix. The main goal of the dendrogram is to identify the clusters of similar time series, i.e. the clustering process involves grouping the analyzed time series based on the similarity of the slower rhythm dynamics of their synchronization with master time series M.

Study 2

The study data were entered and checked for inconsistencies and errors using MS Excel 2007 package. The analyses of the study data were conducted using IBM SPSS Statistics 23.0 version statistical package. The significance level was set at $P<0.05$.

In univariate analysis, the continuous indicators were presented with means and standard deviations (SD), the categorical data – with percentages and absolute prevalence (n). In order to use the parametric statistical methods, the normality of distributions was estimated using skewness and kurtosis, with the criterion of absolute values below 2 as a cutoff for acceptance of normality. Numeric and visual data on the normality parameters of analyzed health indicators is shown in Annex 3. For non-parametric indicators the median and interquartile range (IQR) was calculated.

The biopsychosocial wellbeing and health indicators were analyzed using parametric methods, because in the majority of the cases the indicators followed the Gaussian distribution. The comparison of means by gender and by age group was conducted using the independent samples t-test with regard to Levene's test for homogeneity of variances. Subgroups comparison by age and gender were corrected using Bonferroni method.

Since the geomagnetic fluctuations were not fully following the Gaussian distribution, the correlations between biopsychosocial and geomagnetic indicators were calculated using non-parametric approach, i. e. the Spearman's rho correlation coefficient. Given the presence of weak correlations in the correlational analysis (being below 0.20 in almost all cases), the coefficients in absolute value less than 0.10 were considered negligible, while that of 0.10 and more were considered as slightly stronger.

In order to examine the possible effects not only occurring simultaneously but with lagging intervals, the analysis also included measurements of GMF strengths with laggings of 12, 24, 36 and 48 hours, that is, the analyzed health indicators were associated with GMF strengths at actual time, and then with strengths after 12, 24, 36 and 48 hours. For subgroup analyses, the stratified groups approach was used.

In order to establish whether the GMF associates with the analyzed wellbeing and health indicators, the multivariate logistic regression analysis was also performed. The calculations included the adjustment for age, gender, physical activity, and season of the year. The strength of particular factors was expressed in odds ratios (OR) with 95% confidence intervals (CI), indicating the difference of likelihood for better state of analyzed wellbeing and health indicator comparing target groups with reference groups (OR = 1.00). For the GMF, the effect was calculated for 100 pT difference.

Dichotomization was based on median of every particular variable (Table 3.3.1).

Table 3.3.1. *Dichotomization of analyzed wellbeing and health indicators in multivariate analysis*

	Worse condition	**Better condition**
SF physical	20.06–55.39	55.42–89.87
SF mental	6.45–45.32	45.33–89.89
Physical vitality	1–3	4–5
Emotional vitality	1–3	4–5
Social connectedness	1–3	4–5
Overall wellbeing	1–3	4–5

4. RESULTS

4.1. Geomagnetic field fluctuations in Lithuania

Two figures below are shown to reflect the GMF fluctuations starting from June, 2014, when it started to record the data from the local GMF detecting magnetometer installed in Lithuania, until March, 2020 (Figs. 4.1.1 and 4.1.2). As the figures below reveal, there was a trend of decreasing GMF strength from 2014 till 2016, however, since 2017 there has been an obvious increase each year. In addition, it can be observed that the GMF levels are increasing in the first 6 months of the year and then decrease. This pattern was consistent across all observed years.

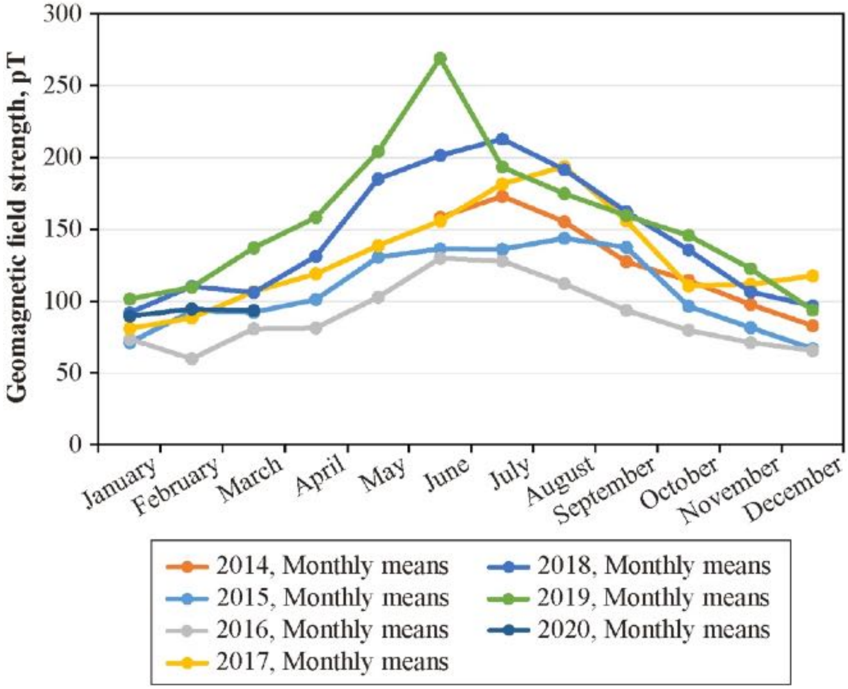


Fig. 4.1.1. *Dynamics of geomagnetic field strength from June 2014 to March 2020: monthly trends*

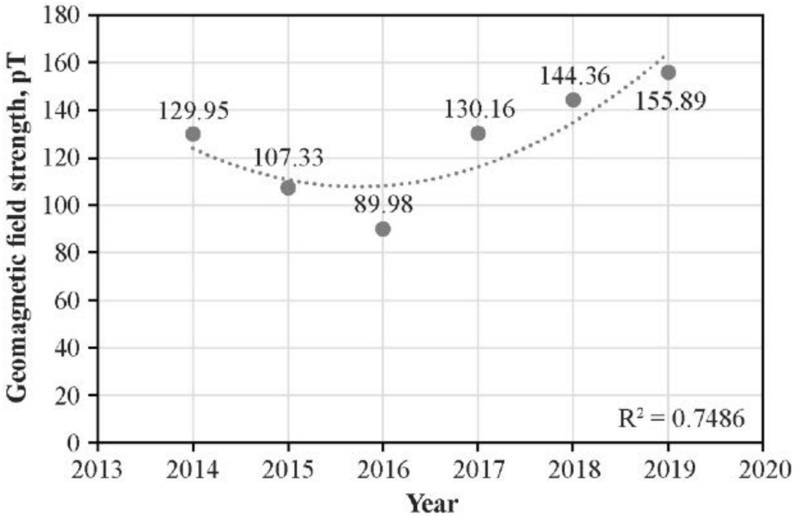


Fig. 4.1.2. *Dynamics of geomagnetic field strength from June 2014 to end of 2019: yearly trends*

R^2 – determination coefficient; ● – mean of geomagnetic field strength.

SR frequencies, captured during the period of *Study 1*, were associated with the main characteristics of the global magnetic field and space weather. Results of the correlational analysis are given in Table 4.1.1. As it may be seen, significantly strong correlations (P<0.05) were observed between the lowest frequency range (0–3.5 Hz) with Kp and Ap indices. Index f10.7 revealed negative significant correlation with three frequency ranges (3.5–7 Hz, 7–15 Hz and 15–32 Hz).

Table 4.1.1. *Associations between Schumann Resonances and main characteristics of the global geomagnetic field (Spearman's correlation coefficients)*

Global GMF indicators	Frequency 0–3.5 Hz	Frequency 3.5–7 Hz	Frequency 7–15 Hz	Frequency 15–32 Hz	Frequency 32–66 Hz	Frequency 0–66 Hz
Solar wind [km/s]	0.4031	–0.3373	–0.1818	–0.2165	–0.1055	–0.1387
Kp Index	**0.5958**	–0.3600	–0.1520	–0.3256	–0.3901	–0.2754
Ap Index	**0.7124**	–0.1995	–0.0086	–0.1502	–0.3361	–0.1327
R Sunspot number	0.3074	0.1675	0.0247	–0.0792	–0.2788	–0.1033
f10.7 Index	0.1209	**–0.7246**	**–0.4970**	**–0.4332**	–0.1427	–0.3743

Note: **bold** indicates P<0.05.

In order to evaluate the dynamics of changes in GMF during the *Study 2* period, the figure below is shown to reflect the averaged estimates of GMF by weeks throughout 2016, when the *Study 2* took place (Fig. 4.1.3). As the figure shows, the strongest GMF throughout 2016 was recorded in the first week of August, and the weakest – in the second week of November.

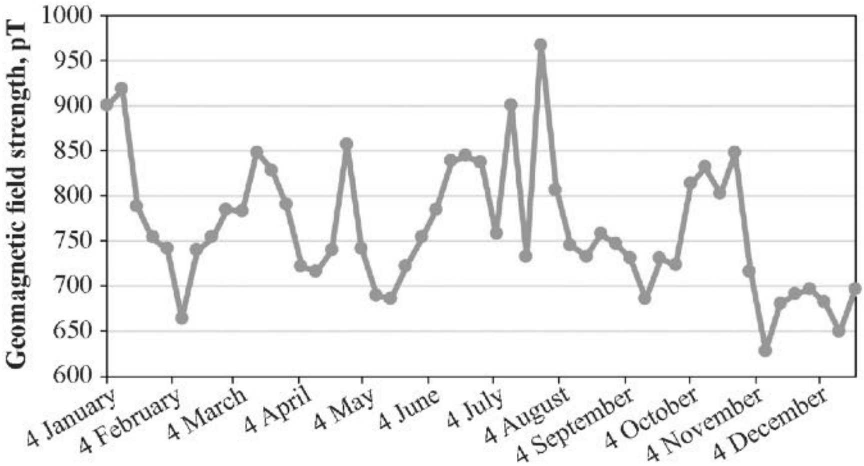


Fig. 4.1.3. *Dynamics of geomagnetic field strength by weeks, 2016*

Further, the dynamics of GMF was also assessed by separate week days. The figure below (Fig. 4.1.4) reflects the means of each week day, assessed throughout 2016. As seen in the figure, at the beginning of the week, GMF reaches its peak strength, and then from Tuesday until Saturday it has a tendency of decreasing, reaching its weakest point on Saturday. Sarting on Sunday, it might increase again.

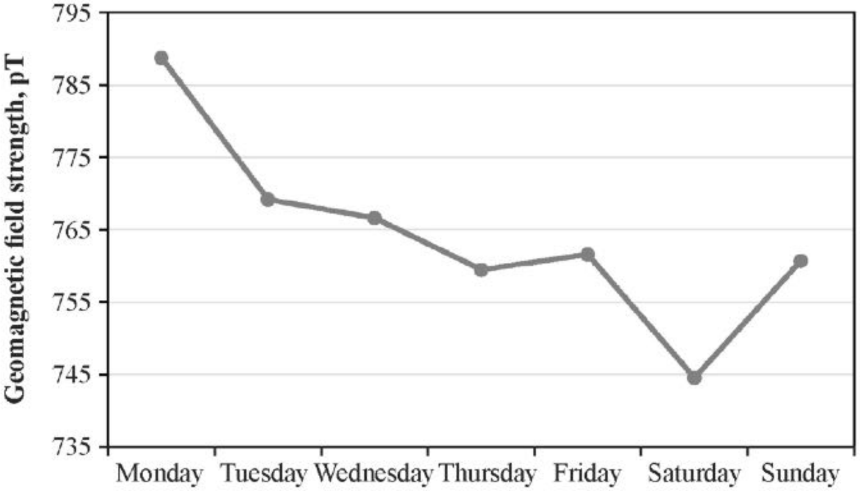


Fig. 4.1.4. *Dynamics of geomagnetic field strength in weekdays, 2016*

Summarizing the subchapter, it can be noted that local GMF through 2016 reached its peak in the late summer time (first week of August), and the weakest point was observed in the late fall time (second week of November). Summarizing the dynamics of local GMF fluctuations from June, 2014 till March, 2020, it is evident that there was a trend of decreasing GMF strength from 2014 till 2016, however, since 2017 there has been an obvious increase each year. In addition, it can be observed that GMF levels are increasing in the first 6 months of the year and then go decreasing.

4.2. Biopsychosocial wellbeing parameters

Study 1

Participants' HRV was measured by ambulatory HRV recorders (Bodyguard2, Firstbeat Technologies Ltd., Jyväskylä, Finland). Each participant underwent daily 24-hour ambulatory HRV recordings. Data on the participants' RR intervals, calculated by the HRV recorded electrocardiograms, is depicted in Fig. 4.2.1. Each row in the figure represents one participant of the study during the whole study period of 14 consecutive days. As seen in the figure, participants' RR intervals varied from 584.77 to 1014.80 ms.

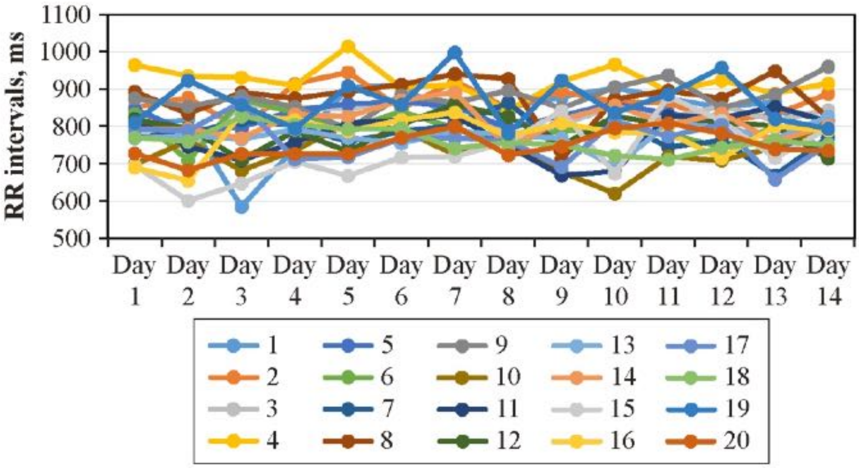


Fig. 4.2.1. *Data on participants' RR intervals during the Study 1 period*

The quality of participants' interaction data is shown in Table 4.2.1. The first column as well as the first row of the table show the participant number for each of the 20 participants. The numbers in the intersection rows and columns equal the sum of the row person ratings of the interaction with the column person ratings over the 14 days. If, for example, the row person specified three positive and two negative interactions with the column person during the two-week study period, the overall interaction value will equal 1. It can be seen that the matrix is nonsymmetric, which means that if the column person positively or negatively affected the row person, this does not necessarily imply that the opposite is true. The matrix is also sparse, since participants did not complete this part of the survey if interactions did not occur.

Table 4.2.1. *Data on participants' interpersonal interaction*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1			–1	–1						2		2					1			–1
2										1						2				
3																				
4			–1								4									
5																				
6																				
7																				3
8																				
9			2		1													6		
10		4				1	1					1			4	1	1			1
11				1																
12	2		1			1													–1	
13		1	4	2							8					1				3
14			2																	
15																	2			
16		2																		
17																				
18																				
19	1	1	2			1	2		1		1	2	1			1		1		
20			1	1			3				1									

In order to illustrate the interaction data, the questionnaire matrix was visualized using the directed weighted graph visualization technique (Fig. 4.2.2). A line with an arrow pointing from person *a* to person *b* represents that person *a* felt positive about person *b*. The width of the line is proportional to the number of times such an interaction did occur. The graph gives a clearer picture of "mutual affection" between the participants. Five participants' pairs (7 and 20; 2 and 16; 4 and 11; 2 and 10; 1 and 12) can be clearly identified. However, it is important to note that the "mutual affection" for pairs 4 and 11; 2 and 10 was not "balanced", since the thickness of lines (4 and 11; 11 and 4) as well as lines between (2 and 10; 10 and 2) is substantially different. Consequently, only the pairs 7 and 20; 2 and 16; and 1 and 12 show bilateral "mutual positive interactions".

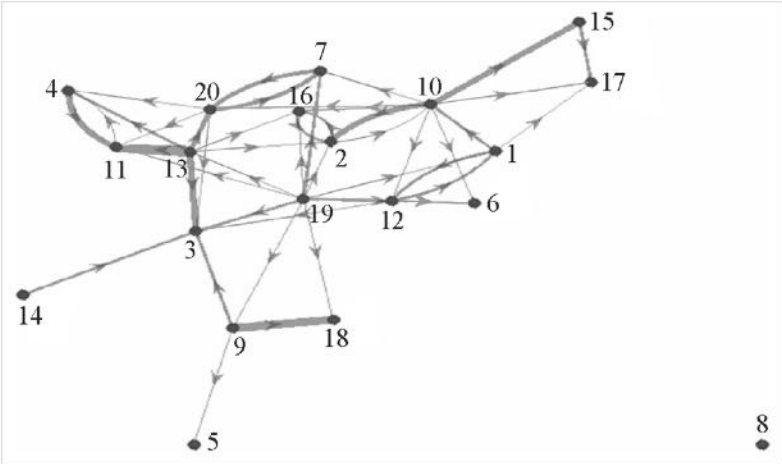


Fig. 4.2.2. Evaluated interaction levels between participants. Nodes represent participants (numbered from 1 to 20). A line with an arrow pointing from person a to b, represents that person a feels positive about person b. The width of the line is proportional to the overall (a and b) interaction value (sum of a's ratings of the interaction with the b's ratings throughout the 14 days)

Study 2

Participants' biopsychosocial wellbeing and health was measured using a 12-Item Short Form Survey (SF-12), which provides two scores, reflecting a person's physical and mental subjectively evaluated health status. In addition, participants had to answer four questions about their subjectively perceived physical vitality, emotional vitality, social wellbeing and overall wellbeing, providing their answers on Likert scale from 1 to 5. It is important to note, that each participant had to assess his/her health status 14 days in a row. The Table 4.2.2 shows the overall data of each participant's 14 days assessments.

As seen in the table below, the study participants scored just above average when assessing their physical health with SF-12 instrument, and their mental health was scored below average with the same instrument, meaning that the SF-12 questionnaire revealed better physical health among the study sample than mental health. Four other questions were scored above average with social connectedness showing the highest score, and physical vitality the lowest score.

Table 4.2.2. *Biopsychosocial wellbeing and health parameters*

Indicator	Mean ± SD	Median (IQR)	Skewness	Kurtosis
Physical Vitality	3.47 ± 1.10	3 [3–4]	–0.31	-0.39
Emotional Vitality	3.62 ± 1.08	4 [3–5]	–0.37	-0.40
Social Connectedness	3.88 ± 1.06	4 [3–5]	–0.68	-0.21
Overall Wellbeing	3.70 ± 1.13	4 [3–5]	–0.66	-0.16
SF-12 Physical Health Domain	53.6 ± 7.0	55.4 [50.1–58.0]	–1.02	1.66
SF-12 Mental Health Domain	44.8 ± 10.4	45.3 [37.9–52.4]	–0.36	-0.13

Additionally, we examined whether the analyzed wellbeing and health parameters differ by gender (Table 4.2.3). As seen in the Table 4.2.3, statistically significant differences were found when assessing SF-12 Mental and Physical health, and also when measuring participants' physical, emotional vitality and overall wellbeing. In all five cases, better health parameters were observed among men (P<0.05). Indicator of social connectedness had also a trend of being better among men than women, though not significantly.

Table 4.2.3. *Biopsychosocial wellbeing and health indicators by gender*

Indicator	Men	Women	t	*P*
Physical Vitality	3.64 ± 1.06	3.40 ± 1.12	5.88	**<0.001**
Emotional Vitality	3.73 ± 1.06	3.57 ± 1.08	3.91	**<0.001**
Social Connectedness	3.92 ± 1.04	3.87 ± 1.07	1.37	0.172
Overall Wellbeing	3.83 ± 1.13	3.65 ± 1.13	4.45	**<0.001**
SF-12 Physical Health Domain	54.5 ± 6.1	53.3 ± 7.4	4.70	**<0.001**
SF-12 Mental Health Domain	46.1 ± 10.1	44.2 ± 10.6	5.20	**<0.001**

Note: **bold** indicates P<0.05.

Table 4.2.4 provides the data on comparing the analyzed wellbeing and health parameters in different age groups. The conducted analysis revealed that age is significantly related to five out of six analyzed health indicators. The participants aged 30–39 years were prone to assess their physical, emotional vitality, social connectedness, overall wellbeing and mental health as being better than younger participants (P<0.05).

Table 4.2.4. *Biopsychosocial wellbeing and health indicators by age group*

Indicator	19–29 years	30–39 years	t	*P*
Physical Vitality	3.40 ± 1.11	3.65 ± 1.06	–6.18	**<0.001**
Emotional Vitality	3.55 ± 1.09	3.80 ± 1.02	–6.47	**<0.001**
Social Connectedness	3.84 ± 1.08	4.00 ± 0.99	–4.09	**<0.001**
Overall Wellbeing	3.60 ± 1.15	3.97 ± 1.03	–9.23	**<0.001**
SF-12 Physical Health Domain	53.5 ± 7.2	53.9 ± 6.5	–1.62	0.104
SF-12 Mental Health Domain	44.0 ± 10.7	46.8 ± 9.4	–7.60	**<0.001**

Note: **bold** indicates P<0.05.

We also examined gender differences in both age groups. Table 4.2.5 reveals that men aged 30–39 expressed better condition across all six analyzed wellbeing and health indicators compared to younger men (19–29) and compared to women of the same age group. Men aged 19–29 indicated better SF mental health than women of the same age group. Women aged 30–39 reported higher scores in emotional vitality, overall wellbeing and SF mental health than younger women aged 19–29.

Table 4.2.5. *Biopsychosocial wellbeing and health indicators by gender and age*

Indicator	Men		Women	
	19–29 years	30–39 years	19–29 years	30–39 years
Physical Vitality	**3.46 ± 1.06**§	**3.96 ± 0.97**§*	3.37 ± 1.13	**3.48 ± 1.08***
Emotional Vitality	**3.61 ± 1.06**§	**3.94 ± 1.01**§*	**3.51 ± 1.10**§	**3.72 ± 1.02**§*
Social Connectedness	**3.77 ± 1.08**§	**4.20 ± 0.88**§*	3.86 ± 1.07	**3.87 ± 1.02***
Overall Wellbeing	**3.67 ± 1.17**§	**4.15 ± 1.00**§*	**3.56 ± 1.14**§	**3.87 ± 1.03**§*
SF-12 Physical Health Domain	**53.9 ± 6.6**§	**55.6 ± 4.9**§*	53.5 ± 7.4	**53.1 ± 7.1***
SF-12 Mental Health Domain	**45.1 ± 10.4**§*	**48.4 ± 8.8**§*	**43.7 ± 10.9**§*	**45.8 ± 9.8**§*

Note: § – different from same gender's another age group (P<0.05), * – different from same age group's another gender (P<0.05).

Summarizing the subchapter, it can be highlighted that physical health among the study sample was evaluated better than mental health. Also, the analysis revealed that gender and age have significance when evaluating wellbeing and health – men and older participants were prone to assess tha majority of analyzed indicators as being better than women and younger participants.

4.3. Associations between biopsychosocial wellbeing and health parameters, and local geomagnetic field fluctuations

4.3.1. *Study 1*

4.3.1.1. Emotional state and synchronization between HRV and GMF

When examining the effect of the coherence technique on synchronization with GMA, it was found that synchronization (positive correlation) between participants' HRV and GMA (Fig. 4.3.1.1.1) on the day when the Heart Lock-In Technique was applied was the highest, which means that all participants were highly positively correlated/synchronized with the local GMF during the day of the application of the Heart Lock-In Technique, which contrasted with the synchronization results with the days before and after the coherence training. Interestingly, the same phenomenon was observed in each of the other locations of the study worldwide. The obtained result implies that such coherence techniques are significant not only psychologically, but also physiologically, since high synchronization between HRV and GMA can help maintain better health conditions.

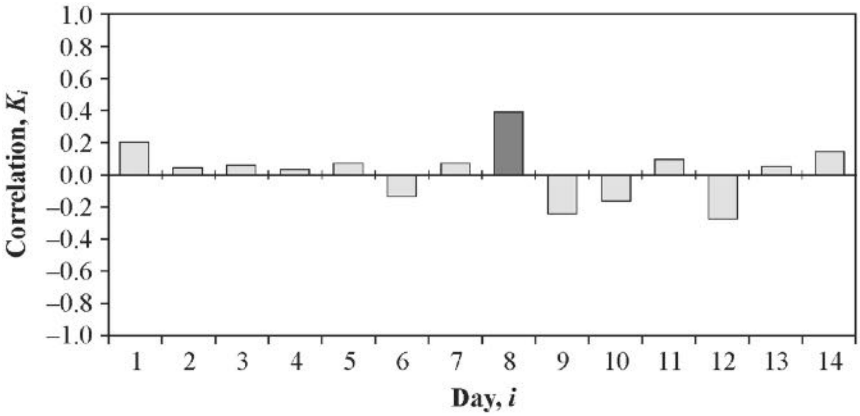


Fig. 4.3.1.1.1. *Mean of Heart Rate Variability/Geomagnetic Activity synchronization for each day of the Study 1 (n = 20)*

4.3.1.2. Identification of clusters based on synchronization between HRV and GMF

Algorithm D was applied to the experimental data (described in Data analysis section) in order to identify clusters of participants based on the slow dynamics of the synchronization between the participants' HRV and the power of local magnetic field.

According to **Algorithm D** time series $X^{(k)}, k = \overline{1,20}$ represent the participants' HRV data collected during the *Study 1*. The master time series M corresponds to the time series of the power of the local magnetic field measured during the time of the study.

Since **Algorithm D** employs **Algorithms B** and **C**, the corresponding parameters for both of those algorithms had to be selected:

1. One of the steps of **Algorithm C** is splitting the participants' HRV and local magnetic field power time series into segments. The standard length of analysis for HRV is 5-minutes. Thus, RR interval and magnetometer data was split into 5-minute segments for analysis. Note that since HRV data consists of time intervals between each pair of heartbeats, the number of samples in the data vectors corresponding to each 5-minute segment vary due to changes in the participants heart rate and other factors which influence HRV, such as stress and emotional states. Since the power of the local magnetic field was computed for 1 second time intervals, the resulting 5-minute segments consisted of the same number of elements (300 data points). However, the difference in the size of the segments of HRV and the power of the local magnetic field time series did not impact the overall result of the study, since all of the segments represented the same concurrent 5-minute time intervals.
2. We selected the number of slices in **Algorithm B** to be 60 because it was empirically observed that a higher number would result in some empty slices.
3. The maximal value of τ in **Algorithm B** is set to 50. Higher values of τ would generate too short trajectory matrices, because the 5-minute segments consist of approximately 300 elements.
4. The value of the parameter h in **Algorithm C**, used for identification of slow dynamics of the synchronization between the two time series, was set to 48. This corresponds to 4-hour averaging of the difference of the optimal time lags. It was observed that this value of h produced the most meaningful averaging.

5. As noted in section 3.2. the magnetometer data contained one-minute-long periods of missing data at the end of each hour. Since these periods in the time series did not contain any information, it was necessary to remove those periods in such a way that would not disrupt the timing between the HRV and magnetic field time series. The solution we implemented was to remove the missing data segments from both the 5-minute magnetometer data and from the 5-minute RR interval series. Since the cropped series obtained after this procedure fully defined the 5-minute series, they were used in the data reduction step.

We applied the clusterization technique on two-day and two-week data sets collected during the study (see Section 3.3) in order to determine how the time span of the data set impacts the quality of the clusterization.

First we analyzed two days of data (2015/02/27 18:05:00 through 2015/03/01 18:05:00). Therefore, each individual's HRV and the magnetometer data consisted of 576 5-minute segments, i.e. $T = 576$.

According to the first step of **Algorithm D** the vector of mean absolute differences $A^{(X^{(k)},M)}$ was computed as described in **Algorithm C**, for each $X^{(k)}, k = \overline{1,20}$. The execution of this step is demonstrated in Fig. 4.3.1.2.1.

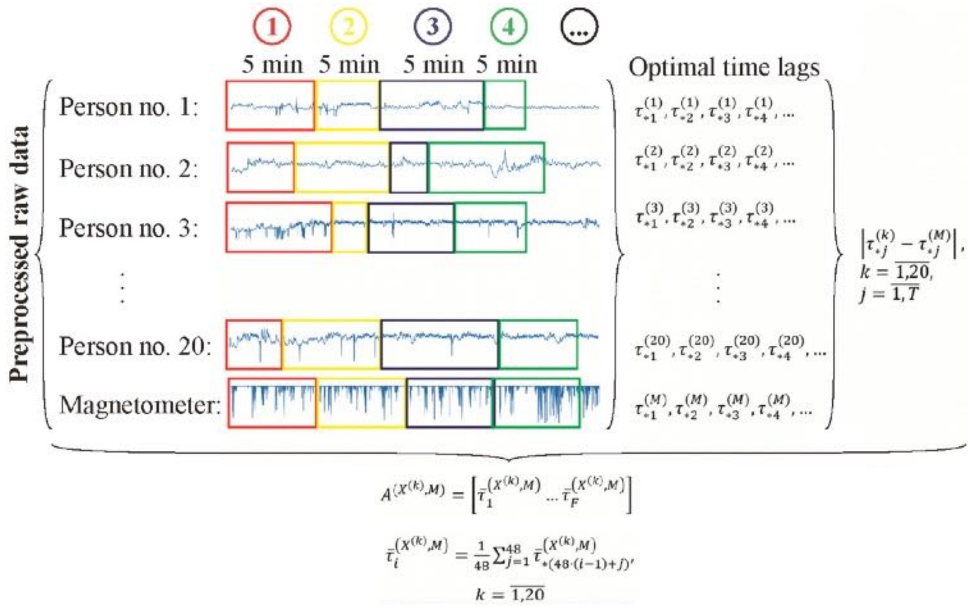


Fig. 4.3.1.2.1. *The scheme of the application of* ***Algorithm C*** *on the study data. The horizontal axis of the depicted data corresponds to the indices of time series*

The application of steps 2 and 3 of **Algorithm D** to the two-day (2015/02/27 18:05:00 through 2015/03/01 18:05:00) data resulted in the dendrogram plot depicted in Fig. 4.3.1.2.2.

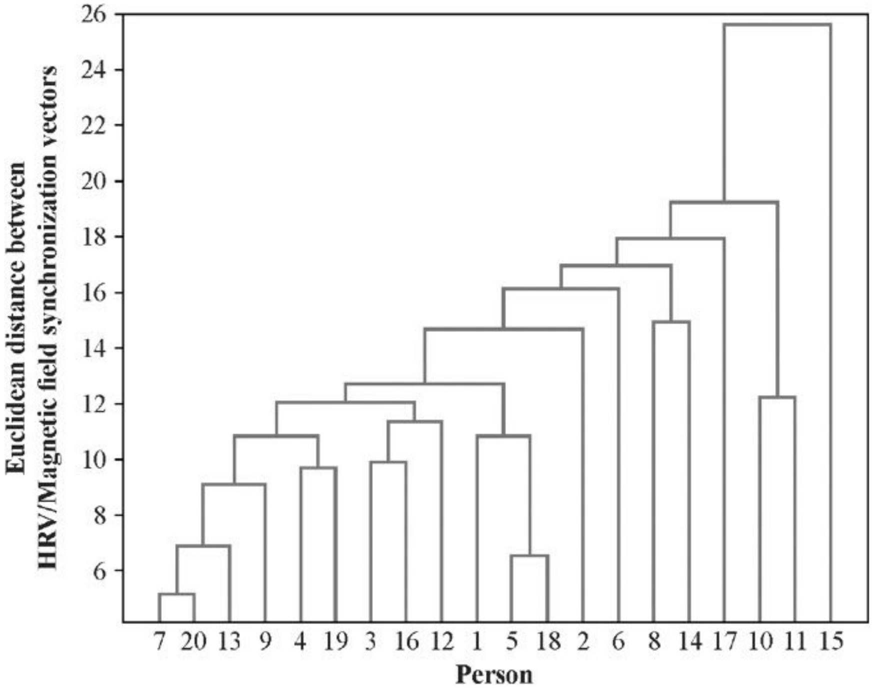


Fig. 4.3.1.2.2. *Dendogram plot for the two-day (2015/02/27 18:05:00 through 2015/03/01 18:05:00) data. Numbers on the X axis represent participants (numbered from 1 to 20)*

The dendrogram depicted in the Fig. 4.3.1.2.2 is a visual representation of the geometrical synchronization between HRV and magnetic field for all 20 participants. Numbers on the X axis represent participants. The height of the branches of the dendrogram is proportional to the Euclidean distance between HRV/Magnetic field synchronization vectors for corresponding participants.

It can be seen in the Fig. 4.3.1.2.2 that participants no. 7 and 20 are the closest (or most similar) in the sense of synchronization between their HRV and local magnetic field power time series. The Euclidean distance between the HRV/Magnetic field synchronization for the pair of participants no. 7 and 20 is equal to 5.15. On the opposite, the 15^{th} participant's synchronization with the magnetic field is least similar to any of the remaining participants.

The variation of the slow dynamics of the synchronization (**Algorithm C**) for a pair of participants no. 7 and 20 as well as no. 7 and 15 is also illustrated in Figs. 4.3.1.2.3 and 4.3.1.2.4, respectively. It can be seen that there is a strong visible similarity between the synchronization dynamics for participants 7 and 20, meaning that they are similarly synchronized with the local magnetic field, and, form a cluster in the dendrogram (Fig. 4.3.1.2.2). On the other hand, there is no visible similarity in the synchronization dynamics of individuals no. 7 and 20, indicating that the relationship between HRV and magnetic field activity for those participants is unlikely (Fig. 4.3.1.2.4). The Euclidean distance between the HRV/Magnetic field synchronization for the pair of participants no. 7 and 20 is equal to 30.09.

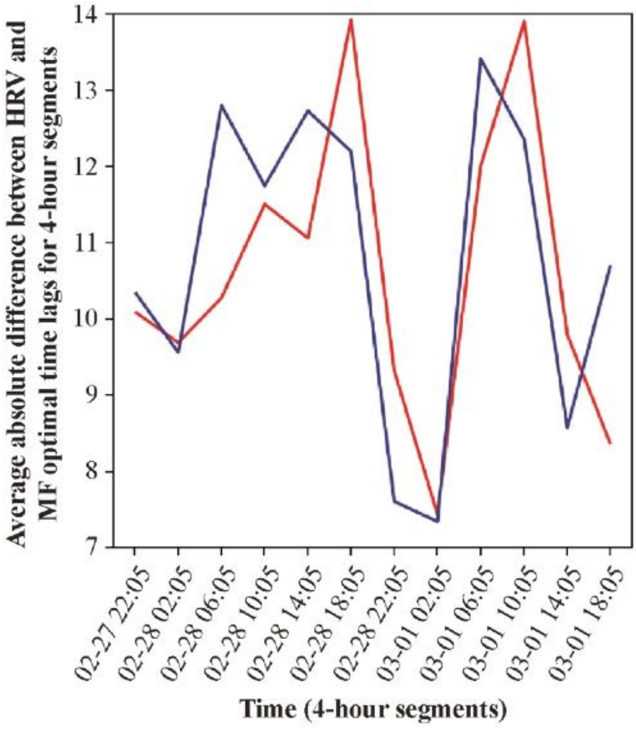


Fig. 4.3.1.2.3. *The variation of the slow dynamics of the geometrical synchronization constructed from optimal time lags for person no. 7 (red line) and person no. 20 (blue line) for the time period between 2015/02/27 18:05:00 – 2015/03/01 18:05:00*

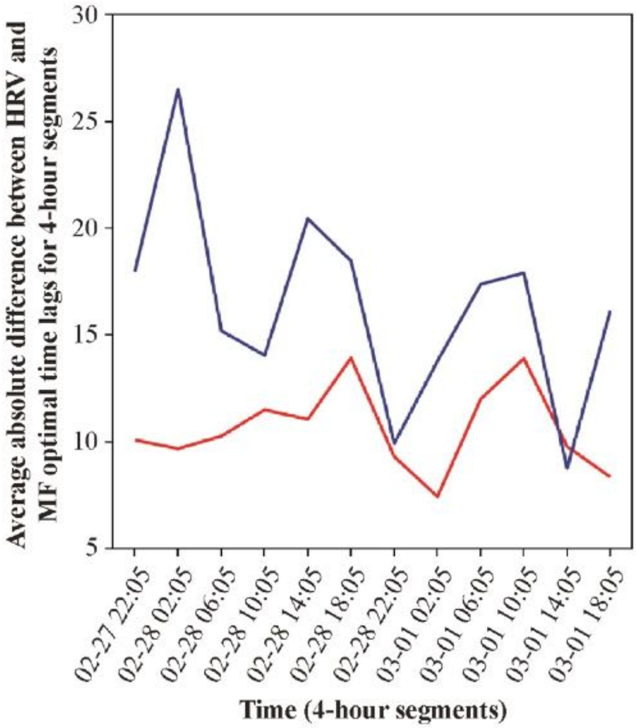


Fig. 4.3.1.2.4. *The variation of the slow dynamics of the geometrical synchronization constructed from optimal time lags for person no. 7 (red line) and person no. 15 (blue line) for the time period between 2015/02/27 18:05:00 – 2015/03/01 18:05:00*

Next, the dendrogram plot (Fig. 4.3.1.2.5) for the entire two-weeks ($T = 4032$) of the study was obtained in an identical manner. The comparison of the two-day (Fig. 4.3.1.2.2) and two-week (Fig. 4.3.1.2.5) clusterization results shows that the use of the data with the longer time span provides better quality of clusterization, since the distances between the identified clusters for two-week data (Fig. 4.3.1.2.5) are greater.

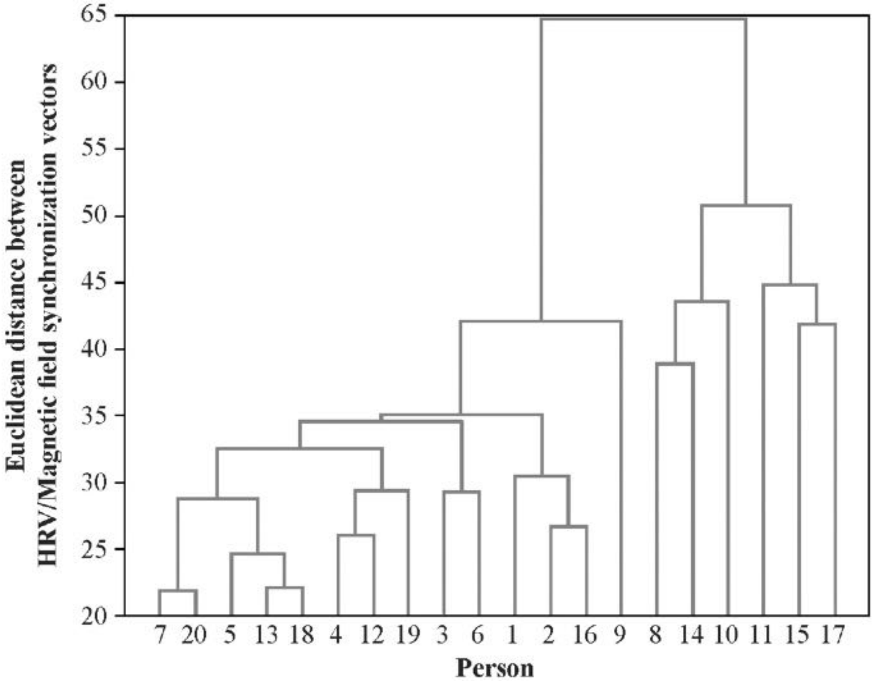


Fig. 4.3.1.2.5. *Dendrogram plot for the two-week data. Numbers on the X axis represent participants (numbered from 1 to 20)*

4.3.2. *Study 2*

In order to evaluate the associations between GMF and health parameters, the discussed health indicators were analyzed at actual time and also with lagging effects of 12, 24, 36 and 48 hours. The analysis was conducted in the total sample and among subgroups by season, gender, age, and physical activity.

Due to the large amount of statistical data, results in the tables of this subchapter are presented excluding *P* values. Exact *P* values of analyzed correlations can be found in Annex 4.

4.3.2.1. Associations between geomagnetic field strength and biopsychosocial wellbeing and health indicators: comparison by actual and lagging time

Table 4.3.2.1.1 presents data about associations between different GMF frequency ranges and analyzed wellbeing and health indicators at actual time and with lagging intervals of 12, 24, 36 and 48 hours. The data reveals very weak statistically significant correlations between all frequency ranges and different wellbeing and health indicators, however, in the majority of the cases the correlations were very poor (<0.10). Slightly stronger (>0.10) correlations appeared when assessing mental health with SF instrument, with 12- and 36-hour laggings and only in the three lowest frequency ranges (0–3.5 Hz, 3.5–7 Hz and 7–15 Hz).

Tables 4.3.2.1.1, 4.3.2.3.1, 4.3.2.3.2, 4.3.2.3.3, 4.3.2.3.4 represent Spearman's correlation coefficients.

Table 4.3.2.1.1. *Wellbeing and health indicators and geomagnetic field at actual time and with lagging intervals*

Lag	**Health indicator**	**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
0 h	Physical vitality	0.040*	0.039*	0.020	0.015	–0.005	0.014
	Emotional vitality	0.029	0.027	0.015	0.008	0.000	0.010
	Social connectedness	–0.016	–0.023	–0.036*	–0.022	0.012	–0.002
	Overall wellbeing	0.052*	0.047*	0.034*	0.030	0.007	0.027
	SF physical	0.029	0.036*	0.042*	0.050*	0.017	0.040*
	SF mental	0.048*	0.027	0.001	0.004	0.029	0.027
12 h	Physical vitality	0.034*	0.035*	0.035*	–0.003	–0.033	–0.018
	Emotional vitality	0.042*	0.052*	0.064*	0.034*	–0.008	0.012
	Social connectedness	0.038*	0.041*	0.058*	0.031	0.005	0.022
	Overall wellbeing	0.038*	0.037*	0.030	0.001	–0.015	–0.003
	SF physical	0.008	0.012	0.000	–0.022	–0.011	–0.012
	SF mental	**0.102***	**0.110***	**0.119***	0.065*	–0.026	0.026
24 h	Physical vitality	0.015	0.011	0.005	0.004	–0.002	0.000
	Emotional vitality	0	–0.007	–0.002	–0.004	–0.007	–0.008
	Social connectedness	–0.033	–0.038*	–0.048*	–0.034*	0.009	–0.018
	Overall wellbeing	0.018	0.021	0.02	0.015	–0.019	–0.004
	SF physical	0.026	0.039*	0.036*	0.044*	0.013	0.032
	SF mental	0.002	–0.012	–0.025	–0.029	–0.018	–0.027
36 h	Physical vitality	0.035*	0.042*	0.046*	0.009	–0.031	–0.014
	Emotional vitality	0.040*	0.053*	0.063*	0.037*	–0.006	0.009
	Social connectedness	0.016	0.033	0.054*	0.03	0.007	0.014
	Overall wellbeing	0.032	0.038*	0.038*	0.011	–0.014	–0.006
	SF physical	–0.028	–0.019	–0.02	–0.022	–0.004	–0.015
	SF mental	0.093*	**0.107***	**0.109***	0.050*	–0.015	0.026

Table 4.3.2.1.1. *Continued*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
48 h	Physical vitality	0.019	0.02	0.006	0.006	–0.016	–0.007
	Emotional vitality	–0.005	–0.013	–0.023	–0.027	–0.036*	–0.042*
	Social connectedness	–0.041*	–0.043*	–0.058*	–0.051*	–0.036*	–0.055*
	Overall wellbeing	0.018	0.017	0.003	–0.011	–0.051*	–0.039*
	SF physical	0.03	0.045*	0.035*	0.031	–0.015	0.012
	SF mental	–0.013	–0.033	–0.049*	–0.043*	–0.009	–0.034*

Note: **bold** indicates ϱ>0.10; *indicates P<0.05.

Based on the results, given that the possible effects of GMF on wellbeing and health indicators show some lagging patterns, further analysis results throughout 4.3.1 subchapter are presented using actual time and aforementioned lagging intervals (12 hours, 24 hours, 36 hours and 48 hours).

4.3.2.2. Associations between geomagnetic field strength and biopsychosocial wellbeing and health indicators: comparison by season, gender, age, and physical activity

We also examined the relationships by dividing the study period into two seasons – from the beginning of March until 30 June (Spring season), and from 1 July until the end of October (Fall season). This was based on our previous finding (Table 4.1.1) that the GMF has increasing trend in the first half of the year and decreasing – in the second. Also, the analysis included differentiating the study sample by gender, age and physical activity. Due to the large amount of results, all tables related to this subchapter are shown in Annex 5.

When analyzing the relationships during the spring season, each wellbeing and health indicator was found to have weak significant (P<0.05) relationships with different GMF frequency ranges. Among all of the found significant correlations, slightly stronger correlations (>0.10) were observed in the three lowest frequency ranges (0–3.5 Hz, 3.5–7 Hz and 7–15 Hz), and namely assessing SF mental health indicator with 12-hour (0.132 at 0–3.5 Hz range, 0.139 at 3.5–7 Hz and 0.143 at 7–15 Hz) and 36-hour (0.111, 0.124 and 0.130 at the same first three frequency ranges, respectively) laggings (Table A5.1).

The analysis of the relationships during the fall season (Table A5.2) revealed that during the fall season, most of the observed significant correlations occurred in the highest frequency range (32–66 Hz). However, only four out of all observed correlations appeared to be stronger than 0.1. Those four concerned the overall wellbeing and SF physical health indicator with 24-hour and 48-hour laggings.

Further analysis examined whether there are significant differences based on gender. It turned out that among men, associations were found when including lagging intervals, however, at least a little stronger ones (>0.10) appeared namely with 12 and 36 hour laggings when assessing SF mental health indicator, emotional and physical vitality. All the found associations, both weaker and stronger, were observed in first four frequency ranges (0–3.5 Hz, 3.5–7 Hz, 7–15 Hz and 15–32 Hz) (Table A5.3).

Analyzing the relationships among women, all the frequency ranges revealed very weak correlations with different health indicators, however, none of them reached the value of 0.10 (Table A5.4).

Further, we examined the associations based on the participants' age. As can be found in Table A5.5 which presents the associations between health parameters and GMF among 19–29 years old group (younger group in the conducted study), many significant, but weak, associations were found, however, only three of them when assessing SF mental health indicator with 12-hour (0.103 at 0.3.5 Hz range and 0.104 at 3.5–7 Hz range) and 36-hour (0.102 at 3.5–7 Hz range) lags in low frequencies were stronger than 0.1.

When analyzing the associations between health parameters and GMF among the 30–39 year old group (older group in the conducted study), we found many statistically significant, however, weak associations. The strongest (>0.10) being when assessing with 24-hour and 48-hour lags. Most of the associations occurred in the first four frequency ranges. It is also worth mentioning that absolutely all the found significant correlations which were above the value of 0.10 were negative (Table A5.6).

Further analysis examined the associations between analyzed health parameters and GMF among physically active participants. It was found that among the revealed significant associations, the strongest (>0.10) appeared in lower frequencies (0–3.5 Hz, 0–3.5 Hz and 7–15 Hz), and almost all of them, except one (Emotional vitality, assessed at actual time), turned out with 12-hour or 36-hour laggings. Most of the associations were found when assessing SF mental health indicator (Table A5.7).

Examining the associations between analyzed health parameters and GMF among physically passive participants, we found that only one of the found significant correlations reached the value of 0.10. This association appeared when assessing SF mental health indicator with 36-hour lag in a low GMF frequency range (0.102 at 3.5–7 Hz range) (Table A5.8).

4.3.2.3. Geomagnetic field strength and biopsychosocial wellbeing and health indicators: associations in different seasons by gender

Since we found that the possible GMF effects on health are specific by gender and season, we also conducted the subgroup analyses for men in spring and fall, and for women in spring and fall. The results are presented below.

Table 4.3.2.3.1 shows the relationships between the analyzed health indicators and GMF at the actual time among men during the spring season. It was found that physical vitality had weak significant relationship with 0–3.5 Hz frequency range, social connectedness – with 7–15 Hz and 15–32 Hz ranges, and SF physical health indicator – with 7–15 Hz range. None of the mentioned correlations reached the value of 0.10.

Table 4.3.2.3.1. *Wellbeing and health indicators and geomagnetic field during spring season among men*

Health indicator		**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
Physical vitality	rho	0.070*	0.023	–0.036	–0.017	0.031	0.023
	P	0.033	0.493	0.271	0.602	0.352	0.483
Emotional vitality	rho	0.008	–0.008	–0.039	–0.044	0.035	0.011
	P	0.800	0.805	0.236	0.180	0.288	0.733
Social connectedness	rho	–0.034	–0.055	–0.099*	–0.068*	0.026	–0.013
	P	0.301	0.093	0.003	0.039	0.435	0.687
Overall wellbeing	rho	0.013	–0.005	–0.050	–0.048	0.008	–0.008
	P	0.697	0.877	0.126	0.147	0.818	0.803
SF physical	rho	0.047	0.000	–0.082*	–0.029	0.021	0.007
	P	0.156	0.991	0.013	0.385	0.525	0.824
SF mental	rho	0.045	0.007	–0.045	–0.033	0.037	0.014
	P	0.178	0.837	0.176	0.314	0.259	0.680

Note: *indicates $P<0.05$.

Table 4.3.2.3.2 presents the relationships between the analyzed health indicators and GMF among women during the spring season. As seen in the table, physical vitality revealed to have weak significant relationship with four out of six frequency ranges, emotional vitality with five out of six ranges; social connectedness with two frequency ranges; overall wellbeing and SF mental health indicator with all six frequency ranges; and SF physical health indicator with first three frequency ranges. Among all of the analyzed health indicators, overall wellbeing and SF mental health stood out as revealing strongest (>0.10) correlations in all frequency ranges.

Table 4.3.2.3.2. *Wellbeing and health indicators and geomagnetic field during spring season among women*

Health indicator		**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
Physical vitality	rho	0.050*	0.081*	0.059*	0.065*	0.048	0.067*
	P	0.047	0.001	0.020	0.010	0.055	0.008
Emotional vitality	rho	0.085*	**0.104***	0.081*	0.086*	0.045	0.078*
	P	0.001	0.000	0.001	0.001	0.077	0.002
Social connectedness	rho	0.014	0.037	0.020	0.049	0.064*	0.065*
	P	0.581	0.145	0.418	0.051	0.012	0.010
Overall wellbeing	rho	**0.110***	**0.126***	**0.102***	**0.110***	**0.072***	**0.102***
	P	0.000	0.000	0.000	0.000	0.004	0.000
SF physical	rho	–0.096*	–0.079*	–0.064*	–0.049	0.014	–0.027
	P	0.000	0.002	0.011	0.052	0.588	0.293
SF mental	rho	**0.112***	**0.110***	0.079*	**0.103***	**0.106***	**0.124***
	P	0.000	0.000	0.002	0.000	0.000	0.000

Note: **bold** indicates ϱ>0.10; * indicates *P*<0.05.

Table 4.3.2.3.3 shows the relationships between the analyzed health indicators and GMF among men during the fall season. As seen in the table, two out of six, overall wellbeing and SF physical, health indicators revealed weak significant negative relationships with high frequency ranges (32–66 Hz and 0–66 Hz).

Table 4.3.2.3.3. *Wellbeing and health indicators and geomagnetic field during fall season in men group*

Health indicator		**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
Physical vitality	rho	–0.107	–0.076	–0.013	–0.084	–0.144	–0.150
	P	0.221	0.388	0.880	0.338	0.100	0.086
Emotional vitality	rho	–0.082	0.001	0.048	–0.044	–0.091	–0.088
	P	0.348	0.988	0.582	0.619	0.301	0.315
Social connectedness	rho	–0.121	–0.117	–0.135	–0.107	–0.158	–0.151
	P	0.166	0.182	0.122	0.220	0.071	0.083
Overall wellbeing	rho	–0.091	–0.115	–0.119	–0.149	**–0.217***	**–0.200***
	P	0.301	0.191	0.176	0.089	0.013	0.022

Table 4.3.2.3.3. *Continued*

Health indicator		**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
SF physical	rho	–0.019	–0.086	–0.025	–0.090	**–0.190***	**–0.181***
	P	0.825	0.329	0.775	0.307	0.029	0.038
SF mental	rho	0.016	0.105	0.031	–0.038	–0.097	–0.078
	P	0.858	0.232	0.727	0.665	0.270	0.373

Note: **bold** indicates ϱ>0.10; * indicates P<0.05.

Table 4.3.2.3.4 shows the relationships between analyzed health indicators and GMF among women during the fall season. As seen in the table, three out of six analyzed health indicators, namely, physical vitality, emotional vitality and SF physical health, had weak significant relationships with different frequency ranges, however, only assessed physical vitality showed the strongest of all found associations with GMF.

Table 4.3.2.3.4. *Wellbeing and health indicators and geomagnetic field during fall season in women group*

Health indicator		**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
Physical vitality	rho	–0.013	–0.045	–0.014	–0.080*	**–0.108****	**–0.101****
	P	0.721	0.206	0.689	0.023	0.002	0.004
Emotional vitality	rho	–0.045	–0.073*	–0.046	–0.073*	–0.085*	–0.094*
	P	0.202	0.039	0.187	0.038	0.016	0.008
Social connectedness	rho	0.027	–0.023	0.007	–0.005	–0.048	–0.041
	P	0.437	0.515	0.833	0.886	0.172	0.250
Overall wellbeing	rho	–0.003	–0.033	0.022	–0.012	–0.055	–0.055
	P	0.922	0.348	0.531	0.724	0.118	0.122
SF physical	rho	0.041	0.019	0.096*	0.065	–0.014	0.015
	P	0.244	0.587	0.006	0.065	0.687	0.675
SF mental	rho	0.004	–0.021	0.031	–0.041	–0.068	–0.055
	P	0.909	0.546	0.383	0.250	0.055	0.117

Note: **bold** indicates ϱ>0.10; * indicates P<0.05.

4.3.2.4. Multivariate analysis of associations between geomagnetical field strength and wellbeing and health indicators

Based on the correlation analysis results, which highlighted that most significant associations that reached the strength of 0.10 were found with 12- and 36-hour laggings, we also conducted a logistic regression analysis, examining the relationship between the analyzed health indicators and GMF with 12- and 36-hour lagging intervals, in order to eliminate the potential effect of gender, age, season and physical activity on the examined relationship.

As the findings reveal, the increase in GMF with 12-hour lagging interval by 100 pT was associated with better mental health independent of other analyzed factors in the first four frequency ranges (Table 4.3.2.4.1). The highest odds were observed in 3.5–7 Hz frequency interval (OR = 2.02, 95% CI 1.16–3.52). Higher odds were found for men, older and physically active participants compared to women, younger and not physically active individuals. Also, odds of better mental health were higher in fall than in spring. When analyzing the effects with 36-hour lagging, GMF lost its significance for perception of mental health.

Table 4.3.2.4.1. *Associations between SF mental health indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	95% CI		*P*
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.34	1.14	1.58	<0.001
	Age group	Older (Younger = 1.00)	1.60	1.36	1.88	<0.001
	Season	Fall (Spring = 1.00)	1.45	1.24	1.71	<0.001
	Physical activity	Active (Passive = 1.00)	1.45	1.25	1.68	<0.001
	GMF strength	100 pT difference	1.60	1.13	2.28	**0.009**
3.5–7 Hz	Gender	Men (Women = 1.00)	1.34	1.14	1.58	<0.001
	Age group	Older (Younger = 1.00)	1.60	1.36	1.88	<0.001
	Season	Fall (Spring = 1.00)	1.47	1.25	1.73	<0.001
	Physical activity	Active (Passive = 1.00)	1.45	1.25	1.69	<0.001
	GMF strength	100 pT difference	2.02	1.16	3.52	**0.013**
7–15 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.58	1.34	1.86	<0.001
	Season	Fall (Spring = 1.00)	1.45	1.23	1.71	<0.001
	Physical activity	Active (Passive = 1.00)	1.45	1.25	1.69	<0.001
	GMF strength	100 pT difference	1.75	1.21	2.54	**0.003**

Table 4.3.2.4.1. *Continued*

			OR	95% CI		*P*
				from	to	
15–32 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.66	1.41	1.94	<0.001
	Season	Fall (Spring = 1.00)	1.46	1.24	1.72	<0.001
	Physical activity	Active (Passive = 1.00)	1.47	1.26	1.71	<0.001
	GMF strength	100 pT difference	1.31	1.02	1.67	**0.034**
32–66 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.69	1.44	1.99	<0.001
	Season	Fall (Spring = 1.00)	1.48	1.26	1.75	<0.001
	Physical activity	Active (Passive = 1.00)	1.47	1.27	1.71	<0.001
	GMF strength	100 pT difference	1.02	0.96	1.09	0.547
0–66 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.70	1.45	1.99	<0.001
	Season	Fall (Spring = 1.00)	1.45	1.23	1.71	<0.001
	Physical activity	Active (Passive = 1.00)	1.47	1.26	1.71	<0.001
	GMF strength	100 pT difference	1.05	1.00	1.10	0.057

Note: **bold** indicates $P<0.05$ for GMF strength analysis.

Table 4.3.2.4.2. *Associations between SF mental health indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	95% CI		*P*
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.34	1.14	1.58	<0.001
	Age group	Older (Younger = 1.00)	1.62	1.38	1.90	<0.001
	Season	Fall (Spring = 1.00)	1.47	1.25	1.72	<0.001
	Physical activity	Active (Passive = 1.00)	1.46	1.25	1.69	<0.001
	GMF strength	100 pT difference	1.36	0.96	1.92	0.086
3.5–7 Hz	Gender	Men (Women = 1.00)	1.35	1.14	1.58	<0.001
	Age group	Older (Younger = 1.00)	1.64	1.40	1.93	<0.001
	Season	Fall (Spring = 1.00)	1.48	1.26	1.74	<0.001
	Physical activity	Active (Passive = 1.00)	1.46	1.26	1.70	<0.001
	GMF strength	100 pT difference	1.32	0.75	2.31	0.335

Table 4.3.2.4.2. Continued

			OR	95% CI		*P*
				from	to	
7–15 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.62	1.38	1.90	<0.001
	Season	Fall (Spring = 1.00)	1.46	1.24	1.71	<0.001
	Physical activity	Active (Passive = 1.00)	1.46	1.26	1.70	<0.001
	GMF strength	100 pT difference	1.42	0.97	2.08	0.069
15–32 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.66	1.42	1.95	<0.001
	Season	Fall (Spring = 1.00)	1.46	1.24	1.72	<0.001
	Physical activity	Active (Passive =1.00)	1.47	1.26	1.71	<0.001
	GMF strength	100 pT difference	1.22	0.94	1.58	0.142
32–66 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.70	1.44	2.00	<0.001
	Season	Fall (Spring = 1.00)	1.48	1.25	1.74	<0.001
	Physical activity	Active (Passive = 1.00)	1.47	1.27	1.71	<0.001
	GMF strength	100 pT difference	1.03	0.96	1.09	0.424
0–66 Hz	Gender	Men (Women = 1.00)	1.35	1.15	1.59	<0.001
	Age group	Older (Younger = 1.00)	1.69	1.44	1.98	<0.001
	Season	Fall (Spring = 1.00)	1.45	1.23	1.71	<0.001
	Physical activity	Active (Passive = 1.00)	1.47	1.27	1.71	<0.001
	GMF strength	100 pT difference	1.04	0.99	1.09	0.142

As seen in Tables 4.3.2.4.3 and 4.3.2.4.4, GMF fluctuations had no significant affect on perception of physical health. Multivariate analysis revealed that higher odds of better physical state (SF physical health indicator) were observed among the elder group, among physically active participants, in the first half of the year.

Table 4.3.2.4.3. *Associations between SF physical health indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	95% CI		*P*
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.793
	Age group	Older (Younger = 1.00)	1.17	1.00	1.37	0.056
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.010
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.12	0.79	1.58	0.532
3.5–7 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.795
	Age group	Older (Younger = 1.00)	1.17	0.99	1.37	0.058
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.011
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.22	0.71	2.10	0.468
7–15 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.778
	Age group	Older (Younger = 1.00)	1.16	0.99	1.36	0.076
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.009
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.24	0.86	1.77	0.246
15–32 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.769
	Age group	Older (Younger = 1.00)	1.18	1.01	1.38	0.039
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.011
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.06	0.84	1.34	0.613
32–66 Hz	Gender	Men (Women = 1.00)	1.03	0.87	1.21	0.753
	Age group	Older (Younger = 1.00)	1.20	1.02	1.41	0.025
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.009
	Physical activity	Active (Passive = 1.00)	1.26	1.08	1.46	0.003
	GMF strength	100 pT difference	1.03	0.97	1.10	0.388
0–66 Hz	Gender	Men (Women = 1.00)	1.03	0.87	1.20	0.755
	Age group	Older (Younger = 1.00)	1.19	1.02	1.39	0.029
	Season	Fall (Spring = 1.00)	0.80	0.68	0.94	0.008
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.03	0.98	1.08	0.280

Table 4.3.2.4.4. *Associations between SF physical health indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	**95% CI**		**p**
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.03	0.87	1.20	0.762
	Age group	Older (Younger = 1.00)	1.20	1.03	1.41	0.022
	Season	Fall (Spring = 1.00)	0.83	0.71	0.97	0.020
	Physical activity	Active (Passive = 1.00)	1.26	1.09	1.46	0.002
	GMF strength	100 pT difference	0.81	0.57	1.14	0.222
3.5–7 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.765
	Age group	Older (Younger = 1.00)	1.20	1.02	1.40	0.026
	Season	Fall (Spring = 1.00)	0.82	0.70	0.97	0.017
	Physical activity	Active (Passive = 1.00)	1.26	1.09	1.46	0.002
	GMF strength	100 pT difference	0.78	0.45	1.36	0.379
7–15 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.779
	Age group	Older (Younger = 1.00)	1.18	1.00	1.38	0.044
	Season	Fall (Spring = 1.00)	0.82	0.69	0.96	0.013
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.02	0.70	1.49	0.903
15–32 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.776
	Age group	Older (Younger = 1.00)	1.18	1.01	1.38	0.037
	Season	Fall (Spring = 1.00)	0.81	0.69	0.96	0.013
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.45	0.003
	GMF strength	100 pT difference	1.02	0.79	1.32	0.873
32–66 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.764
	Age group	Older (Younger = 1.00)	1.20	1.02	1.41	0.027
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.009
	Physical activity	Active (Passive = 1.00)	1.26	1.08	1.46	0.002
	GMF strength	100 pT difference	1.03	0.96	1.09	0.443
0–66 Hz	Gender	Men (Women = 1.00)	1.02	0.87	1.20	0.773
	Age group	Older (Younger = 1.00)	1.18	1.01	1.38	0.034
	Season	Fall (Spring = 1.00)	0.81	0.69	0.95	0.012
	Physical activity	Active (Passive = 1.00)	1.25	1.08	1.46	0.003
	GMF strength	100 pT difference	1.01	0.96	1.06	0.698

Data in Table 4.3.2.4.5 reveal that an increase by 100 pT with 12-hour lagging in the lowest GMF frequency range (0–3.5 Hz) was strongly associated with better physical vitality (OR = 1.44, 95% CI 1.02–2.04). Higher odds of better physical vitality were observed among men and among older participants – both with 12- and 36-hour laggings (Tables 4.3.2.4.5 and 4.3.2.4.6).

Table 4.3.2.4.5. *Associations between physical vitality indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	**95% CI**		**p**
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.17	1.00	1.38	0.050
	Age group	Older (Younger = 1.00)	1.49	1.27	1.74	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.30	0.215
	Physical activity	Active (Passive = 1.00)	1.14	0.98	1.32	0.092
	GMF strength	100 pT difference	1.44	1.02	2.04	**0.039**
3.5–7 Hz	Gender	Men (Women = 1.00)	1.18	1.00	1.38	0.047
	Age group	Older (Younger = 1.00)	1.50	1.28	1.76	0.000
	Season	Fall (Spring = 1.00)	1.12	0.95	1.31	0.165
	Physical activity	Active (Passive = 1.00)	1.14	0.98	1.32	0.082
	GMF strength	100 pT difference	1.46	0.85	2.50	0.173
7–15 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.042
	Age group	Older (Younger = 1.00)	1.50	1.28	1.76	0.000
	Season	Fall (Spring = 1.00)	1.12	0.95	1.31	0.181
	Physical activity	Active (Passive = 1.00)	1.14	0.99	1.33	0.078
	GMF strength	100 pT difference	1.26	0.88	1.80	0.201
15–32 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.041
	Age group	Older (Younger = 1.00)	1.54	1.32	1.79	0.000
	Season	Fall (Spring = 1.00)	1.13	0.96	1.32	0.148
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.067
	GMF strength	100 pT difference	1.04	0.82	1.31	0.760
32–66 Hz	Gender	Men (Women = 1.00)	1.18	1.00	1.39	0.044
	Age group	Older (Younger = 1.00)	1.52	1.30	1.79	0.044
	Season	Fall (Spring = 1.00)	1.14	0.97	1.33	0.123
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.069
	GMF strength	100 pT difference	0.99	0.93	1.05	0.656

Table 4.3.2.4.5. *Continued*

			OR	95% CI		p
				from	to	
0–66 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.041
	Age group	Older (Younger = 1.00)	1.54	1.32	1.80	0.000
	Season	Fall (Spring = 1.00)	1.12	0.96	1.32	0.160
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.067
	GMF strength	100 pT difference	1.01	0.96	1.06	0.756

Note: **bold** indicates $P<0.05$ for GMF strength analysis.

Table 4.3.2.4.6. *Associations between physical vitality indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	95% CI		p
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.18	1.00	1.38	0.045
	Age group	Older (Younger = 1.00)	1.51	1.29	1.77	0.000
	Season	Fall (Spring = 1.00)	1.12	0.95	1.31	0.180
	Physical activity	Active (Passive = 1.00)	1.14	0.98	1.33	0.079
	GMF strength	100 pT difference	1.21	0.86	1.71	0.272
3.5–7 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.043
	Age group	Older (Younger = 1.00)	1.53	1.31	1.79	0.000
	Season	Fall (Spring = 1.00)	1.13	0.96	1.32	0.146
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.070
	GMF strength	100 pT difference	1.08	0.62	1.87	0.796
7–15 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.042
	Age group	Older (Younger = 1.00)	1.51	1.29	1.77	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.30	0.204
	Physical activity	Active (Passive = 1.00)	1.14	0.99	1.33	0.075
	GMF strength	100 pT difference	1.26	0.86	1.83	0.232
15–32 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.041
	Age group	Older (Younger = 1.00)	1.54	1.32	1.79	0.000
	Season	Fall (Spring = 1.00)	1.12	0.95	1.32	0.174
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.067
	GMF strength	100 pT difference	1.08	0.84	1.40	0.552

Table 4.3.2.4.6. ***Continued***

			OR	95% CI		p
				from	to	
32–66 Hz	Gender	Men (Women = 1.00)	1.18	1.00	1.39	0.044
	Age group	Older (Younger = 1.00)	1.52	1.30	1.79	0.000
	Season	Fall (Spring = 1.00)	1.14	0.97	1.34	0.117
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.071
	GMF strength	100 pT difference	0.98	0.92	1.05	0.580
0–66 Hz	Gender	Men (Women = 1.00)	1.18	1.01	1.39	0.042
	Age group	Older (Younger = 1.00)	1.54	1.32	1.80	0.000
	Season	Fall (Spring = 1.00)	1.13	0.96	1.33	0.148
	Physical activity	Active (Passive = 1.00)	1.15	0.99	1.33	0.067
	GMF strength	100 pT difference	1.00	0.95	1.05	0.983

As further findings reveal (Tables 4.3.2.4.7 and 4.3.2.4.8), increases by 100 pT with 12-hour (OR = 1.48, 95% CI 1.03–2.13) and 36-hour (OR = 1.47, 95% CI 1.01–2.14) laggings was statistically associated with better emotional vitality only in the 7–15 Hz frequency range. Higher odds of better emotional vitality were observed among older and physically active participants.

Table 4.3.2.4.7. *Associations between emotional vitality indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	95% CI		p
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.729
	Age group	Older (Younger = 1.00)	1.53	1.31	1.80	0.000
	Season	Fall (Spring = 1.00)	1.03	0.88	1.21	0.708
	Physical activity	Active (Passive = 1.00)	1.34	1.15	1.55	0.000
	GMF strength	100 pT difference	1.36	0.96	1.93	0.082
3.5–7 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.717
	Age group	Older (Younger = 1.00)	1.54	1.32	1.81	0.000
	Season	Fall (Spring = 1.00)	1.04	0.89	1.22	0.628
	Physical activity	Active (Passive = 1.00)	1.34	1.16	1.56	0.000
	GMF strength	100 pT difference	1.46	0.85	2.53	0.171

Table 4.3.2.4.7. *Continued*

			OR	95% CI		p
				from	**to**	
7–15 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.686
	Age group	Older (Younger = 1.00)	1.52	1.29	1.78	0.000
	Season	Fall (Spring = 1.00)	1.03	0.88	1.21	0.736
	Physical activity	Active (Passive = 1.00)	1.34	1.16	1.56	0.000
	GMF strength	100 pT difference	1.48	1.03	2.13	**0.033**
15–32 Hz	Gender	Men (Women = 1.00)	1.04	0.88	1.22	0.655
	Age group	Older (Younger = 1.00)	1.57	1.34	1.84	0.000
	Season	Fall (Spring = 1.00)	1.03	0.88	1.21	0.676
	Physical activity	Active (Passive = 1.00)	1.35	1.16	1.57	0.000
	GMF strength	100 pT difference	1.19	0.94	1.51	0.146
32–66 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.683
	Age group	Older (Younger = 1.00)	1.58	1.35	1.86	0.000
	Season	Fall (Spring = 1.00)	1.05	0.89	1.23	0.568
	Physical activity	Active (Passive = 1.00)	1.35	1.16	1.57	0.000
	GMF strength	100 pT difference	1.00	0.94	1.07	0.944
0–66 Hz	Gender	Men (Women = 1.00)	1.04	0.88	1.22	0.662
	Age group	Older (Younger = 1.00)	1.59	1.36	1.86	0.000
	Season	Fall (Spring = 1.00)	1.03	0.88	1.21	0.699
	Physical activity	Active (Passive = 1.00)	1.35	1.16	1.57	0.000
	GMF strength	100 pT difference	1.03	0.98	1.08	0.308

Note: **bold** indicates $P<0.05$ for GMF strength analysis.

Table 4.3.2.4.8. *Associations between emotional vitality indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	95% CI		p
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.715
	Age group	Older (Younger = 1.00)	1.53	1.30	1.79	0.000
	Season	Fall (Spring = 1.00)	1.03	0.88	1.21	0.732
	Physical activity	Active (Passive = 1.00)	1.34	1.15	1.55	0.000
	GMF strength	100 pT difference	1.39	0.99	1.96	0.061

Table 4.3.2.4.8. *Continued*

			OR	95% CI		p
				from	**to**	
3.5–7 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.696
	Age group	Older (Younger = 1.00)	1.56	1.33	1.83	0.000
	Season	Fall (Spring = 1.00)	1.04	0.89	1.22	0.611
	Physical activity	Active (Passive = 1.00)	1.35	1.16	1.56	0.000
	GMF strength	100 pT difference	1.23	0.70	2.14	0.471
7–15 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.684
	Age group	Older (Younger = 1.00)	1.53	1.30	1.79	0.000
	Season	Fall (Spring = 1.00)	1.02	0.87	1.20	0.809
	Physical activity	Active (Passive = 1.00)	1.34	1.16	1.56	0.000
	GMF strength	100 pT difference	1.47	1.01	2.14	**0.046**
15–32 Hz	Gender	Men (Women = 1.00)	1.04	0.88	1.22	0.654
	Age group	Older (Younger = 1.00)	1.57	1.34	1.84	0.000
	Season	Fall (Spring = 1.00)	1.02	0.87	1.20	0.816
	Physical activity	Active (Passive = 1.00)	1.35	1.17	1.57	0.000
	GMF strength	100 pT difference	1.29	0.99	1.67	0.056
32–66 Hz	Gender	Men (Women = 1.00)	1.03	0.88	1.21	0.685
	Age group	Older (Younger = 1.00)	1.58	1.34	1.85	0.000
	Season	Fall (Spring = 1.00)	1.05	0.89	1.23	0.561
	Physical activity	Active (Passive = 1.00)	1.35	1.16	1.57	0.000
	GMF strength	100 pT difference	1.00	0.94	1.07	0.997
0–66 Hz	Gender	Men (Women = 1.00)	1.04	0.88	1.22	0.669
	Age group	Older (Younger = 1.00)	1.59	1.36	1.86	0.000
	Season	Fall (Spring = 1.00)	1.03	0.87	1.21	0.724
	Physical activity	Active (Passive = 1.00)	1.35	1.17	1.57	0.000
	GMF strength	100 pT difference	1.02	0.98	1.08	0.339

Note: **bold** indicates P<0.05 for GMF strength analysis.

Tables 4.3.2.4.9 and 4.3.2.4.10 show that an increase by 100 pT with 12-hour lagging in the lower GMF frequency ranges was strongly associated with better social connectedness. When analyzing the effects with 36-hour lagging, GMF kept its significance for perception of social connectedness only within two frequency ranges – 7–15 Hz (OR = 2.07, 95% CI 1.39–3.10) and 15–32 Hz (OR = 1.56, 95% CI 1.18–2.06). Higher odds of better social connectedness were observed among older and physically active individuals, and in the second half of the year.

Table 4.3.2.4.9. *Associations between social connectedness indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	**95% CI**		**p**
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.213
	Age group	Older (Younger = 1.00)	1.38	1.16	1.63	0.000
	Season	Fall (Spring = 1.00)	1.22	1.03	1.44	0.021
	Physical activity	Active (Passive = 1.00)	1.25	1.07	1.46	0.005
	GMF strength	100 pT difference	1.67	1.16	2.41	**0.006**
3.5–7 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.211
	Age group	Older (Younger = 1.00)	1.38	1.17	1.64	0.000
	Season	Fall (Spring = 1.00)	1.23	1.04	1.46	0.014
	Physical activity	Active (Passive = 1.00)	1.25	1.07	1.46	0.005
	GMF strength	100 pT difference	2.20	1.22	3.96	**0.009**
7–15 Hz	Gender	Men (Women = 1.00)	1.12	0.95	1.33	0.181
	Age group	Older (Younger = 1.00)	1.35	1.14	1.60	0.001
	Season	Fall (Spring = 1.00)	1.21	1.02	1.43	0.029
	Physical activity	Active (Passive = 1.00)	1.25	1.07	1.46	0.005
	GMF strength	100 pT difference	2.14	1.44	3.19	**0.000**
15–32 Hz	Gender	Men (Women = 1.00)	1.13	0.95	1.34	0.158
	Age group	Older (Younger = 1.00)	1.43	1.22	1.69	0.000
	Season	Fall (Spring = 1.00)	1.22	1.03	1.44	0.020
	Physical activity	Active (Passive = 1.00)	1.27	1.08	1.48	0.003
	GMF strength	100 pT difference	1.43	1.10	1.86	**0.008**
32–66 Hz	Gender	Men (Women = 1.00)	1.12	0.95	1.33	0.181
	Age group	Older (Younger = 1.00)	1.45	1.22	1.72	0.000
	Season	Fall (Spring = 1.00)	1.26	1.06	1.49	0.008
	Physical activity	Active (Passive = 1.00)	1.27	1.08	1.48	0.003
	GMF strength	100 pT difference	1.00	0.94	1.07	0.972
0–66 Hz	Gender	Men (Women = 1.00)	1.13	0.95	1.33	0.166
	Age group	Older (Younger = 1.00)	1.47	1.24	1.74	0.000
	Season	Fall (Spring = 1.00)	1.22	1.03	1.45	0.021
	Physical activity	Active (Passive = 1.00)	1.27	1.08	1.48	0.003
	GMF strength	100 pT difference	1.05	0.99	1.10	0.086

Note: **bold** indicates $P<0.05$ for GMF strength analysis.

Table 4.3.2.4.10. *Associations between social connectedness indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	**95% CI**		**p**
				from	**to**	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.12	0.95	1.32	0.192
	Age group	Older (Younger = 1.00)	1.41	1.19	1.67	0.000
	Season	Fall (Spring = 1.00)	1.23	1.04	1.46	0.014
	Physical activity	Active (Passive = 1.00)	1.26	1.08	1.47	0.004
	GMF strength	100 pT difference	1.33	0.93	1.90	0.122
3.5–7 Hz	Gender	Men (Women = 1.00)	1.12	0.94	1.32	0.193
	Age group	Older (Younger = 1.00)	1.41	1.19	1.67	0.000
	Season	Fall (Spring = 1.00)	1.24	1.05	1.46	0.013
	Physical activity	Active (Passive = 1.00)	1.26	1.08	1.47	0.004
	GMF strength	100 pT difference	1.58	0.88	2.85	0.125
7–15 Hz	Gender	Men (Women = 1.00)	1.12	0.95	1.33	0.179
	Age group	Older (Younger = 1.00)	1.36	1.15	1.61	0.000
	Season	Fall (Spring = 1.00)	1.19	1.00	1.41	0.045
	Physical activity	Active (Passive = 1.00)	1.25	1.07	1.47	0.004
	GMF strength	100 pT difference	2.07	1.39	3.10	**0.000**
15–32 Hz	Gender	Men (Women = 1.00)	1.13	0.95	1.34	0.160
	Age group	Older (Younger = 1.00)	1.44	1.22	1.70	0.000
	Season	Fall (Spring = 1.00)	1.19	1.01	1.42	0.040
	Physical activity	Active (Passive = 1.00)	1.27	1.09	1.48	0.003
	GMF strength	100 pT difference	1.56	1.18	2.06	**0.002**
32–66 Hz	Gender	Men (Women = 1.00)	1.12	0.95	1.33	0.176
	Age group	Older (Younger = 1.00)	1.46	1.23	1.74	0.000
	Season	Fall (Spring = 1.00)	1.24	1.05	1.48	0.012
	Physical activity	Active (Passive = 1.00)	1.27	1.09	1.48	0.003
	GMF strength	100 pT difference	1.02	0.95	1.09	0.558
0–66 Hz	Gender	Men (Women = 1.00)	1.13	0.95	1.33	0.168
	Age group	Older (Younger = 1.00)	1.47	1.25	1.74	0.000
	Season	Fall (Spring = 1.00)	1.21	1.02	1.44	0.030
	Physical activity	Active (Passive = 1.00)	1.27	1.09	1.48	0.003
	GMF strength	100 pT difference	1.05	1.00	1.11	0.061

Note: **bold** indicates P<0.05 for GMF strength analysis.

Finally, Tables 4.3.2.4.11 and 4.3.2.4.12 revealed that an increase by 100 pT in GMF was not associated with perception of overall wellbeing. Higher odds of better overall wellbeing were observed among older and physically active participants.

Table 4.3.2.4.11. *Associations between overall wellbeing indicator, GMF and other analyzed factors in different SR intervals with 12-hour lagging effect*

			OR	95% CI		p
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.31	0.224
	Age group	Older (Younger = 1.00)	2.05	1.73	2.43	0.000
	Season	Fall (Spring = 1.00)	1.10	0.93	1.29	0.268
	Physical activity	Active (Passive = 1.00)	1.47	1.26	1.72	0.000
	GMF strength	100 pT difference	1.30	0.91	1.87	0.149
3.5–7 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.31	0.219
	Age group	Older (Younger = 1.00)	2.06	1.74	2.44	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.30	0.224
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.72	0.000
	GMF strength	100 pT difference	1.37	0.77	2.42	0.281
7–15 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.31	0.206
	Age group	Older (Younger = 1.00)	2.06	1.74	2.44	0.000
	Season	Fall (Spring = 1.00)	1.10	0.94	1.30	0.238
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.72	0.000
	GMF strength	100 pT difference	1.22	0.84	1.77	0.303
15–32 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.200
	Age group	Older (Younger = 1.00)	2.10	1.78	2.47	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.31	0.217
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.08	0.84	1.37	0.553
32–66 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.205
	Age group	Older (Younger = 1.00)	2.10	1.77	2.50	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.31	0.200
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.00	0.94	1.07	0.925

Table 4.3.2.4.11. *Continued*

			OR	95% CI		p
				from	to	
0–66 Hz	Gender	Men (Women = 1.00)	1.12	0.94	1.32	0.199
	Age group	Older (Younger = 1.00)	2.11	1.79	2.50	0.000
	Season	Fall (Spring = 1.00)	1.10	0.93	1.30	0.245
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.02	0.97	1.07	0.526

Table 4.3.2.4.12*. Associations between overall wellbeing indicator, GMF and other analyzed factors in different SR intervals with 36-hour lagging effect*

			OR	95% CI		p
				from	to	
0–3.5 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.31	0.209
	Age group	Older (Younger = 1.00)	2.09	1.76	2.47	0.000
	Season	Fall (Spring = 1.00)	1.11	0.94	1.31	0.212
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.07	0.75	1.53	0.696
3.5–7 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.204
	Age group	Older (Younger = 1.00)	2.11	1.78	2.50	0.000
	Season	Fall (Spring = 1.00)	1.12	0.95	1.32	0.181
	Physical activity	Active (Passive = 1.00)	1.49	1.27	1.73	0.000
	GMF strength	100 pT difference	0.92	0.52	1.64	0.787
7–15 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.31	0.205
	Age group	Older (Younger = 1.00)	2.07	1.75	2.46	0.000
	Season	Fall (Spring = 1.00)	1.10	0.94	1.30	0.244
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.15	0.78	1.70	0.468
15–32 Hz	Gender	Men (Women = 1.00)	1.12	0.94	1.32	0.197
	Age group	Older (Younger = 1.00)	2.10	1.78	2.47	0.000
	Season	Fall (Spring = 1.00)	1.09	0.93	1.29	0.283
	Physical activity	Active (Passive = 1.00)	1.48	1.27	1.73	0.000
	GMF strength	100 pT difference	1.17	0.90	1.53	0.251

Table 4.3.2.4.12. *Continued*

			OR	95% CI		p
				from	to	
32–66 Hz	Gender	Men (Women = 1.00)	1.11	0.94	1.32	0.200
	Age group	Older (Younger = 1.00)	2.13	1.79	2.52	0.000
	Season	Fall (Spring = 1.00)	1.10	0.94	1.30	0.243
	Physical activity	Active (Passive = 1.00)	1.49	1.28	1.73	0.000
	GMF strength	100 pT difference	1.02	0.96	1.09	0.529
0–66 Hz	Gender	Men (Women = 1.00)	1.12	0.94	1.32	0.199
	Age group	Older (Younger = 1.00)	2.12	1.79	2.50	0.000
	Season	Fall (Spring = 1.00)	1.10	0.93	1.30	0.281
	Physical activity	Active (Passive = 1.00)	1.49	1.27	1.73	0.000
	GMF strength	100 pT difference	1.02	0.97	1.07	0.405

To summarize the subchapter, the analysis of the associations between biopsychosocial wellbeing and health parameters and local GMF fluctuations highlighted the impact of inner coherence on synchronization between HRV and GMF. Moreover, the quality of two person's relationship turned out to be significant when discussing the similarity of their physiological response towards GMA. The analysis also revealed that SF mental health indicator was most responsive to GMF fluctuations. Also, most significant associations were observed across lower frequency ranges, and with 12- and 36-hour lagging intervals. It was also revealed that the effects in spring take less time to occur than in fall, and mental health is more responsive during spring, whereas physical health and overall wellbeing are more responsive during the fall. Higher odds of better mental state (SF mental health indicator) were observed among men, among elder group, among physically active participants, in the second half of the year. An increase by 100 pT in the lower GMF frequency ranges was more strongly associated with better mental health.

DISCUSSION

Although the associations between live organisms, including humans, and GMF began to be examined globally several decades ago, the characterristics of the local rather than the global magnetic field and its effects on health-related issues have not been studied extensively. Regarding Lithuania, there were no such studies at all for technical reasons up until 2014 when a magnetometer capturing local GMF fluctuations was installed, allowing to start observations of the dynamics of GMF and to carry out various related researches.

For the research of this dissertation, we examined the study participants' objective as well as subjectively evaluated biopsychosocial wellbeing and health, including mental, physical, social elements, and overall self-reported health assessment. Socio-demographic data and data on participants' physical activity were also collected. During the study period, GMA was monitored and the data obtained was then used to examine its associations with the above-mentioned wellbeing and health indicators. To better understand and evaluate parameters of the local GMF fluctuations in Lithuania, the dynamics of the GMF changes was observed not only during the study year (2016), but up until March, 2020.

Measuring GMF fluctuations, the following six frequency ranges were being captured and observed: 0–3.5 Hz, 3.5–7 Hz, 7–15 Hz, 15–32 Hz, 32–66 Hz, and 0–66 Hz. In *Study 2*, we examined the associations not only at actual time, but also with lagging intervals of 12, 24, 36 and 48 hours. Naturally, since the analysis included many different parameters and patterns, quite a large number of different types and intensity associations were observed. Thus, it is important to try to discover general trends in that context in order to better understand the tendencies of examined associations. Therefore, we will discuss the results in an effort to highlight the significant features/patterns of the analyzed associations.

Seasonality and gender

Examining the associations between health indicators and GMF fluctuations, certain differences based on seasonality were found. In the spring season, at least a little stronger (>0.10) correlations were more observed in lower frequencies (0–3.5 Hz, 3.5–7 Hz, 7–15 Hz), and those found correlations were found when assessing SF mental health indicator with 12- and 36-hour lagging intervals. Meanwhile in the fall season, more significant correlations that reached 0.10 and above, were found in higher frequencies (7–15 Hz and 32–66 Hz), and those correlations were observed when assessing overall wellbeing and physical health. It is important to note that in the spring season the associations were found with 12- and 36-hour lagging intervals, whereas in the fall season the effects of GMF took longer to occur where the most associations were observed with 24- and 48-hour lagging intervals.

These findings provide definite insights about different effects of the seasons on human functionality. Similar observations have already been disseminated by different authors [35, 116, 166], who found that physical health ailments, such as heart activity failure (ischemic heart disease, stroke), deaths, etc. are more likely to occur in the cold season of the year (fall-winter), whereas psycho-emotional difficulties, such as suicidal cases, social unrest, etc., are observed more often in the warmer time of the year. These observations are in agreement with the findings of the study of this dissertation, which found that in the spring season, most responsive to GMF disturbances was mental health, which potentially reflects the greater psycho-emotional sensitivity during this period. Whereas in the fall season, the greater effect was observed on physical health and wellbeing. Some authors [35, 116] argue that perhaps temperature differences, increased incidence of side-effects, etc. may also contribute to more sensitive health responses during the cold season.

Although we did not succeed in finding any studies in literature examining the seasonality impact on different GMF frequency ranges, the study in this dissertation observed the greater significance of lower frequencies in the spring season, and higher frequencies were more likely to correlate in the fall season. The highest Gamma (32–66 Hz) frequency range's correlation with overall wellbeing in the fall season was negative, meaning that an increase in GMF strength in this frequency range resulted in poorer self-reported overall wellbeing of participants. As the HeartMath Institute observations claim, Gamma waves can be associated with hyperactivity, panic, fright, tension [39], which means that an increase in these waves' intensity increases an inclination to hyperactivity and destruction, and this could possibly explain why in the conducted study of this dissertation the correlations between the ultra-high waves and participants overall wellbeing was negative.

When discussing seasonality, it is inevitable to talk over the significance of gender as well. Authors especially point out in terms of physical health [165] that women tend to have better physical health, and this might be one of the reasons, explaining differences in male and female longevity in most industrialized countries [163]. When examining the seasonality and gender factors altogether, more specific effects clear up. For instance, when examining the associations between GMF and health indicators among men, slightly stronger (>0.01) correlations were observed with mental, emotional and physical wellbeing, and those occurred in the lower, first four, frequency ranges with 12- and 36-hour lagging intervals. Meanwhile significantly among women, very weak correlations were found in all six frequency ranges with some of the health indicators. But none of the observed correlations reached 0.01, thus, it might seem that men are more sensitive to GMF fluctuations than women.

However, the inclusion of the seasonality factor into the analysis showed the opposite that among women, the spring season revealed quite a number of significant correlations in all GMF frequencies, the strongest of which were when assessing overall wellbeing and SF mental health indicator. Among men, the same season revealed only four associations, three of which were negative, meaning that an increase in GMF strength during this season had a negative affect on men's health.

Speaking of the cooler, fall season, there was a particularly strong (compared to all other found in this study) ~0.20 negative correlation between GMF peak (Gamma) frequency range and overall wellbeing and physical health. Among women, a more outstanding association was observed only with physical vitality, but like in the men's group, in the women's group the association was also negative. Thus, it could be summarized that an increase in GMF strength during the fall season, especially in the highest frequency range, has adverse effect on both women and men's wellbeing.

Age factor

Another significant factor that emerged in the study of this dissertation was age. All participants of the study were divided into two age groups: 19–29 years and 30–39 years, to compare whether younger and older adults respond differently to GMF disturbances. In examining differences between those two age groups, it was found that more significant associations were observed among older participants (30–39 years) than younger ones (19–29 years). It is interesting to note that the found associations were revealed across the first four frequency ranges and were found both at actual time and with all analyzed lagging intervals, however, slightly stronger ones (>0.10) were observed at actual time and with 24- and 36-hour lagging intervals. Moreover, absolutely all of the significant associations were negative. Therefore, it can be concluded that older adults are more responsive to the changes in GMF, and that increases in GMF strength have adverse effects on their mental, physical health, social and overall wellbeing.

Meanwhile, among younger participants, the more significant associations were observed only with 12- and 36-hour lagging intervals, and only within the first two lowest frequency ranges. It is also important to note that the mentioned associations are positive, in contrary to the older participants' correlations.

We see then from what has been discussed that an increase in GMF strength has a positive impact on younger adults' health and wellbeing, and an adverse impact on older ones. There is quite a number of research studies on the age factor's significance on health and wellbeing outcomes with a particular emphasis on heart function, cognitive abilities, psychological resilience, etc. As some authors claim, HRV declines with age [179] and aging often involves nervous system changes, which may reduce regulatory capacity [74], which, in turn, may contribute to various inflammations, hypertension and other health issues [52]. Of course, in our study, the age groups that were compared are not radically alienated, however, a period of 20 years is perhaps sufficient to develop various biologically determined and/or lifestyle related health and wellbeing outcomes.

When discussing mental and emotional wellbeing, age may also be relevant, having its significance through physiological changes. HRV is also an indicator of psychological resiliency and behavioral flexibility and, as the authors Gary G. Berntson et al. [15] argue, it reflects the individual's capacity to adapt effectively to changing social or environmental demands and challenges [15]. And the social environment and the change and development in new social roles is especially relevant at the age of our target group, as it is the age groups of the senior group of the study that is mostly characterized by making important personal and professional decisions, such as marriage, career development, etc. Age, as being a significant biological factor influencing mental health and wellbeing, has been also mentioned in the reports conducted by the Lithuanian Republic Ministry of Education and Science [170]. Thus, it is becoming clear that the associations that are being discussed are very complex, occurring between processes of different levels and complexity.

The different capabilities and skills of adults, depending on their age, are also discussed and well described by the WHO in its reports and analyses. This organization pays quite a big attention to the factor of age and, therefore, has developed and published guidelines and recommendations for health promotion, which vary for different age groups [55]. Moreover, in its last year's report the WHO stated that a significant number of adults do not follow the recommendations for maintaining good health status, so it is logical to assume that the older a person becomes (and that means more years of their lifestyle not contributing to their health support), the more obvious negative consequences for health and wellbeing occur.

From what has been discussed, the differences between the two age groups in terms of their associations with different health and wellbeing parameters are clear. However, this does not yet explain why our study revealed differences between those two groups' responses to GMF disturbances.

We can only assume, from the reviewed scientific literature in the field, that the quality of current health status and wellbeing, and the level of vulnerability in one's physical, mental or social wellbeing, all may play a significant role in one's ability to adapt to environmental changes and challenges. This was also confirmed by a recent study [174], which revealed that our level of HRV response to GMF disturbances may even depend on the quality of interpersonal relationships. At this point, it would be possible to assume that with age, a person develops his/her social competences and is increasingly capable of establishing and maintaining a better quality and closer interpersonal relationships. This assumption would raise a question, why in our study, on the contrary, a senior group of participants revealed more complex associations with GMF fluctuations than younger ones. We may have to consider that nowadays, modern lifestyle features do not guarantee any social development with age. A report by Beaumont [9] revealed that despite the ongoing fast technological progress that provides people with more and more different tools and ways how to connect to each other, loneliness and social isolation are an ever-growing complex challenge in the society worldwide.

Emotional state and interpersonal relationships

When examining the effect of a coherence technique on synchronization with GMA during the *Study 1*, it was found that among all of the study days, synchronization (positive correlation) between participants' HRV and GMA was highest exactly on the day when the Heart Lock-In Technique was applied. As authors Fred Shaffer, Rollin McCraty and Christopher L. Zerr [150] indicate, HRV is typically used as an indicator of ANS function, dynamics, and functional status of interdependent regulatory systems that operate to help a person to adapt to environmental and psychological challenges. Thus, it is evident that there is a clear link between the mental state of a person and his/her HRV. However, to the best of our knowledge, there are no studies examining how mental state can influence HRV's associations with GMA. More over, our study revealed the there is evidence that links the quality of interpersonal relationships and synchronization with GMA. Results of the *Study 1* showed that two participants (number 7 and 20) were most similar in the sense of synchronization between their HRV and local GMA. But what is also important in these findings, is that from the analysis of the participants' interpersonal interaction data, it was clear that participants 7 and 20 shared mutual positive attitudes towards one another.

Since there are no similar studies that could be compared to what we have found, we can only try to reason and philosophize how such factor as mutual interconnection can affect the two persons' relationship to geophysical environmental factors. Is it their similar physiological patterns (HRV synchronization to GMA) that inspires better mutual connection and positive attitude towards one another, or vice versa? From the overall tendency in scientific literture it could be assumed that mutual attractiveness or sympathy for each other involves many more internal associations and dynamics than could be thought at first sight. And that shifting our emotional state can instantly shift our physiological responses to geophysical environmental factors.

The discussed observations lead towards understanding that, together with other factors, it is also important to pay attention to social wellbeing and quality of interpersonal relationships of a person when discussing health effects related to geophysical environment.

Physical activity

The study of this dissertation also examined possible differences between physically active and physically passive participants. The obtained results showed that a lot more significant associations between GMF fluctuations and health indicators were observed in the group of regularly practicing physical activity, compared the with physically passive group. Among the found correlations, slightly stronger ones (>0.10) were found in the first three frequency ranges, when assessing SF mental health indicator, emotional vitality and social connectedness. All the mentioned correlations appeared with 12- and 36-hour lagging intervals. Among those who indicated being physically passive, only one significant correlation reached the strength of 0.10 when assessing SF mental health indicator in the frame of 0–3.5 Hz frequency and with 36 hour lagging interval.

There is a large number of scientific research studies about the importance and benefits of physical fitness and regular physical activity, which show the obvious significant associations between physical activity and improved social, mental, physical and general health and wellbeing. However, the question is, how/why did our study reveal the differences between those two groups' responses to GMF fluctuations.

First, it is noticeable that among physically active participants, most of the associations were with mental/emotional wellbeing indicators. A regular, physically active lifestyle has been proved by many authors to significantly influence better psychological wellbeing, higher joy of life, better quality of life and higher overall satisfaction with one's life, and this positive impact is observed regardless of age or socio-economic status [16, 180]. As the obtainned results from the *Study 1* revealed, after the application of the emotional wellbeing balancing technique (Heart Lock-In Technique), the participants' synchronization (positive correlation) with GMF fluctuations significantly shifted into the more positive level. These findings may indicate that the more harmonious and balanced the inner state is, and the better a person overall feels, the more optimal associations with the geophysical environment he/she develops, being able to stay more resilient to various greater disturbances. Thus, evaluating these results from *Study 1*, further analysis of the main study has also demonstrated the same tendency and logic in the group of physically active participants, numerous associations with namely SF mental health and emotional vitality indicators were observed, indicating that, perhaps, the participants' physically active lifestyle contributes significantly to a variety of their health outcomes and overall wellbeing resulting in improved synchronization with GMF fluctuations.

Also, interesting to notice is that in the group of physically active compared with physically passive, an association with social connectedness was found. This is also in agreement with a number of other authors‘ observations, which showed that regular physical activity, contributing to various improved indicators of physical health (reduced hypertension and obesity, indicators of inflammation, metabolic dysfunction, etc.), has significant benefits for quality social relationships maintenance and engagement into social activities, which, in turn, helps to avoid feelings of abandonment and loneliness [188–190, 192].

Looking at the results in the physically passive group, which showed only one correlation that reached 0.10, it is noticeable that this correlation was observed with a 36-hour lagging interval, whereas in the physically active groups, slightly stronger associations (>0.10) were observed with a 12-hour lagging interval, meaning that effects occurred much earlier. The question is whether those who do not practice regular physical activity are in a more disadvantaged position regarding associations with GMF? As we have discussed in the literature review section, being isolated from GMF (which also implies no associations with GMF fluctuations) is not beneficial neither for animals, nor for humans. On the contrary, it can adversely affect blood pressure, other cardiovascular features, and even cognitive functions [11, 57, 176]. Therefore, an overall summary of the discussed observations would suggest that those who lead a healthier lifestyle (through regular physical activity) and thus maintain a better health and wellbeing, are more likely to be in more beneficial associations with GMF disturbances in terms of their health and wellbeing.

Lagging effect

When assessing associations between GMF fluctuations and health parameters with lagging intervals, it turned out that most statistically significant correlations were revealed with 12- and 36-hour lagging intervals (although multivariate analysis highlighted only the interval of a 12-hour lag). Associations were also found at actual time and with other analyzed lagging intervals (24 and 48 hours), however, there were very few of them. The question of why the GMF effects on human health and wellbeing occur with certain time laggings, is indeed worth discussing. If we looked at other scientific literature on this topic, we would find such mentioned time intervals as daily cycle [56, 135]. A more recent study [150] allowed the authors to distinguish the concept of adaptation, meaning that certain body processes, especially the HRV indicator, reflect the ability to adapt to environmental and psychological challenges. And adaptation, as a process, implies by default a certain necessary time interval. So, in this sense, the significance of lagging intervals seems logical and plausible. Of course, people are definitely different in their abilities to adapt to environmental changes, and perhaps this is why we can observe so many differences in the results when assessing associations between GMF changes and health indicators with different lagging intervals.

On the other hand, there is a wealth of research that shows undoubted associations already at actual time, without laggings. For instance, ANS is highlighted to possess a feature to respond quickly to [109] and even synchronize simultaneously with [104] the changes in GMA. The HRV responses, occurring already during geomagnetic storms [20, 33, 40, 104] or at least within a relatively short time interval (between 4–30-minute-long periods) [195] have been also observed.

From what has been discussed, it can be seen that in literature we find authors showing associations both at actual time and with various time lagging intervals. From the results of this study and other authors' research it can be assumed that there is no general conclusion about which time lagging interval is the most optimal for the evaluation of the discussed associations between GMF changes and health indicators. Perhaps this is understandable, given that human health processes are complex, nonlinear, ambiguous, and what is especially important to note is that those parameters of associations can be affected by many individual factors, such as even the quality of interpersonal relationships. Therefore, it could be concluded that different people respond differently to GMF changes, at different times and intensities.

Lower versus higher frequency ranges

Our study examined the associations between health indicators and GMF changes across six different frequency ranges: 0–3.5 Hz, 3.5–7 Hz, 7–15 Hz, 15–32 Hz, 32–66 Hz and 0–66 Hz. The results revealed that most of the found significant and at least slightly stronger (>0.10) correlations were observed in the three lowest frequency ranges: 0–3.5 Hz, 3.5–7 Hz, 7–15 Hz.

Some authors have already shown that it is namely the lower frequency ranges that are more associated with human health and wellbeing. Among many health related outcomes, they point out the human nervous system, which couples with low or ultra-low frequency standing waves that overlap with human physiological rhythms [104]. Another study [42] also found evident links between EEG rhythms, blood pressure and heart rate with namely low-frequency geomagnetic rhythms. The same low frequencies were distinguished also by Zenchenko et al. [195], who found significant associations with heart rhythms.

Insights from the mentioned studies support the findings of our research, which highlighted that lower frequencies demonstrate more significant impacts on human health and wellbeing than higher frequencies. Nevertheless, speaking of more specific effects, recent studies show that both weak and strong GMF disturbances are linked to negative health outcomes [60, 70, 132, 167, 168], whereas, most of the significant associations found in our study were positive (except when analyzing the groups of senior participants). It should also be noted that the associations found at lower frequencies were observed mostly when assessing SF mental health indicator. Therefore, the conclusion might be that an increase of namely low-frequency GMF has a positive effect on adults' mental health and wellbeing.

As just mentioned, the senior group of the study participants stood out as revealing that their associations were negative. However, it is also noticeable that those negative associations are already occurring not only at low frequencies, but also at higher frequencies (15–32 Hz and 0–66 Hz). The more negative effects of higher frequencies are not surprising. In the literature review we found that the highest among the analyzed frequencies, Gamma waves, are mostly associated with panic, hyperactivity, fright and tension [39]. Another very recent study [75] also showed that negative health outcome such as myocardial infarction is significantly linked to the highest frequencies.

Summarizing the discussed findings and observations of this work and other authors, it becomes clear that lower frequency ranges have a more positive impact and significant associations with adults' indicators of health and wellbeing.

Overall subjective health assessment among men and women

Evaluation of the relationship between health indicators and GMF changes revealed significant differences based on gender, which have already been discussed at the beginning of this chapter. However, it would be worth considering whether the fact that there are significant differences in how men's and women's health parameters respond to GMF disturbances can be at all associated with the overall tendency of how men and women subjectively perceive their health and wellbeing.

As the results of our study revealed, statistically significant differences between men and women perception of their health and wellbeing were found when assessing SF-12 Mental health indicator, also when measuring participants' physical and emotional vitality: in all three cases, better health parameters were observed among men ($P<0.05$). Three other indicators had also a trend of being better among men than women, though not significantly. These findings show that men tend to perceive their health and wellbeing as better than women. These observations are in agreement with another conducted research with Lithuanian population [90], which revealed that women reported their mental health (vigor, vitality and emotional state) and physical condition as being statistically significantly poorer than men.

The question then, is whether the way a person perceives his/her wellbeing and how one feels about their health status, can influence that person's sensitivity to GMF disturbances? Understanding such complex peculiarities is not that simple, but perhaps it can be assumed that, given the results of the *Study 1*, which showed that improved psycho-emotional state and increased inner coherence improved the participants' synchronization with GMF, the greater inner coherence is, the less a person should be disturbed by the GMF changes. If we accept that individuals who tend to better evaluate their health (in our case men) are more likely to feel better in general and that their inner coherence is to some extent higher, then they should be in a more positive association with GMF disturbances.

The results of our study revealed that among women, many significant correlations across all analyzed frequency ranges were observed in the spring season, the strongest of which being when assessing overall wellbeing and SF mental health indicator. In the same season, only four associations (when assessing physical vitality, social wellbeing and SF physical health indicator) emerged among men, however, none of them reached 0.10. Such a large difference between those two groups suggests that GMF disturbances affect women more than men. The fall season revealed a more moderate quantity of significant correlations for both men and women groups.

It is difficult to make categorical generalizations from the observations discussed, however, it is possible to notice a tendency that women, who are generally more likely to perceive their health as poorer than men, reveal being more sensitive and responsive to GMF disturbances.

Study limitations, strengths and future perspectives

After implementing the research of this dissertation and after evaluating the obtained multidimensional results, it is important to highlight certain aspects that appeared to be our study limitations and/or strengths, and that may help in planning future researches:

1. Our study sample consisted of 19–39 years old adults, which is a relatively young age group. It is likely that including a wider age range would reveal more specific health and wellbeing related factors and effects, thus, we can assume that the chosen young age group might have limited access to more in-depth and meaningful research findings. Future research should include a wider age group of participants.
2. It should also be noted that the study was conducted by implementing five study waves during 2016, from March till October. All five waves included different participants, meaning no participant took part in the study twice. Since seasonality was included in the data analysis, it is important to keep in mind that when comparing different seasons, the subjects from those seasons were different, meaning that the groups were different.
3. Since seasonality appeared to be a significant factor, it would be reasonable in future studies to cover winter months as well, to ensure that all periods of a year are included.
4. Our study included both objective and subjective health and wellbeing assessment, which enables us to discuss health related patterns from a broader perspective, rather than limiting merely to objective measures.
5. Finally, our study examined the associations at actual time and with lagging intervals of 12, 24, 36 and 48 hours. However, in the future, it would be also reasonable and important to take into consideration the opposite time intervals prior to the observed event or health assessment. A number of authors have already noticed that anticipatory reactions occurring several days before a magnetic storm, are also evident, resulting in changes of blood pressure, HRV and other biopsychosocial processes [40, 41, 85, 104].

CONCLUSIONS

1. From 2014 till 2016, a decreasing trend of local geomagnetic field strength was observed. Since 2017, the strength has been increasing each year. Geomagnetic field strength reaches its peak in late summer and then goes down to its lowest point in late fall.
2. Young adults evaluated their physical health as better than mental health. Men and older (30–39 years old) participants assessed their mental, physical health and emotional vitality better than women and younger (19–29) participants.
3. The analysis of the associations between local geomagnetic field fluctuations and biopsychosocial wellbeing and health parameters revealed the following:
   - Increased inner coherence has a positive impact on synchronization between heart rate variability and geomagnetic field fluctuations.
   - Quality of two persons' interpersonal relationship has shown to be linked with synchronization of their heart rate variability to local geomagnetic field fluctuations – the closer their relationship, the more similar their synchronization is.
   - Most pronounced effects of geomagnetic field strength on wellbeing and health occur with 12- and 36-hour lagging intervals within the three lowest frequency ranges (0–3.5 Hz, 3.5–7 Hz and 7–15 Hz).
   - In spring, geomagnetic field strength has been associated with wellbeing and health in the three lowest frequency ranges, whereas in fall it is associated with the higher frequency ranges; the effect of the geomagnetic field occurs faster in spring than in fall; mental health is more responsive to geomagnetic field fluctuations in spring, whereas physical health and overall wellbeing in fall; in spring, women are more responsive to geomagnetic activity than men.
   - Younger participants respond faster (within 12–36 hours) to local geomagnetic field fluctuations than older ones; moreover, the associations among younger participants were positive, whereas among older ones they were negative.

IMPLICATIONS FOR PRACTICE

For successful implementation of the obtained results about the associations between health and wellbeing parameters and GMF fluctuations, it is essential that public health specialists and representatives include this kind of information among other publicly disseminated information, making it easily accessible for the general public. The following actions could be considered for implementation:

1. Public Health Bureaus could regularly cooperate with representatives that access the GMF fluctuations data and could establish a timely information system tool for the public about the dynamics and/or prognoses of the GMF fluctuations.
2. After that, Public Health Bureaus might regularly publish in their websites or other kinds of informational tools, the main scientific findings concerning possible GMF effects on certain health and wellbeing aspects. Since it has been observed by a number of researchers [40, 41, 85, 104] that already several days before the onset of geomagnetic storms, health status changes might occur, knowing this kind of information might help the society to prepare for health changes and take actions to raise health resilience or avoid some drastical health outcomes (stroke, heart attack, etc.).
3. Since it has been shown that increased inner coherence (positive emotions, feelings of peace and harmony, etc.) has a positive impact on the synchronization between the human heart rate variability and the GMF fluctuations, practicing psychologists and psychotherapists might pay additional attention to helping their clients manage stress and shift out of being in the Gamma waves (30–100 Hz) into a more balanced and harmonious state, in order to be more resilient to environmental geophysical factors.

SUMMARY IN LITHUANIAN

ĮVADAS

Praeito amžiaus 6-ame dešimtmetyje vokiečių fizikas Vinfridas O. Šumanas (Winfried O. Schumann) atrado ir pradėjo tyrinėti geomagnetinio (GM) lauko fluktuacijas, atsirandančias ertmėje tarp žemės paviršiaus ir jonosferos. Rezonansai, kuriuos jis aptiko, yra žemo dažnio elektromagnetinės fluktuacijos, kurios savo ypatybėmis yra artimos žmogaus fiziologiniams procesams [28, 146]. Vėliau sekė daugybė tyrimų, analizuojančių žmogaus ir geofizinės aplinkos sąveikas. Daugybė mokslinių tyrimų patvirtino GM kitimų sąsajas su miokardo infarkto atvejų skaičiais, aukštu kraujospūdžiu, mirčių statistika ir t. t. [107, 108, 165, 166]. Padidėję nusikaltimų, žiaurių išpuolių atvejai, revoliucijos, teroristinių atakų padažnėjimas – šie ir panašūs procesai visuomenėse taip pat pat buvo daugumos mokslininkų susieti su GM svyravimais [58, 122, 158]. Tapo aišku, kad sąsajos tarp GM aktyvumo, skirtingų Šumano rezonansų dažnių ir žmogaus fiziologijos yra ypač stiprios. Tačiau specifiškesnių tyrimų stoka iki šiol riboja nuodugnesnį supratimą apie minėtus poveikius bei apie tai, kaip gaunamus tyrinėjimų rezultatus būtų galima panaudoti žmogaus sveikatos gerinimui.

Be to, svarbu atskirti globalaus ir lokalaus GM lauko sąvokas. Didžioji dalis pasaulyje atliekamų tyrimų vyksta pasitelkiant globalaus GM lauko duomenis, tačiau lokaliam laukui fiksuoti yra būtina lokaliai instaliuota ypač jautri įranga. Dėka HeartMath instituto (Kalifornija, JAV), tokia įranga – ypač jautrus GM lauko aktyvumo pokyčius fiksuojantis magnetometras – nuo 2014 m. kovo mėn. yra instaliuota ir Lietuvoje, tad nuo tada Lietuvos mokslininkai turi technines galimybes stebėti būtent lokalaus GM lauko aktyvumą ir tyrinėti jo sąsajas su žmogaus ir gyvūnų įvairiais sveikatos ir elgesio aspektais. Lietuvoje instaliuotas magnetometras yra penktas visame pasaulyje iš šiuo metu esančių šešių (JAV, Kanadoje, Saudo Arabijoje, Lietuvoje, Naujojoje Zelandijoje ir Pietų Afrikoje).

Mokslinis naujumas. Nuo 2014 m. kovo mėnesio turint būtent Lietuvai skirtą ir Lietuvos teritorijoje instaliuotą magnetometrą, iškart pradėta telkti interdisciplininė mokslininkų komanda, galinti apdoroti ir suprasti didelės apimties duomenis, taip pat pradėta ruoštis šios disertacijos tyrimo atlikimui. Šis tyrimas – pirmasis pradėtas tyrimas Lietuvoje, kuriame panaudojami šio magnetometro duomenys ir analizuojamos jų sąsajos su Lietuvos suaugusiųjų sveikatos parametrais.

Praktinė reikšmė. Geresnis supratimas apie žmogaus sveikatos parametrų sąsajas su GM lauko aktyvumu, ypač detaliau pažįstant Šumano rezonansus ir jų skirtingus dažnius bei intensyvumus, gali padėti ne tik paaiškinti kai kurių su žmogaus sveikata susijusių reiškinių (ligos, mirtis ir kt.) apraiškų priežastis ir dinamiką, bet taip pat ir prognozuoti tam tikras jų eigas, o taip pat – planuoti ir įgyvendinti prevencinius veiksmus, siekiant gerinti sveikatą ar išvengti kritinių sveikatos pablogėjimų.

DARBO TIKSLAS IR UŽDAVINIAI

Darbo tikslas – nustatyti sąsajas tarp jaunų suaugusiųjų biopsichosocialinės gerovės ir lokalaus GM lauko pokyčių.

Uždaviniai:

1. Įvertinti lokalaus GM lauko kitimų parametrus Lietuvoje;
2. Įvertinti jaunų suaugusiųjų biopsichosocialinės gerovės parametrus;
3. Nustatyti sąsajas tarp biopsichosocialinės gerovės parametrų ir lokalaus GM lauko kitimų Lietuvoje.

TYRIMO METODIKA IR TIRIAMIEJI

Konsultuojantis su HeartMath instituto mokslo centru ir ieškant optimalaus tyrimo dizaino, buvo suplanuoti du tyrimo etapai. Juos aprašant, toliau jie bus vadinami 1 tyrimu ir 2 tyrimu.

1 tyrimui buvo atrinkta 20 tiriamųjų. Tyrimo tikslas buvo įvertinti sinchronizaciją tarp tiriamųjų širdies dažnio (ŠD) variabilumo ir magnetinio lauko kitimų. Vėliau šie duomenys buvo panaudoti tam, kad sukonstruoti tarp tiriamųjų klasterius pagal jų ŠD variabilumo sinchronizaciją su GM lauku, bei ištirti, ar emocinė būsena gali turėti šiai sinchronizacijai reikšmės. Tiriamųjų amžiaus vidurkis (st. nuokr.) buvo 23.3 (0,6). Visi dalyviai buvo LSMU medicinos studentai. Tiriamiesiems dvi savaites iš eilės ambulatoriškai 24 valandas per parą buvo matuojamas jų ŠD, pasitelkiant ŠD matuoklius. Taip pat tiriamieji kasdien turėjo pažymėti, ar kažkuris kitas jų grupės narys tą dieną turėjo jiems teigiamą arba neigiamą poveikį. Tyrimo laikotarpio viduryje visai tiriamųjų grupei buvo pravesta 15-os minučių relaksacija, siekiant ištirti, ar emocinės būsenos subalansavimas gali turėti įtakos jų ŠD sinchronizacijai su magnetinio lauko kitimais.

2 tyrimas buvo atliktas penkiais srautais 2016 m. kovo-spalio mėnesiais. Kiekvieno srauto tyrimas vyko po dvi savaites iš eilės. Tyrimo dalyviai buvo pasirinkti patogiosios atrankos būdu, bendradarbiaujant su įvairių organizacijų atstovais, sutikusiais suburti grupę tyrime sutinkančių dalyvauti asmenų. Susitikus su kiekviena grupe, buvo kiekvienam dalyviui asmeniškai įteikiamas vokas su tyrimo anketomis. Tiriamiesiems buvo paaiškinamas tyrimo tikslas, eiga bei galimybė bet kuriuo metu nutraukti tyrimą ir jame nebedalyvauti. Pasirinkta tirti 18–39 metų amžiaus suaugusiuosius. Atrenkant grupes, buvo įvardintas amžiaus kriterijus. Anketos, kuriose buvo nurodytas šiam tyrimui netinkantis amžius, buvo neįtrauktos į tolimesnę duomenų analizę. Iš viso į galutinę tyrimo duomenų analizę buvo įtrauktos 264-ių tiriamųjų anketos. Tyrime dalyvavo 79 vyrai (30 proc.) ir 184 moterys (70 proc.). Tiriamųjų amžiaus vidurkis (st. nuokr.) – 26 metai (6,37).

Instrumentai

1 tyrimo metu ŠD matuokliais buvo matuojamas dalyvių ŠD. Tai neinvazinė matavimo priemonė, atspindinti autonominės nervų sistemos aktyvumą ir dinamiką. ŠD matuoklis iš elektrokardiogramos, registruojamos 1000 Hz dažnyje, apskaičiuoja RR intervalus (laiko intervalus tarp dviejų iš eilės einančių širdies plakimų). Vadovaujantis Europos kardiologų asociacijos standartais, kiekvienos dienos įrašai buvo apdoroti iš eilės einančiais 5-ių minučių segmentais.

Tyrimo eigos viduryje tiriamiesiems buvo pravesta *Heart Lock-In®* relaksacinė technika. Pristatyta 1992 m., ši technika skirta vystyti gebėjimą palaikyti nuoširdžiai teigiamas emocijas. *Heart Lock-In* laikoma emocijų perstruktūravimo technika, kuri gali veiksmingai padėti palengvinti susikaupusį stresą ir neigiamus jausmus. Paprastai po šios technikos atlikimo apninka ramybės, harmonijos ir vidinės šilumos jausmas, be to, įrodyta, jog ji padidina širdies ritmo darną.

Lokalaus GM lauko pokyčiai ir jų intensyvumas 1 ir 2 tyrimų metu buvo matuojami pasitelkiant instaliuotą Lietuvoje magnetometrą, kuris yra globalaus stebėjimo tinklo dalis [109]. Du GM lauko detektoriai (Zonge Engineering ANT-4) yra nustatyti šiaurės-pietų ir rytų-vakarų ašimis (1 pT jautrumu) ir geba fiksuoti pokyčius gana plačiame dažnių diapazone – 0,01–65 Hz.

2 tyrimo dalyviai dvi savaites iš eilės pildė SF-12® klausimyną, kurį sudaro 12 klausimų, vertinančių aštuonias gyvenimo sritis: fizinį aktyvumą, veiklos apribojimą dėl fizinių ir emocinių problemų, skausmą, bendrą sveikatos vertinimą, energingumą ir gyvybingumą, socialinius ryšius bei emocinę būklę. Šios aštuonios sritys galiausiai suvedamos į dvi sveikatos kategorijas – fizinę ir psichikos.

Šalia SF-12 klausimyno, dalyviams taip pat buvo pateikti 4 papildomi klausimai, kurie vertino tiriamųjų požiūrį į jų fizinį bei emocinį gyvybingumą, socialinį bendravimą bei bendrą gerovę.

Duomenų analizė

1 tyrimas. ŠD sinchronizacijai su lokalaus GM lauko kitimais apskaičiuoti buvo pasitelkiami matematiniai algoritmai, kurių panaudojimas ir validavimas aprašyti [174].

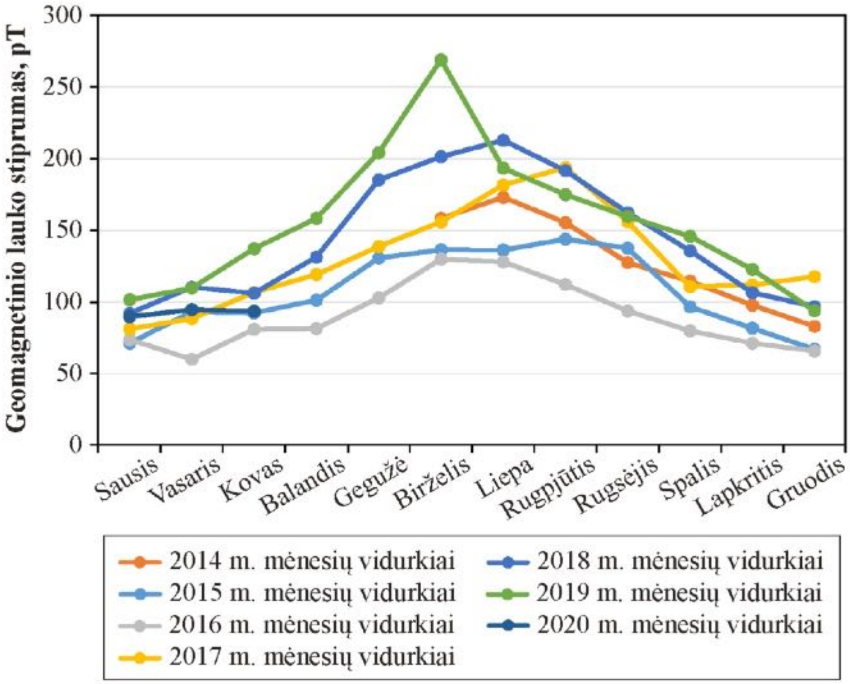
Klasterių pagal tiriamųjų ŠD sinchronizaciją su GM lauku tiriamųjų grupės viduje identifikavimui buvo atlikta 3.3 skyriuje matematiškai aprašyta trijų žingsnių procedūra.

2 tyrimo duomenys buvo apdorojami ir tikrinami dėl netikslumų ir klaidų su *MS Excel 2007* programa. Duomenų analizė buvo atliekama pasitelkiant *IBM SPSS 23,0* versijos statistinį programinį paketą. Reikšmingumo lygmuo pasirinktas $p<0{,}05$. Kadangi beveik visais atvejais gautos reikšmingos sąsajos koreliacinėje analizėje buvo žemiau 0,20, tai vertinant rezultatus, atsižvelgta buvo tik į tuos koreliacijų koeficientus ir šiek tiek stipresniais buvo interpretuojami tie, kurie siekė 0,10 ir daugiau. Siekiant įvertinti galimus poveikius, pasireiškiančius ne tik tuo pačiu duotuoju metu, bet ir po kurio laiko, į analizę buvo įtraukti GM lauko stiprumo matavimai su 12, 24, 36 ir 48 valandų vėlavimu, t. y., analizuotos sąsajos tarp sveikatos ir gerovės rodiklių su GM lauko rodikliais tuo pačiu metu, taip pat su GM lauko rodikliais po 12, 24, 36 ir 48 valandų. Siekiant įvertinti GM lauko sąsają su analizuotais gerovės bei sveikatos rodikliais, taip pat buvo atlikta ir daugiamatė logistinė regresinė analizė.

REZULTATAI

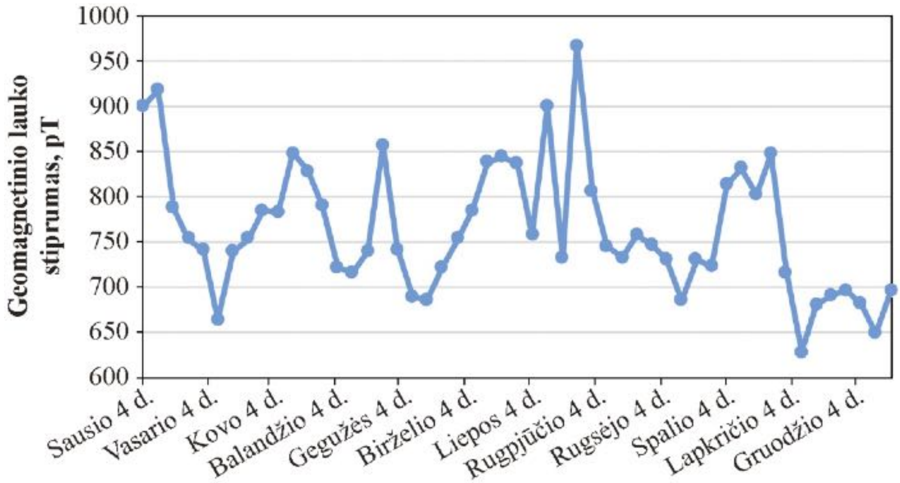
1. Lokalaus GM lauko kitimų parametrai Lietuvoje.

Vertinant GM lauko dinamiką nuo 2014 m. iki 2020 m. kovo mėnesio, paaiškėjo, jog iki pat 2016 m. kasmetinis GM lauko stiprumas mažėjo, tuo tarpu nuo 2017 m. pradėjo ryškiai kilti (1 pav.).



1 pav. *GM lauko dinamika nuo 2014 m. birželio mėn. iki 2020 m. kovo mėn.*

Didžiausias GM lauko intensyvumas 2016 metais buvo užfiksuotas pirmąją rugpjūčio savaitę, o silpniausias intensyvumas – antrąją lapkričio savaitę (2 pav.).



2 pav. *Lokalaus GM lauko stiprumas savaitėmis, 2016 m.*

Vertinant GM lauko dinamiką savaitės dienomis, paaiškėjo, jog savaitės pradžioje stiprumas pasiekia piką, tuomet nuo antradienio iki šeštadienio pastebima stiprumo mažėjimo tendencija, o sekmadienį vėl stebimas kilimas aukštyn.

2. Biopsichosocialinės gerovės parametrai.

1 tyrimo dalyviams dvi savaites matavus jų ŠD ir apžvelgus abiejų savaičių visų tiriamųjų duomenis, paaiškėjo, jog dalyvių RR intervalai pasiskirstė nuo 584,77 iki 1014,80 ms.

2 tyrimo metu išanalizavus tiriamųjų biopsichosocialinės gerovės ir sveikatos parametrus paaiškėjo, jog tyrimo dalyvių fizinės sveikatos balų vidurkiai, vertinant juos SF-12 instrumentu, buvo šiek tiek aukščiau populiacinio vidurkio, o psichikos sveikata – šiek tiek žemiau vidurkio, tad tai reiškia, jog tiriamųjų fizinė sveikata buvo vertinta kaip geresnė negu psichikos. Kiti keturi klausimai buvo vertinti aukščiau vidutinio įvertinimo, o socialinio bendravimo vidurkis buvo aukščiausias iš minėtų keturių klausimų, tuo tarpu fizinio gyvybingumo – žemiausias.

Lyčių analizė atskleidė statistiškai reikšmingus skirtumus, vertinant penkis iš šešių analizuotų rodiklių: fizinio ir emocinio gyvybingumo, bendros gerovės, SF fizinės bei SF psichikos sveikatos geresni įvertinimai rasti tarp vyrų (p<0,05) (1 lentelė).

1 lentelė. *Biopsichosocialinės gerovės ir sveikatos rodikliai pagal lytį*

Rodiklis	Vyrai	Moterys	t	p
Fizinis gyvybingumas	3,64 ± 1,06	3,40 ± 1,12	5,88	**<0,001**
Emocinis gyvybingumas	3,73 ± 1,06	3,57 ± 1,08	3,91	**<0,001**
Socialinis bendravimas	3,92 ± 1,04	3,87 ± 1,07	1,37	0,172
Bendra gerovė	3,83 ± 1,13	3,65 ± 1,13	4,45	**<0,001**
SF-12 fizinė sveikata	54,5 ± 6,1	53,3 ± 7,4	4,70	**<0,001**
SF-12 psichikos sveikata	46,1 ± 10,1	44,2 ± 10,6	5,20	**<0,001**

Pastaba: **paryškinta** reiškia p<0,05.

Vertinant skirtumus tarp amžiaus grupių, atsiskleidė, jog vyresni tiriamieji (30–39 m.) geriau įvertino visus analizuotus, išskyrus SF fizinės sveikatos, rodiklius negu jaunesni tiriamieji (p<0,05) (2 lentelė).

__2 lentelė.__ Biopsichosocialinės gerovės ir sveikatos rodikliai pagal amžių

Rodiklis	19–29 metai	30–39 metai	t	p
Fizinis gyvybingumas	3,40 ± 1,11	3,65 ± 1,06	–6,18	**<0,001**
Emocinis gyvybingumas	3,55 ± 1,09	3,80 ± 1,02	–6,47	**<0,001**
Socialinis bendravimas	3,84 ± 1,08	4,00 ± 0,99	–4,09	**<0,001**
Bendra gerovė	3,60 ± 1,15	3,97 ± 1,03	–9,23	**<0,001**
SF-12 fizinė sveikata	53,5 ± 7,2	53,9 ± 6,5	–1,62	0,104
SF-12 psichikos sveikata	44,0 ± 10,7	46,8 ± 9,4	–7,60	**<0,001**

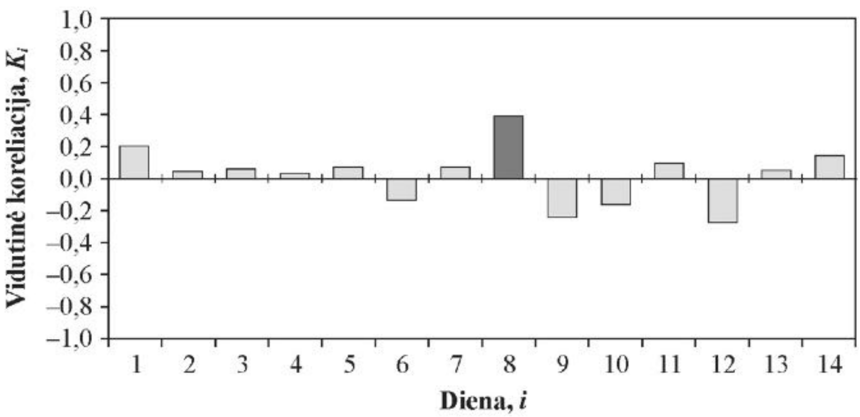
Pastaba: **paryškinta** reiškia p<0,05.

Analizuojant lyčių skirtumus skirtingose amžiaus grupėse, paaiškėjo, jog vyresni vyrai (30–39 m.) visus šešis analizuotus rodiklius įvertino geriau negu jaunesni vyrai (19–29 m.) bei negu to paties amžiaus moterys (p<0,05).

3. Biopsichosocialinės gerovės sąsajos su lokalaus GM lauko kitimais Lietuvoje.

1 tyrimas.

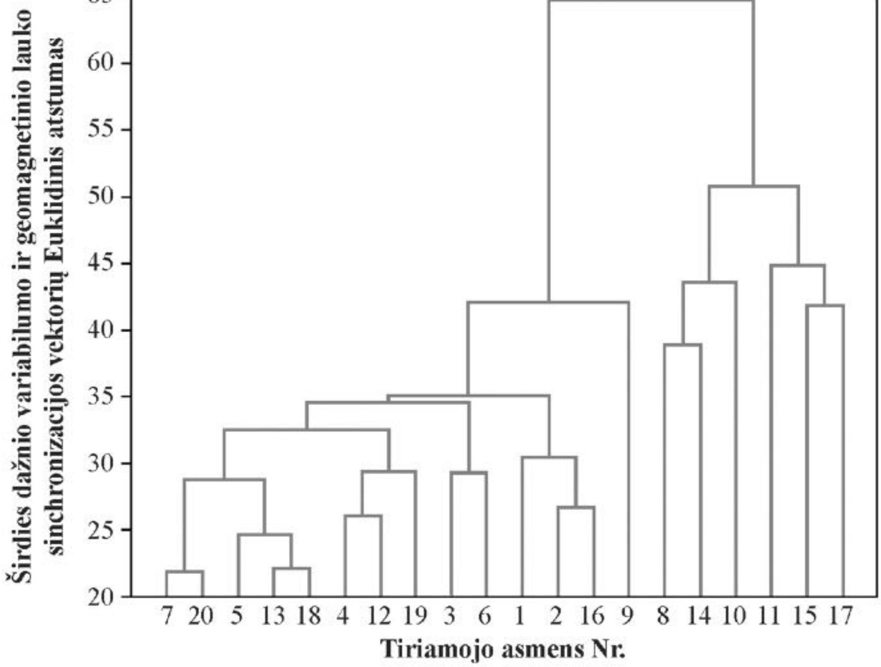
Vertinant relaksacinės technikos poveikį ŠD sinchronizacijai su GM lauko kitimais, paaiškėjo, jog tiriamųjų ŠD sinchronizacija su GM lauku buvo didžiausia būtent tą dieną, per kurią buvo pravesta relaksacinė technika (3 pav.).



***3 pav.** ŠD ir GM lauko sinchronizacijos koreliacija kiekvieną tyrimo dieną (n=20)*

Identifikuojant klasterius tarp visos tiriamųjų grupės narių (n=20) pagal jų ŠD sinchronizaciją su GM lauku, buvo sukonstruota dendrograma (4 pav.) – vaizdinis geometrinės sinchronizacijos atvaizdavimas. X ašyje atvaizduojami tiriamieji (sunumeruoti nuo 1 iki 20). Išsišakojimų aukštis proporcingas

Euklidiniam atstumui tarp ŠD ir GM lauko sinchronizacijos atitinkamiems tiriamiesiems.



4 pav. *Dendrograma pagal tiriamųjų ŠD sinchronizaciją su GM lauku*

Kaip matyti iš dendogramos, tiriamieji Nr. 7 ir 20 yra arčiausi (arba labiausiai panašūs) pagal jų ŠD sinchronizaciją su GM lauko kitimais.

***2 tyrimas*.**

Koreliacinė duomenų analizė atskleidė, jog bent kiek stipresnės (>0,10) koreliacijos išryškėjo vertinant GM lauko sąsajas su psichikos sveikata (SF-12 instrumentas) žemiausiuose trijuose dažniuose (0–3,5 Hz, 3,5–7 Hz ir 7–15 Hz), ir būtent su 12 ir 36 valandų atsilikimo intervalais. Pavasario sezono metu, bent kiek stipresnės (>0,10) koreliacijos išryškėjo žemiausiuose trijuose dažniuose (0–3,5 Hz, 3,5–7 Hz ir 7–15 Hz), ir būtent vertinant psichikos sveikatą su 12 ir 36 valandų atsilikimo intervalais. Rudens sezono metu koreliacijos išryškėjo aukščiausiame dažnyje (32–66 Hz), tačiau tik keturios iš visų reikšmingų koreliacijų pasiekė 0,10 stiprumo ribą. Šios stipresnės koreliacijos išryškėjo vertinant fizinę sveikatą bei bendrą gerovę su 24 ir 48 valandų atsilikimu.

Vertinant *lyčių* skirtumus, paaiškėjo, jog vyrų grupėje bent kek stipresnės (>0,10) koreliacijos išryškėjo pirmuose keturiuose dažniuose (0–3,5 Hz, 3,5–7 Hz, 7–15 Hz ir 15–32 Hz), vertinant psichikos sveikatą, emocinį ir fizinį gyvybingumą su 12 ir 36 valandų atsilikimu. Tarp moterų, nei viena iš rastų reikšmingų koreliacijų nesiekė 0,10 ribos.

Vertinant skirtumus tarp *amžiaus* grupių, atsiskleidė, jog jaunesniųjų (19–29 m.) grupėje išryškėjo tik trys koreliacijos aukščiau 0,10 stiprumo ribos – vertinant psichikos sveikatą su 12 ir 36 valandų atsilikimu žemesniuose dažniuose. Vyresniųjų grupėje (30–39 m.) stipresnės (>0,10) koreliacijos išryškėjo pirmuose keturiuose dažniuose ir su 24 bei 48 valandų atsilikimo intervalais. Taip pat pastebėtina, jog šioje grupėje visos koreliacijos, pasiekusios 0,10 ribą, buvo neigiamos.

Vertinant *fizinio aktyvumo* reikšmę, paaiškėjo, jog reguliariai fizinį aktyvumą praktikuojančiųjų grupėje beveik visos reikšmingos ir pasiekusios 0,10 stiprumą koreliacijos išryškėjo žemesniuose dažniuose vertinant psichikos sveikatą su 12 ir 36 valandų atsilikimu. Neužsiimančių reguliaria fizine veikla grupėje rasta tik viena reikšminga koreliacija, siekianti 0,10 stiprumo ribą – vertinant psichikos sveikatą su 36 valandų atsilikimu žemiausiame dažnyje (0–3,5 Hz).

Daugiamatė regresinė analizė atskleidė, jog didesni geresnės *psichikos būklės* (SF psichikos sveikatos rodiklis) šansai pastebimi tarp vyrų, vyresnių bei fiziškai aktyvių tiriamųjų, antrąjį metų pusmetį, bei su 12 ir 36 valandų atsilikimu. Taip pat nustatytas statistiškai reikšmingas GM lauko kitimų poveikis psichikos sveikatai, tačiau šis poveikis neišliko, vertinant psichikos sveikatą su 36 valandų atsilikimu. Didesni geresnės *fizinės būklės* (SF fizinės sveikatos rodiklis) šansai pastebimi tarp vyresnių ir fiziškai aktyvių tiriamųjų, bei pirmąjį metų pusmetį. Fizinei sveikatai magnetinio lauko kitimų poveikis nenustatytas. Didesni geresnio *fizinio gyvybingumo* šansai pastebėti tarp vyrų bei vyresnių tiriamųjų. GM lauko kitimai turėjo reikšmingą poveikį fiziniam gyvybingumui tik žemiausiame dažnyje (0–3,5 Hz) ir tik su 12 valandų atsilikimu. Didesni geresnio *emocinio gyvybingumo* šansai pastebėti tarp vyresnių, tarp fiziškai aktyvių tiriamųjų. GM lauko poveikis šiam rodikliui nustatytas tik 7–15 Hz dažnyje. Didesni geresnio *socialinio bendravimo* šansai pastebėti tarp vyresnių, tarp fiziškai aktyvių tiriamųjų, antrąjį metų pusmetį. GM lauko poveikis šiam rodikliui nustatytas tik žemesniuose dažniuose. Didesni geresnės *bendros gerovės* šansai pastebėti tarp vyresnių, tarp fiziškai aktyvių tiriamųjų. Reikšmingas GM lauko kitimų poveikis šiam vertintam kriterijui nenustatytas.

IŠVADOS

1. Nuo 2014 m. iki pat 2016 m., kasmetinis geomagnetinio lauko stiprumo vidurkis mažėjo. Nuo 2017 m. stiprumo vidurkis pradėjo kasmet ženkliai kilti. Geomagnetinio lauko stiprumas pasiekia aukščiausią piką vėlyvą vasarą, o tuomet pradeda kristi iki žemiausio stiprumo vėlyvą rudenį.
2. Tyrimo dalyviai savo fizinę sveikatą vertino geriau negu psichikos sveikatą. Vyrai bei vyresni tiriamieji (30–39 m.) savo psichikos sveikatą, fizinį bei emocinį gyvybingumą vertino statistiškai reikšmingai geriau negu moterys bei jaunesni (19–29 m.) tiriamieji.
3. Biopsichosocialinės gerovės bei sveikatos rodiklių ir lokalaus geomagnetinio lauko kitimų sąsajų analizė atskleidė:
   - Didesnė vidinė žmogaus darna turi teigiamą poveikį sinchronizacijai tarp širdies dažnio ir geomagnetinio lauko kitimų;
   - Dviejų asmenų tarpusavio santykių kokybė turi sąsajų su jų širdies dažnio sinchronizacija su geomagnetinio lauko kitimais – kuo pozityviai artimesnis jų santykis, tuo panašesnė jų sinchronizacija;
   - Ryškiausi geomagnetinio lauko poveikiai atsiskleidė analizuojant sąsajas su 12 ir 36 valandų atsilikimo intervalais trijuose žemiausiuose dažniuose (0–3,5 Hz, 3,5–7 Hz ir 7–15 Hz);
   - Pavasario sezonu ryškiausios geomagnetinio lauko stiprumo sąsajos su gerove ir sveikata atsiskleidė trijuose žemiausiuose dažniuose, tuo tarpu rudenį – aukštesniuose dažniuose; pavasarį poveikiai išryškėja greičiau negu rudenį; psichikos sveikata labiau reaguoja į geomagetinio lauko stiprumą pavasarį, tuo tarpu fizinė sveikata ir bendra gerovė – rudenį; pavasarį moterys labiau reaguoja į geomagnetinį aktyvumą nei vyrai;
   - Jaunesni tiriamieji į lokalaus geomagnetinio lauko kitimus reaguoja greičiau (per 12–36 valandas) negu vyresni; be to, jaunesniųjų grupėje sąsajos buvo teigiamos, o vyresniųjų – neigiamos.

TYRIMO RIBOTUMAI, PRIVALUMAI IR ATEITIES PERSPEKTYVOS

Įvertinus atlikto tyrimo daugialypius rezultatus, svarbu paminėti keletą reikšmingų aspektų, kurie išryškėjo kaip mūsų tyrimo ribotumai ar/ir stiprybės, ir kurie gali pagelbėti planuojant panašaus pobūdžio tyrimus ateityje:

- Tyrime pasirinkta ištirti 19–39 metų amžiaus asmenis, o tai yra sąlyginai jauna amžiaus grupė. Tikėtina, jog įtraukus ir vyresnius asmenis, asispindėtų daugiau su sveikata ir gerove susijusių veiksnių ir poveikių, todėl galimai pasirinkta jauno amžiaus imtis apribojo galimybę gauti nuodugnesnius ir reikšmingesnius tyrimo rezultatus – ateityje vertėtų įtraukti platesnę pagal amžių tiriamųjų grupę;

- 2 tyrimas vykdytas penkiais srautais 2016 m. kovo–spalio mėnesiais. Visais penkiais srautais buvo tirti skirtingi asmenys. Kadangi į analizę buvo įtrauktas ir sezoniškumas, svarbu turėti omenyje, kad lyginant skirtingus sezonus, tiriamieji taip pat buvo skirtingi, tad grupės buvo nevienodos;
- Kadangi sezoniškumas paaiškėjo esantis reikšmingas faktorius, tai ateityje atliekant tyrimus vertėtų įtraukti ir žiemos mėnesius, nes atliktas tyrimas apėmė laikotarpį nuo pavasario iki rudens vidurio;
- Mūsų tyrimas apėmė tiek objektyvius, tiek subjektyvius sveikatos ir gerovės vertinimus, o tai suteikia galimybę vertinti su sveikata susijusius aspektus iš platesnės perspektyvos, negu kad apsiribojant vien objektyviais matavimais;
- Galiausiai, atliktame tyrime į analizę buvo įtraukti poveikiai su atsilikimo intervalais – po 12, 24, 36 ir 48 valandų. Tačiau ateityje taip pat vertėtų analizuoti ir poveikius, pasireiškiančius prieš, o ne tik po GM lauko svyravimų.

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Local geomagnetic field fluctuations relationship with mental and physical health among adults in Lithuania

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Abstract. The study examined the relationship between local geomagnetic field fluctuations and physical and mental health among young adults in Lithuania. 264 participants were recruited for a two-week period study, during which they had to fill-in paper questionnaires, consisting of a 12-Item Short Form Survey (SF-12), assessing physical and mental health, 4 questions about physical vitality, emotional vitality, social wellbeing and overall wellbeing, and questions regarding sociodemographic data. The results of the study revealed that possible influence of geomagnetic field fluctuations appear not simultaneously with the changes in human health status, but with a 12-hour lag. This relationship was found to be weak but significant, however, only with mental health.

Keywords: geomagnetic field, mental health, physical health.

1. Introduction

Invisible fluctuating magnetic fields inevitably reach all human beings on the Earth, as being a part of a biological system [1]. Scientists have well described that geomagnetic field resonances generate a range of resonant frequencies that are directly linked to the physiological processes in human brain, autonomic nervous system (ANS), and cardiovascular system. It is also proposed that every living organism on the Earth has a specific and unique sensitivity to the strength and frequency of geomagnetic field fluctuations [2, 3].

Recent studies proved that both – weak and strong – geomagnetic field disturbances are associated with negative health outcomes [4, 5]. It is commonly recognized, that geophysical environment factors may stimulate social unrest by influencing the mental state of people [6]. Increased rates of violence, crime, revolutions, frequency of terrorist attacks also have been significantly linked to geomagnetic activity factors [7-9]. A number of studies have demonstrated evidence that geomagnetic and solar influences affect human behavioral and health outcomes, the nervous and cardiovascular systems being the most clearly impacted [10-12].

Doronin et al. [13] in their study that compared low-frequency geomagnetic rhythms with electroencephalogram (EEG) rhythms, blood pressure, heart rate, and reaction times, revealed that the variations in both heart and brain patterns were associated with changes in geomagnetic activity simultaneously. Stoupel et al. [14] have found significant links between geomagnetic activity, accompanied by high Cosmic Ray Activity (neutron activity), and rises in more medical emergencies and total daily death number. In another study performed by this researcher [15], low GMA was associated with more sudden deaths, some increase in electrical heart instability number of ventricular and supraventricular extrasystoles and higher rate of ventricular tachycardia.

From what has been discussed, it becomes obvious that quite a large number of psychophysiological rhythms are affected by and can synchronize with solar and geomagnetic activity [9, 11, 13, 16]. However, most of the introduced researches reflect objective health parameters, which produces a lack of studies that would assess subjectively perceived data on physical, mental wellbeing and its relationship with geomagnetic activity. Subjectively perceived wellbeing of a person is an important and significant indicator for analyzing and predicting his/her immediate future health changes and healthcare needs [17]. A person's subjective assessment of his/her health status and overall wellbeing is most often determined by biomedical, functional and emotional components [17, 18]. A number of scientists [17, 19, 20] emphasize that it is the subjective rather than the objective assessment of health status and wellbeing that is a particularly important and significant prognostic indicator, therefore, it was decided in this study to rely on subjectively assessed health and wellbeing of the subjects.

2. Methods and procedures

2.1. Participants

The study took place in Kaunas, Lithuania. Healthy young adults (19-39 age) were recruited for the study. The study for each participant lasted two weeks in a row, therefore, in order to recruit a sufficient number of participants who would agree to stay in the study for this period, participants were recruited in groups. Starting in March, 2016, until the end of October, 2016, 5 runs of two-week study periods were organized. A total of 264 participants data were included into the final analysis. The mean age (sd) of the 264 participants in the analysis was 26 (6,37) years consisting of 184 females and 79 males.

2.2. Ethics statement

The performed study was in compliance with the ethics of experimentation in accordance with the Declaration of Helsinki. The permit to perform biomedical research was granted by the Kaunas Regional Ethics Committee for Biomedical Investigations, No. BE-2-51, 23.12.2015 (copies of documents are enclosed as supplemental data). Each participant signed a paper consent prior to the study.

2.3. Health parameters data collection

Participants had to fill in paper questionnaires, consisting of 12-Item Short Form Survey (SF-12), 4 questions about physical vitality, emotional vitality, social wellbeing and overall wellbeing, and questions regarding sociodemographic data.

SF-12 has been extensively used as a valid measure of self-reported health-related quality of life in a variety of population groups [21], including adults' population in Kaunas city [22]. The questionnaire consists of twelve questions that measure eight health domains to assess physical and mental health. Physical health-related domains include General Health, Physical Functioning, Role Physical, and Body Pain. Mental health-related scales include Vitality, Social Functioning, Role Emotional, and Mental Health.

4 questions about physical vitality, emotional vitality, social wellbeing and overall wellbeing were constructed consulting the HeartMath Institute Research Director Rollin McCraty. The questions asked the participants to provide their responses by using a 5-point Likert scale.

2.4. Magnetic field data

The local magnetic field fluctuations data was gathered using a magnetometer located in Lithuania. The device is a part of the Global Coherence Monitoring Network [1]. Two magnetic field detectors (Zonge Engineering ANT-4) at the site are positioned in the north-south and east-west axes to detect local time-varying magnetic field strengths (sensitivity 1 pT) over a wide frequency range (0.01-65 Hz) while maintaining a flat frequency response. The mechanism of the data acquisition captures, then stamps the global positioning system time, and transmits the data to the common server.

2.5. Identification of correlations between health parameters and geomagnetic field fluctuations

For identification of correlations between mental, physical health parameters and geomagnetic field fluctuations, Spearman's correlation coefficient was applied. For the analysis, the Statistical Package for the Social Sciences (SPSS), 20 version was used.

3. Results

The results of the analysis of correlations between geomagnetic field fluctuations, mental and physical health are presented in Table 1 and Table 2. Geomagnetic field is ranged in 6 different frequency ranges. Table 1 reflects the relationships at the same time, whereas Table 2 shows the relationships with a 12-hour lag (geomagnetic field fluctuations that occurred 12 hours prior the participants' health parameters were assessed).

Table 1. Geomagnetic field fluctuations relationship with physical and mental health

		Frequency 0-3,5 Hz	Frequency 3,5-7 Hz	Frequency 7-15 Hz	Frequency 15-32 Hz	Frequency 32-65 Hz	Frequency 0-65 Hz
SF physical	*R*	0,029	0,036	0,042	0,050	0,017	0,040
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3420	3420	3420	3420	3420	3420
SF mental Physical vitality	*R*	0,048	0,027	0,001	0,004	0,029	0,027
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3420	3420	3420	3420	3420	3420
SF physical	*R*	0,040	0,039	0,020	0,015	–0,005	0,014
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3449	3449	3449	3449	3449	3449
SF mental	*R*	0,029	0,027	0,015	0,008	0,000	0,010
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3448	3448	3448	3448	3448	3448

R – Spearman's correlation coefficient; *p* – Spearman's correlation coefficient's *p* value

Table 2. Geomagnetic field fluctuations relationship with physical and mental health with a 12-hour lag

		Frequency 0-3,5 Hz	Frequency 3,5-7 Hz	Frequency 7-15 Hz	Frequency 15-32 Hz	Frequency 32-65 Hz	Frequency 0-65 Hz
SF physical	*R*	0,008	0,012	0,000	–0,022	–0,011	–0,012
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3420	3420	3420	3420	3420	3420
SF mental Physical vitality	*R*	0,102	0,110	0,119	0,065	–0,026	0,026
	p	< 0,001	< 0,001	< 0,001	< 0,001	> 0,001	> 0,001
	N	3420	3420	3420	3420	3420	3420
SF physical	*R*	0,034	0,035	0, 035	–0,003	–0,033	–0,018
	p	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001	> 0,001
	N	3449	3449	3449	3449	3449	3449
SF mental	*R*	0,042	0,052	0, 064	0,034	–0,008	0,012
	p	> 0,001	> 0,001	< 0,001	> 0,001	> 0,001	> 0,001
	N	3448	3448	3448	3448	3448	3448

R – Spearman's correlation coefficient; *p* – Spearman's correlation coefficient's *p* value

As it can be seen from Table 1, that there were no significant relationships found between geomagnetic field fluctuations and health parameters when estimating at the same time of occurrence.

From the data in Table 2, it can be seen that weak correlations appear in four different frequency ranges when estimating mental health and geomagnetic field fluctuations with a

12-hour lag.

4. Limitations of the study

Our study has some limitations. First, we included only subjectively assessed data about the participants' health parameters. Due to a study period of two weeks, this may have resulted in a loss of motivation to provide sincere answers regarding the participants' everyday health status, which, in turn, may have influenced inaccurate results of the study. Objective measures of health parameters would have contributed to more accurate results. Further studies including not only subjective, but also objective measures of health parameters, or/and shortening the study period in order to maintain the participants motivation, are necessary.

5. Conclusions

The discussed study examined geomagnetic field fluctuations relationship with mental and physical health among young adults in Lithuania. The results of the conducted study suggest that possible influence of geomagnetic field fluctuations appear not simultaneously with the changes in human health status, but with a 12-hour lag. This relationship was found to be weak but significant, however, only with mental health. Results of the study propose that perhaps not only subjective, but also objective assessment of current health parameters might be of great value in order to obtain better and more accurate data. A more complex design of the study, including objective data about participants' health parameters, is an object for future analysis.

Acknowledgements

In 2014, HeartMath Institute (California, USA) financed and coordinated the installation of two magnetic field detectors (Zonge Engineering ANT-4) that measure a local time-varying magnetic field strengths (sensitivity 1 pT) over a wide frequency range (0.01-65 Hz) in Lithuania. Thanks to this huge investment, we have been able to start researching relationships between various health related phenomena and local geomagnetic field fluctuations in Lithuania.

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The influence of heart coherence on synchronization between human heart rate variability and geomagnetic activity

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Abstract. Results of a study on the effect of the Heart Lock-In meditation technique on the synchronization between heart rate variability and local magnetic field activity is presented in this paper. A technique based on the near-optimal chaotic attractor embedding was applied in order to evaluate the geometrical synchronization between analyzed time series. The results demonstrate that Heart Lock-In technique had a strong influence on the relationship between cardiac and geomagnetic activity.

Keywords: Earth's magnetic field, geomagnetic field, heart rate variability, HRV, ANS, nonlinear dynamical systems.

1. Introduction

All biological systems, which are embedded within the Sun and Earth's magnetospheres, are exposed to invisible fluctuating magnetic fields that span a wide range of frequencies [1]. It is well known that geomagnetic field line resonances and the Schumann resonances, which exist in the cavity between Earth and the ionosphere, generate a range of resonant frequencies that directly overlay those of the human brain, autonomic nervous system (ANS), and cardiovascular system. Of all the physiological systems studied, the rhythms produced by the brain and heart are most affected by changes in geomagnetic conditions [2-8]. It has been demonstrated that numerous physiological rhythms are affected by and can synchronize with solar and geomagnetic activity [9-12]. However, several recent studies that utilized continuous monitoring of heart rate variability (HRV) over longer time periods have shown that ANS activity can synchronize to a surprising degree with changes in the amplitude of resonant frequencies produced by geomagnetic field-line resonances, Alfvén waves and the Schumann resonances [13, 14].

HRV is the measurement of the time intervals between adjacent pairs of heartbeats, which reflects autonomic nervous system dynamics [15]. The amount of naturally occurring HRV one has reflects the functional status of codependent regulatory systems that operate over different time scales to adapt to environmental and psychological challenges [16]. Lower levels of variation in age-adjusted HRV indicate pathology, chronic stress, or insufficient functioning in regulatory systems in the neuro axis and is associated with of all-cause mortality [17-19]. Higher levels of HRV are associated with resiliency, capacity to self-regulate and to adapt to changing demands [16, 19].

Several studies have found that an intensification in field-line resonances can lead to alterations in cardiovascular function and it has been suggested that this may be due to the fact that many of the field line resonances have frequencies that directly overlap with those of the ANS and cardiovascular system [9, 12, 13, 20].

A previously conducted study provided evidence suggesting that participant's psychological state and quality of interactions between group members was related the degree of HRV synchronization with the magnetic field data and other participants in the group [14]. It has also been proposed that when one is in a state called physiological or HRV coherence that one is more likely to be coupled to and therefore synchronized to the Earth's magnetic fields [21]. In order to test this hypothesis, we also examined the potential effects of a heart focused mediation technique called the Heart Lock-In, which increases the coherence in one's heart rhythms, and has been shown to increase the synchronization of heart rhythms between participants in a group setting [22].

In order to improve the assessment of physiological synchronization and identify individuals' response patterns, we utilized a newly developed and validated analysis approach using near-optimal chaotic attractor embedding techniques. This allowed us to identify specific patterns of synchronization between heart rate variability and local magnetic field data, and assess potential effects of participants being in a state of HRV coherence on synchronization in a group of people located in Lithuania.

2. Methods and procedures

2.1. Participants

The experiment location had a local site coordinator who was responsible for participant recruitment, logistics coordination and participant training in the study procedures and use of the HRV recorders. Study coordinator in Lithuania recruited a total of 20 participants. The mean age (sd) of the 20 participants in the analysis was 23.3 (0.6) years consisting of 16 females and 4 males.

During the 14 day period between 26 February and 12 March 2015, 20 participants located in Lithuania participated in the study. All of the participants were healthy and either worked or attended classes during daytime hours. The Lithuanian group consisted of 20 medical students attending the Lithuanian University of Health Sciences.

2.2. Ethics statement

The research met all applicable standards for the ethics of experimentation in accordance with the Declaration of Helsinki. The permit to perform biomedical investigation was granted by the Kaunas Regional Ethics Committee for Biomedical Investigations, No. BE-2-51, 23.12.2015 (copies of documents are enclosed as supplemental data). Participants provided written informed consent prior to the experiment.

2.3. HRV data collection

HRV is a noninvasive measure that reflects ANS activity and dynamics. All participants underwent daily 24-hour ambulatory HRV recordings during a two-week period between 26 February and 12 March 2015 (Bodyguard2, Firstbeat Technologies Ltd., Jyväskylä, Finland). Prior to the start of the study, each participant received instructions on attaching, starting, and stopping the recorders as well as instructions to participants for logging day to day activity, sleep, waking, etc. from the local site coordinator.

The group coordinator was instructed in how to retrieve data from the HRV recorders and upload it to the data collection FTP site. Participants were instructed to stop the recorder each morning after waking up to start the day, and allowed up to 50 minutes to shower or bathe before reattaching the recorder and starting the new day's recording. Ambu Blue Sensor VL microporous breathable disposable electrodes were used for all of the recordings. The electrodes were placed in a modified V5 position. To minimize skin irritation over the two weeks, participants were encouraged to locate the electrodes around three different positions near the V5 electrode sites. The HRV recorder calculates the RR Interval (R is a point corresponding to the peak of the QRS complex of the ECG wave; and RR is the interval between successive Rs) from the electrocardiogram sampled at 1000 Hz. The RR interval data were stored locally in the device memory, and downloaded to a computer workstation at the completion of the study.

All of the HRV recordings were downloaded from the FTP site to a computer workstation and analyzed using DADiSP 6.7. Inter-Beat-Intervals greater or less than 30 % of the mean of the previous four intervals were considered artifacts, and were removed from the analysis record. Following an automated editing procedure, all of the recordings were manually reviewed by an experienced technician, and, if needed, corrected. Daily recordings were processed in consecutive 5-min segments in accordance with the standards established by the HRV Task Force. Any 5-min segment with >10 % of the IBIs either missing or removed in editing were excluded from the analysis. The local time stamps in the HRV recordings were converted to Coordinated Universal Time (UTC) to enable synchronization between locations and magnetic field data sets.

2.4. Magnetic field data

The local magnetic field intensity was measured using magnetometer located in Lithuania which is a part of the Global Coherence Monitoring Network [21]. Two magnetic field detectors (Zonge Engineering ANT-4) at the site are positioned in the north-south and east-west axes to detect local time-varying magnetic field strengths (sensitivity 1 pT) over a wide frequency range (0.01-300 Hz) while maintaining a flat frequency response. The data acquisition infrastructure captures, then stamps, the global positioning system time, and transmits the data to the common server. Each magnetometer in the network is continuously sampled at a rate of 130 Hz.

2.5. Heart Lock-In procedure

On March 5th, the group participated in the Heart Lock-In technique for a 15-minute period. The Heart Lock-In technique focuses on building the capacity to sustain heartfelt positive emotions. The technique is generally practiced for five to fifteen minutes at a time, although longer sessions may be used as well. The steps of Heart Lock-In are:

Step 1: Focus your attention in the area of the heart. Imagine your breath is flowing in and out of your heart or chest area, breathing a little slower and deeper than usual.

Step 2: Activate and sustain a regenerative feeling such as appreciation, care or compassion.

Step 3: Radiate that renewing feeling to yourself and others [23].

Use of this technique is typically accompanied by feelings of peacefulness, harmony, and a sense of inner warmth, and is often an effective means to diffuse accumulated stress and negative feelings [24].

2.6. Computation of the power of the local magnetic field

The spectral power of the local magnetic field was computed using the magnetic field intensity values and applying the algorithm denoted in [14] as Algorithm A. The main steps of the algorithm included the computation of the spectrogram of the magnetic field intensity data signal (for one-second time intervals), clipping the spectrogram to a certain level in order to minimize the noise (manmade noise, lightning) in the magnetic field data and summing the values over the frequency range [0, 1] Hz. Empirically obtained optimal noise clipping level was 1.25 $(pT)^2/Hz$.

2.7. Determination of geometrical synchronization between participants' HRV and local magnetic field power time series

For the determination of synchronization between participants' HRV and the signal of the power of local magnetic field, computed for 1s time intervals (see Section 2.6), we employed techniques developed, validated and described in detail in [14]. This approach is based on the fact, that it is possible to map a data signal into an integer which describes the geometrical dynamics of the data signal. The integer corresponds to the optimal time lag value that maximizes the area of the attractor constructed from the data series.

We slightly modified the algorithm described in [14] as Algorithm C to be relevant to this study to the following procedure:

Let $RR = (RR_1, \dots, RR_n)$ and $M = (M_1, \dots, M_n)$ be synchronously sampled participant's HRV and local magnetic field (MF) power signals of size n.

1) Divide series RR and M into T 5-minute-long observation windows (according to HRV analysis standards [25]) and compute optimal time lag values for each observation window for HRV time series $\left(\tau_*^{(RR)} = \left(\tau_{*1}^{(RR)}, \dots, \tau_{*T}^{(RR)}\right)\right)$ and magnetic field power data signal $\left(\tau_*^{(M)} = \left(\tau_{*1}^{(M)}, \dots, \tau_{*T}^{(M)}\right)\right)$. This step reduces the analyzed HRV and MF time series to integer vectors, characterizing geometrical features of those series.

2) Smooth obtained optimal time lag vectors in order to identify averaged changes in time lags for HRV $\left(\bar{\tau}_*^{(RR)}\right)$ and magnetic field data $\left(\bar{\tau}_*^{(M)}\right)$.

3) Calculate the Pearson correlation coefficient between the obtained mean time lag vectors $C^{(RR,M)} = \rho\left(\bar{\tau}_*^{(RR)}, \bar{\tau}_*^{(M)}\right)$.

Consider a set of HRV time series $RR^{(k)} = \left(RR_1^{(k)}, \dots, RR_n^{(k)}\right)$, $k = \overline{1, K}$, corresponding to K participants. In order to calculate the mean synchronization between the HRV of all K participants and magnetic field, we compute HRV/Magnetic field correlation coefficients $C^{\left(RR^{(k)},M\right)}$ for each participant $k = \overline{1, K}$ and calculate the mean correlation coefficient $C^{\left(RR^{(1..K)},M\right)} = \frac{1}{K}\sum_{k=1}^{K} C^{\left(RR^{(k)},M\right)}$.

2.8. Identification of the effect of being in a coherent state using the Heart Lock-In technique on synchronization with the magnetic field

Procedures for the estimation of synchronization between participants' HRV and local magnetic field power time series, described in Section 2.7, were applied to the data described above.

Since the Heart Lock-In technique took place once for a 15-minute period (on March 5th, 2015), we calculated participants' HRV/MF synchronization for each day of the study separately in order to see if the synchronization between participants' HRV and magnetic field activity on the day of the Heart Lock-In was different compared to days before and after the using the technique.

3. Results

The results of the analysis of the synchronization between participants' HRV and magnetic field activity are presented in Fig. 1. Each figure consists of plots displaying the synchronization between each participant's HRV and magnetic field activity for six days (2015/03/01 – 2015/03/06). The Fig. 1(e) part of each figure corresponds to the day of the application of the Heart Lock-In technique.

Fig. 2 depicts the mean synchronization between groups' HRV and magnetic field power for each day of the experiment (red bar corresponds to the day the participants did the Heart Lock-In).

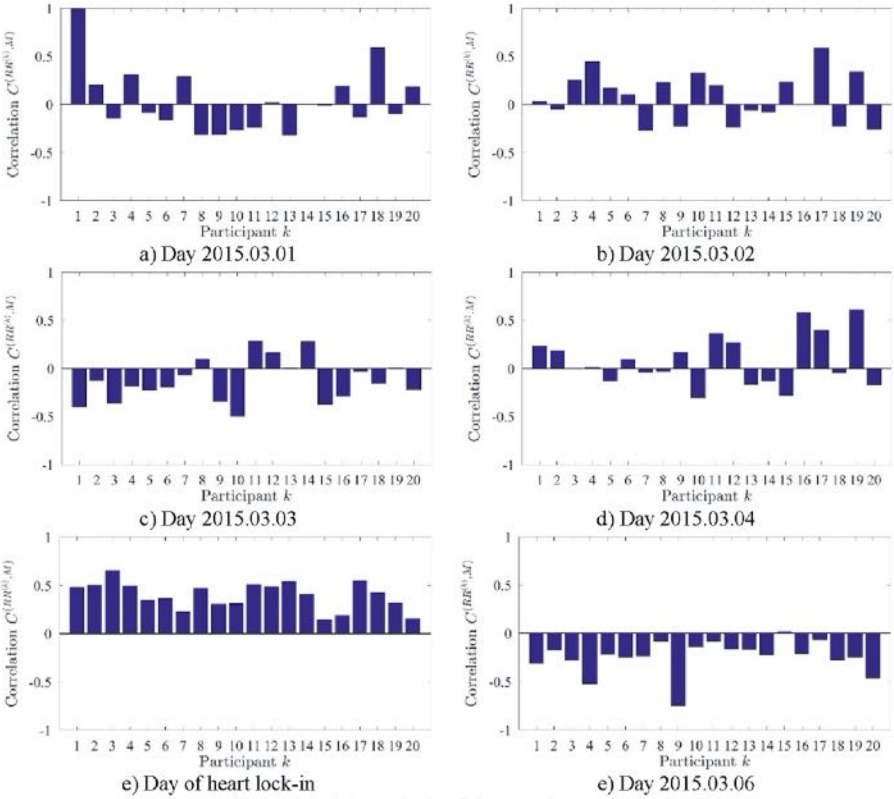

Fig. 1. The results of the analysis of the HRV/MF synchronization. Each part of the figure displays participants' HRV/MF synchronization for the indicated day. Part (e) corresponds to the day of the Heart Lock-In

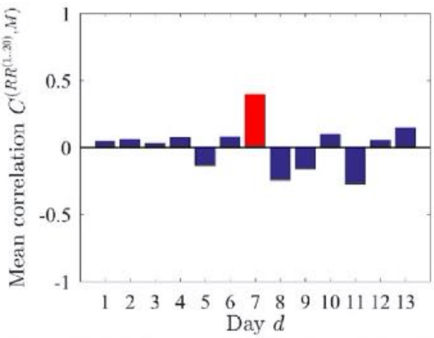

Fig. 2. Groups' mean HRV/MF synchronization for each day of the experiment

It can be seen that the synchronization (positive correlation) between participants' HRV and magnetic field activity (Fig. 2) on the day of the Heart Lock-In was the highest. Furthermore, all participants were highly positively correlated/synchronized with the local magnetic field during the day of the application of the Heart Lock-In technique (Fig. 1(f)) which contrasted with the synchronization results for days before and after the training.

4. Conclusions

A technique based on the near-optimal chaotic attractor embedding was applied in order to evaluate the geometrical synchronization between analyzed time series. The results of the conducted study indicate that the applied Heart Lock-In meditation technique has a positive impact on the synchronization between the human heart rate variability and the Earth's magnetic field. Thus, such medical techniques are shown to be valuable not only psychologically (in sustaining positive emotions), but also physiologically since high synchronization between heart rate variability and geomagnetic activity has been associated with better health conditions. Further study of these effects using different computational and experimental techniques are a definite objective of future research.

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Article

Identification of a Group's Physiological Synchronization with Earth's Magnetic Field

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Abstract: A new analysis technique for the evaluation of the degree of synchronization between the physiological state of a group of people and changes in the Earth's magnetic field based on their cardiac inter-beat intervals was developed and validated. The new analysis method was then used to identify clusters of similar synchronization patterns in a group of 20 individuals over a two-week period. The algorithm for the identification of slow wave dynamics for every person was constructed in order to determine meaningful interrelationships between the participants and the local magnetic field data. The results support the hypothesis that the slow wave rhythms in heart rate variability can synchronize with changes in local magnetic field data, and that the degree of synchronization is affected by the quality of interpersonal relationships.

Keywords: earth's magnetic field; geomagnetic field; heart rate variability; psychophysiology; nonlinear dynamical systems

1. Introduction

There are numerous investigations examining correlations between human health and the Earth's magnetic field activity. Many interesting studies have shown strong influences on a number of human pathologic and behavioral states.

It is well established that geomagnetic field line resonances and the cavity between Earth and the ionosphere generate a number of resonant frequencies that directly overlap those of the human brain, autonomic nervous system, and cardiovascular system. Of all the physiological systems studied thus far, the rhythms of the heart and the brain are most strongly associated with changes in geomagnetic conditions [1–11].

For example, numerous studies have demonstrated significant relationships between magnetic storms and decreased heart rate variability (HRV), the measurement of beat-to-beat changes in heart rate [12], which is suggestive of a potential mechanism linking geomagnetic activity with increased incidents of myocardial infarction and coronary disease [7,13–19]. In a review of the health effects of geomagnetic disturbances [20], Palmer et al. suggest these "definite conclusions": (1) geomagnetic disturbances have a greater effect on humans at higher geomagnetic latitudes; (2) unusually high values of geomagnetic activity have an effect on cardiovascular system health; (3) unusually low values of geomagnetic activity appear to have a negative effect on health; (4) approximately 10% to

15% of people in areas studied are negatively affected by disturbed geomagnetic activity; and (5) HRV is negatively correlated with geomagnetic disturbance.

There is a wide range of magnetic waves occurring in the magnetosphere that are excited by various processes within the magnetosphere as well as the solar wind. The most common source of ultra low-frequency wave energy measured on the ground is due to the field line resonances that exhibit the largest magnetic wave amplitudes occurring in the magnetosphere [21]. The frequency of these oscillations depends on the field strength, the number of charged ions spinning around the field lines, and specifically, the length of the magnetic field line. Quasi-sinusoidal oscillations are called "Pc" (pulsations continuous), and irregular waveforms are called "Pi" (pulsations irregular). Each major type is divided into frequency ranges associated with distinct phenomena. Standing field line oscillations are typically in the Pc3 to Pc5 range, which correspond to a frequency range between 1–100 mHz. Oscillations classified as Pc1 and 2 are oscillations with frequencies up to 5 hertz, which are typically excited by geomagnetic substorms [22].

The ionosphere is a layer of plasma, a term that describes highly ionized gases threaded by magnetic fields, which surrounds the Earth. The charged particles in the plasma can spiral around the magnetic field lines and travel along it, creating auroras as high-energy particles flow along the field lines to the Earth's magnetic poles. This process was described by Hannes Alfven to explain how low-frequency waves that propagate along magnetic field lines are created [23].

Standing waves in the magnetosphere involve many magnetic field lines, with lengths several times the Earth's radius, which are excited and oscillate at their resonant frequency, similar to a plucked guitar string. Longer field lines have a lower resonant frequency, while shorter ones resonate at a higher frequency. Field lines with more or heavier particles spiraling around them tend to have lower frequencies. Changes in solar wind velocity or the polarity and orientation of the interplanetary magnetic field can have dramatic effects on the waves, as measured on the surface of the Earth [24].

Studies have shown that increased amplitudes of field line resonances can affect the cardiovascular system, most likely because their frequencies are in the same range as the primary rhythms found in the cardiovascular and autonomic nervous systems [25].

There has been a rapidly growing use of HRV since new devices have made obtaining the electrocardiogram (ECG) and HRV more accessible, and the understanding that HRV reflects autonomic nervous system dynamics [12] and provides an index of stress and emotions [26] and social interaction [27].

In a study conducted by Doronin et al. [28], electroencephalogram (EEG) rhythms, blood pressure, heart rate, and reaction times were compared with the low-frequency geomagnetic rhythms. They found that the oscillations in both heart and brain patterns changed simultaneously with changes in geomagnetic activity. Experiments conducted by Zenchenko et al. [29] monitored healthy individuals' heart rates at rest and compared them with low-frequency variations between 0.5–3.0 mHz in the geomagnetic field. They found that in two-thirds of the experiments, there was a synchronization between the heart rhythms and the rhythms in the geomagnetic field that occurred between 4 and 30 minute-long periods.

A more recent study [30] by McCraty et al. found a surprising degree of synchronization between geomagnetic activity and human nervous system function by continuous monitoring of participants HRV over a 31-day period in a group of individuals who went about their normal day-to-day lives. Overall, the study found evidence suggesting that daily autonomic nervous system activity not only responds to changes in solar and geomagnetic activity, but also is synchronized with the time-varying magnetic fields associated with geomagnetic field line resonances and Schumann resonances. More specifically, it was found that the participants exhibited a previously unidentified slow wave rhythm in their HRV, which was highly synchronized among the study participants and the time-varying magnetic field data, with a rhythm of approximately 2.5 days.

Following these findings of a significant interconnection between changes in local magnetic field activity and heart rate variability, this study examined potential relationships between human physiology (HRV), the geomagnetic field activity, and the quality of interpersonal relationships.

It has been found that individuals have widely varying levels of sensitivity to changes in the Earth's magnetic field, and can respond in opposite ways to fluctuations in the same environmental variable [31]. In order to improve the assessment of physiological synchronization and also identify different clusters of individuals' response patterns, we first developed and validated a new analysis approach using near-optimal chaotic attractor embedding techniques. This allowed us to identify specific patterns of synchronization between heart rate variability and local magnetic field data, and assess potential relationships between interpersonal dynamics and physiological synchronization in a group of people.

2. Methods and Procedures

2.1. Participants

During the two-week period between 26 February and 12 March 2015, a group of 20 medical students attending the Lithuanian University of Health Sciences continuously wore cardiac monitors (Bodyguard 2, Firstbeat Technologies Ltd., Jyväskylä, Finland) that gathered inter-beat intervals (IBI) from each participant. Consequently, we obtained a total of 20 IBI series, which is the time between the consecutive R wave peaks in the electrocardiogram from the 20 participants.

2.2. Ethics Statement

The research met all applicable standards for the ethics of experimentation in accordance with the Declaration of Helsinki. The permit to perform biomedical investigation was granted by the Kaunas Regional Ethics Committee for Biomedical Investigations, No. BE-2-51, 23.12.2015 (copies of documents are enclosed as Supplementary Materials). Participants provided written informed consent prior to the experiment.

2.3. Computational Estimation of the Synchronization of a Group's HRV Time Series with Earth's Magnetic Field Data

The main objective of this study was to assess the synchronization between the HRV time series of each participant and the magnetic field data. This information was then used to construct clusters of participants within the group based on the estimated synchronization between their HRV and the magnetic field.

2.3.1. Magnetic Field Data

The local magnetic field intensity was measured using a local magnetometer located in Lithuania (Coordinates: Latitude: 55.634068 Longitude: 23.704563), which is part of the Global Coherence Monitoring Network [32]. Two magnetic field detectors (Zonge Engineering ANT-4) were positioned in the north–south and east–west axes to detect local time-varying magnetic field strengths (sensitivity 1 pT) over a wide frequency range (0.01–300 Hz) while maintaining a flat frequency response. The data acquisition infrastructure captures, then stamps, the global positioning system time, and transmits the data to the common server. Each magnetometer in the network is continuously sampled at a rate of 130 Hz. Used data can be obtained from the HeartMath Institute website [33].

2.4. Computation of the Power of Local Magnetic Field

Consider magnetic field intensity $\{I_t\}_{t=0}^{N-1}$, where t is a discrete time variable. In order to transform $\{I_t\}_{t=0}^{N-1}$ to the frequency domain the discrete Fourier transform (DFT) was used:

$$f(\omega) = \sum_{t=0}^{N-1} I_t \cdot e^{-\frac{2\pi i t \omega}{N}}, \omega \in \mathbb{Z} \quad (1)$$

In order to observe changes in spectral density over time, the analysis interval was broken up into smaller sections using the discrete time short-time Fourier transform (STFT) for $\{I_t\}_{t=0}^{N-1}$:

$$F(\theta,\omega) = \sum_{t=-\infty}^{\infty} I_t \cdot \xi(t-\theta)e^{-it\omega}, \omega \in \mathbb{Z} \quad (2)$$

This is essentially a partitioned form of Equation (1) using the windowing function $\xi(t)$. A windowing function has a value close to 1 in each of a series of sliding segments of t and a value of 0 elsewhere.

The squared magnitude of the STFT $F(\theta,\omega)$ results in the spectrogram of I_t, which is utilized in the subsequent analysis since the STFT provides better time resolution:

$$S(\theta,\omega) = |F(\theta,\omega)|^2 \quad (3)$$

$S(\theta,\omega)$ is typically referenced as power spectral density (PSD). Thus, the value of $S(\theta,\omega)$ is interpreted as the signal power at the time interval $\Delta\theta$ and at the frequency range $\Delta\omega$.

Consider that it is required to find the local magnetic field power in the frequency range $\omega \in [\omega_{min}; \omega_{max}]\,Hz$ at time interval t_0 through $t_1 = t_0 + \Delta\theta\,(s)$.

The power of the local magnetic field is computed using **Algorithm A**:

(1) Compute the spectrogram $S(\theta,\omega)$ (as described previously).
(2) Crop the spectrogram $S = \min\{S; S_{crop}\}$ in order to eliminate intermittent chaotic outbreaks in the measured data due to manmade noise, lightening, etc.
(3) Apply the Gaussian median filter of dimensions 3×3 to S for the reduction of noise.
(4) Compute the signal power as $P = \sum_{\omega=\omega_{min}}^{\omega_{max}} \left(\frac{1}{\Delta\theta}\sum_{t=t_0}^{t_1} S(t,\omega)\right)$.

Thus, the signal power time series is the sum of the values of the spectrogram corresponding to the specified frequency and time intervals.

2.4.1. Example: Computation of the Local Magnetic Field Power

An example of the magnetic field intensity series is shown in Figure 1.

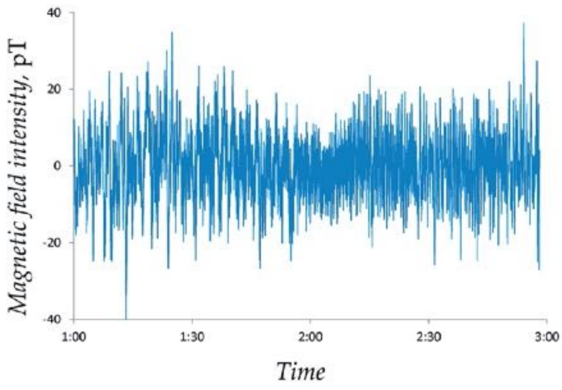


Figure 1. An example of the local magnetic field intensity data (measured in Lithuania during the time period between 2015/02/26 01:00:01 and 2015/02/26 03:00:01).

An example of the spectrogram $S(\theta,\omega)$ of the magnetic field signal depicted in Figure 1 for $\Delta\theta = 4$ hours, $\omega \in [0; 52]$Hz is displayed in Figure 2.

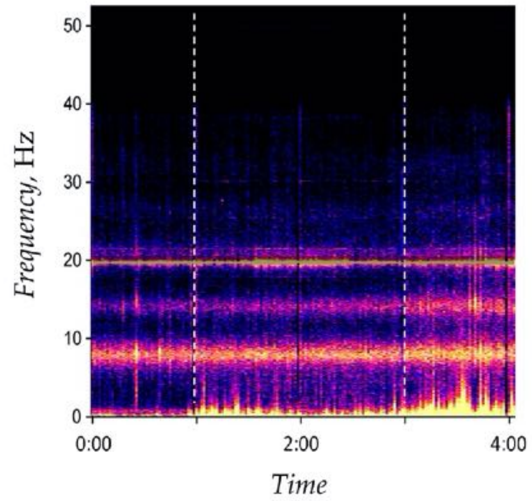


Figure 2. An example of the spectrogram for the magnetic field data presented in Figure 1. Frequency resolution is $\frac{1}{4096}$, $\Delta\theta = 4$ hours, $\Delta\omega = 52$ Hz, $\omega \in [0; 52]$Hz.

In order to calculate local magnetic field power in the frequency range $\omega \in [0; 1]\, Hz$ at time interval $t_0 = 2015/02/26\ 01{:}00{:}02$ through $t_1 = 2015/02/26\ 01{:}00{:}03$, the corresponding spectrogram is calculated as described above. The spectrogram is then cropped to $S = \min\{S; 0.25\}$. The signal power $P = 7.7405\ ((\text{pT})^2/\text{Hz})$ is then computed from the filtered spectrogram.

2.5. Algorithm for the Computation of Geometrical Synchronization between Two Time Series

2.5.1. Computation of the Area of an Attractor in the State Space

Let a signal $X = (X_1, \ldots, X_n)$ be a scalar time series of size n.

It is possible to embed the time series into a 2D delay coordinate space:

$$X_i, i = \overline{1, n} \to (X_i, X_{i+\tau}), i = \overline{1, n-\tau}, \tau \in \mathbb{N}$$

For $\tau = 1$ the following trajectory matrix is obtained:

$$\begin{bmatrix} X_1 & X_2 \\ X_2 & X_3 \\ \vdots & \vdots \\ X_{n-1} & X_n \end{bmatrix},$$

where every row of the matrix corresponds to the coordinates of an embedded point in the delay coordinate space. The time lag τ can be different ($\tau \in \mathbb{N}$). Thus, at $\tau = k$, the trajectory matrix reads:

$$\begin{bmatrix} X_1 & X_k \\ X_2 & X_{k+1} \\ \vdots & \vdots \\ X_{n-k+1} & X_n \end{bmatrix}$$

The ordered set of the embedded points is called an attractor, and the 2D plane itself is called the state space [34]. Note that the area occupied by the embedded attractor is one of the attributes characterizing the dynamics of the time series. However, the area of the attractor depends on the time lag τ used for the reconstruction of the state space. The maximal area of the embedded attractor (and the corresponding optimal time lag) is a feature that can be exploited for the description of the underlying model governing the evolution of the time series [35].

We employed a straightforward algorithm for the computation of the area of the embedded attractor based on the direct assessment of the geometric area occupied by the set of points of the trajectory matrix in the state space. The steps of **Algorithm B** read:

(1) Compute the center of the mass of the points comprising the attractor. Move the origin of the state space to the center of the mass.
(2) Divide the state space of the attractor into the slices with equal central angles of a circle centered on the origin. The number of slices depends on the number of points in the observation window of the time series.
(3) Set the radius of each slice to the maximal distance between a point belonging to that slice and the origin.
(4) Compute the area of the attractor S_τ as the sum of areas of all slices.

As noted previously, the area S_τ depends on τ. We consider a finite range of time lag values $\tau = 1, \ldots, \tau_{max}$; S_τ is calculated for each value of τ. The area of the embedded attractor is maximized in respect to τ: $\tau_* = \arg\left(\max_\tau S_\tau\right)$. The optimal time lag τ_* can be used as a scalar identifier representing the geometrical features of the analyzed data series in the corresponding observation window. The computation of the optimal time lag τ_* can be considered as the information reduction algorithm where a set of numbers in the original time series is mapped into a single scalar.

2.5.2. Example 1: Identification of the Optimal Time Lag

We will consider a nonlinear pendulum model with harmonic excitation as a paradigmatic chaotic oscillator in this example:

$$x'' + x' + \sin(x) = b\cos(\omega t) \quad (4)$$

Equation (4) exhibits a chaotic solution at $b = 2.048; \omega = \frac{2}{3}$ [36]. Figure 3 illustrates 500 data points of the chaotic solution $X = (X_1, \ldots, X_{500})$.

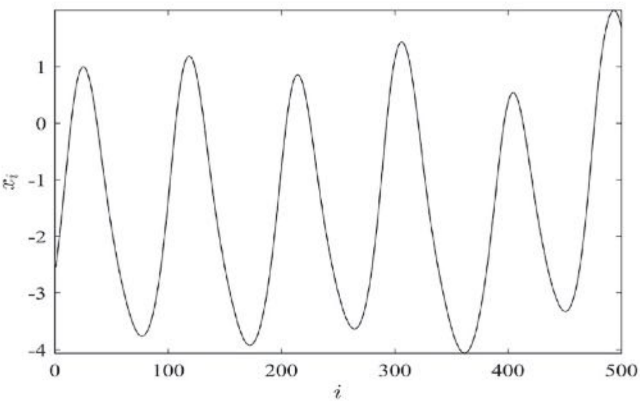


Figure 3. Time series $X = (X_1, \ldots, X_n)$ representing a numerical solution to Equation (4) with initial conditions $x(0) = 0$; $x'(0) = 0.8$.

The images of embedded attractors for the time series depicted in Figure 3 using several different values of the time lag τ are presented in Figure 4.

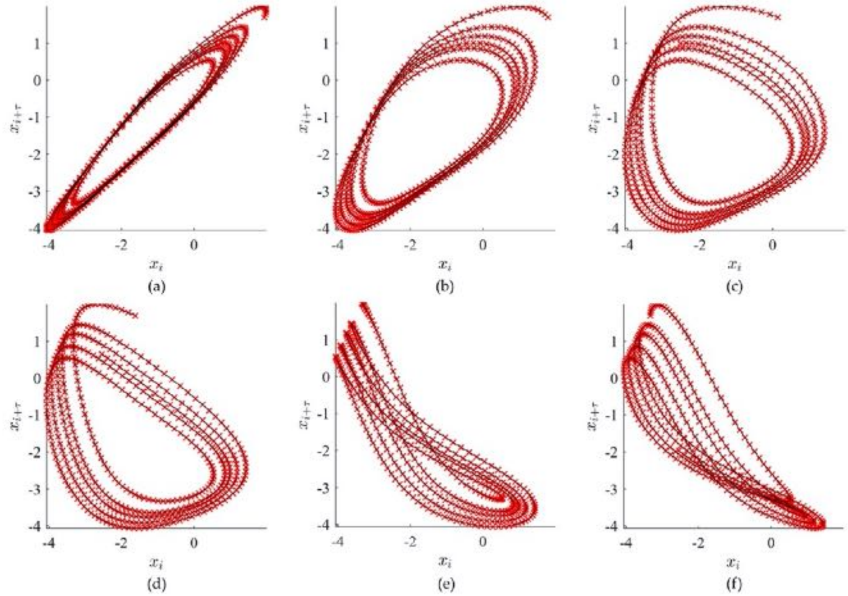


Figure 4. Examples of attractors for different time lag values. In (**a**) $\tau = 4$; (**b**) $\tau = 12$; (**c**) $\tau = 23$; (**d**) $\tau = 31$; (**e**) $\tau = 43$; (**f**) $\tau = 50$.

According to the algorithm presented above, the first step is shifting the origin to the center of the mass of the embedded attractor. The results of this procedure are illustrated in Figure 5. Note that this transformation does not impact the geometrical shape of the attractor.

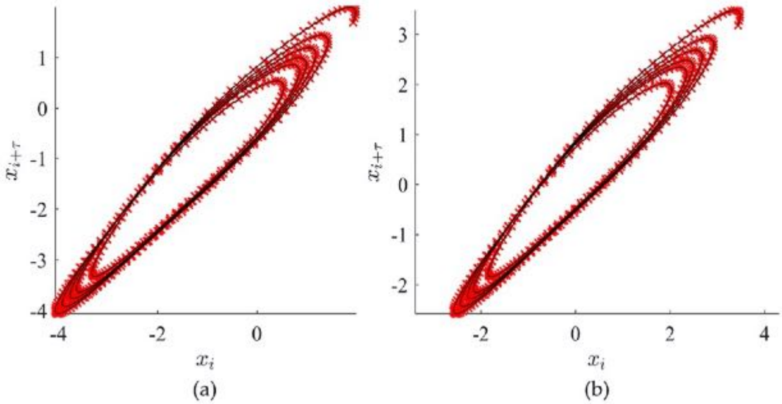


Figure 5. Shifting the origin to the center of mass of the attractor for $\tau = 4$: (**a**) the original attractor; (**b**) the origin shifted to the center of the mass of the attractor.

We select the number of slices to be 45. The execution of steps 2 and 3 of the algorithm with the six attractors (which correspond to six distinct time lag values) shown in Figure 4 results in the corresponding sliced diagrams illustrated in Figure 6.

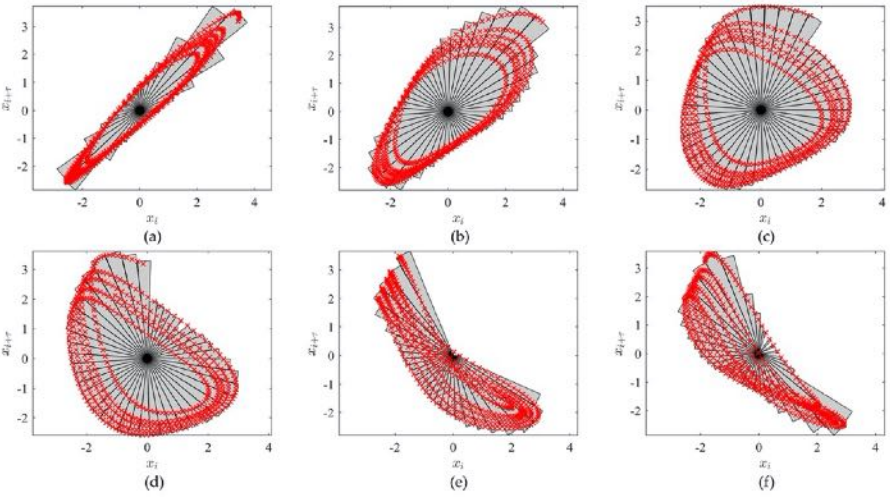


Figure 6. Sliced diagrams of the attractors shown in Figure 4.

The maximal value of τ is set to 50, because the total number of data points in the observation window is 500 (higher values of τ would generate too short trajectory matrices). In order to compute τ_* in the range [1,50], the areas of embedded attractors must be computed for each value of τ. A plot representing the relationship between an area of the attractor S_τ and τ is presented in Figure 7. The largest area of the embedded attractor $S_\tau = 24.9527$ is achieved at $\tau_* = 23$.

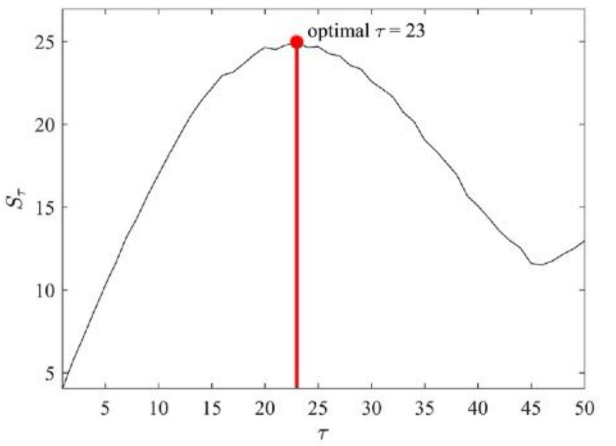


Figure 7. The identification of optimal time lag value τ_*.

2.5.3. Construction of the Algorithm for the Estimation of the Geometrical Synchronization between Two Time Series

Let $X = (X_1, \ldots, X_n)$ and $Y = (Y_1, \ldots, Y_n)$ be synchronously sampled time series of size n. The following procedure for the estimation of the geometrical synchronization between those two time series. The steps of **Algorithm C** read:

(1) Divide signals X and Y into T observation windows of size m (m should be large enough to enable the reconstruction of a meaningful attractor in the state space):

$$(X_1, \dots, X_m), (X_{m+1}, \dots, X_{2m}), \dots, (X_{n-m+1}, X_n);$$
$$(Y_1, \dots, Y_m), (Y_{m+1}, \dots, Y_{2m}), \dots, (Y_{n-m+1}, Y_n).$$

(2) Compute optimal time lags for each observation window for both time series using **Algorithm B**. Such computations result in two vectors of optimal time lags: $\tau_{*j}^{(X)}, \tau_{*j}^{(Y)}$ $(j = \overline{1,T})$. This information reduction algorithm allows the identification of similarities between attractors reconstructed from different time series from the geometrical point of view. The variation of optimal time lags reconstructed for a pair of time series is used for the quantification of the generalized geometrical synchronization between those time series.

(3) Calculate the vector of absolute differences between obtained optimal time lags for each observation window: $\tau_{*j}^{(X,Y)} = \left|\tau_{*j}^{(X)} - \tau_{*j}^{(Y)}\right|$ $(j = \overline{1,T})$. The differences between the optimal time lags are used as the metric of geometrical similarity between the analyzed time series.

(4) In order to identify the slow dynamics reflecting averaged changes in absolute differences between optimal time lags for each data signal, divide the vector of absolute differences into $F = \frac{T}{h}$ segments: $\left[\tau_{*(h\cdot(i-1)+1)}^{(X,Y)}, \dots, \tau_{*(h\cdot i)}^{(X,Y)}\right]$ $(i = \overline{1,F})$. The number of points h in each segment should be large enough to produce a meaningful averaging.

(5) Calculate the mean absolute difference $\bar{\tau}_i^{(X,Y)} = \frac{1}{h}\sum_{j=1}^{h} \tau_{*(h\cdot(i-1)+j)}^{(X,Y)}$ $(i = \overline{1,F})$ between optimal time lags for each segment. The obtained vector of mean absolute differences $A^{(X,Y)} = \left[\bar{\tau}_1^{(X,Y)} \bar{\tau}_2^{(X,Y)} \ \dots \ \bar{\tau}_F^{(X,Y)}\right]$ is defined as a measure representing the geometrical synchronization between data signals X, Y.

2.5.4. Computational Validation of the Geometrical Synchronization Algorithm

To validate the analysis method, we used a system of two nonlinear pendulum models with harmonic excitation (given in Equation (4)) coupled with diffusive terms:

$$\begin{aligned} x'' + x' + \sin(x) &= b_1 \cos(\omega t) + \varepsilon(y - x); \\ y'' + y' + \sin(y) &= b_2 \cos(\omega t) + \varepsilon(x - y), \end{aligned} \quad (5)$$

where $\omega = \frac{2}{3}; b_1 = 2.048; b_2 = 2.049$. The coupling parameter $\varepsilon \geq 0$ determines the coupling strength: low values of ε correspond to low synchronization between the pendulum models, while high values lead to highly synchronized oscillations [36].

Two time series $X = (X_1, \dots, X_n), Y = (Y_1, \dots, Y_n)$ of size $n = 48{,}000$ are illustrated in Figure 8. Time series X and Y are constructed as follows: firstly, ε is set to zero and the equations are integrated until transient processes die down. Then, the first 12,000 data points are sampled (first quarter of Figure 8). After sampling, ε is set to 0.03 (weak diffusive coupling) and another 12,000 data points are sampled (second quarter of Figure 8). The process is repeated two more times for $\varepsilon = 0.1$ in the third quarter, and $\varepsilon = 0$ in the last quarter, which are shown in Figure 8.

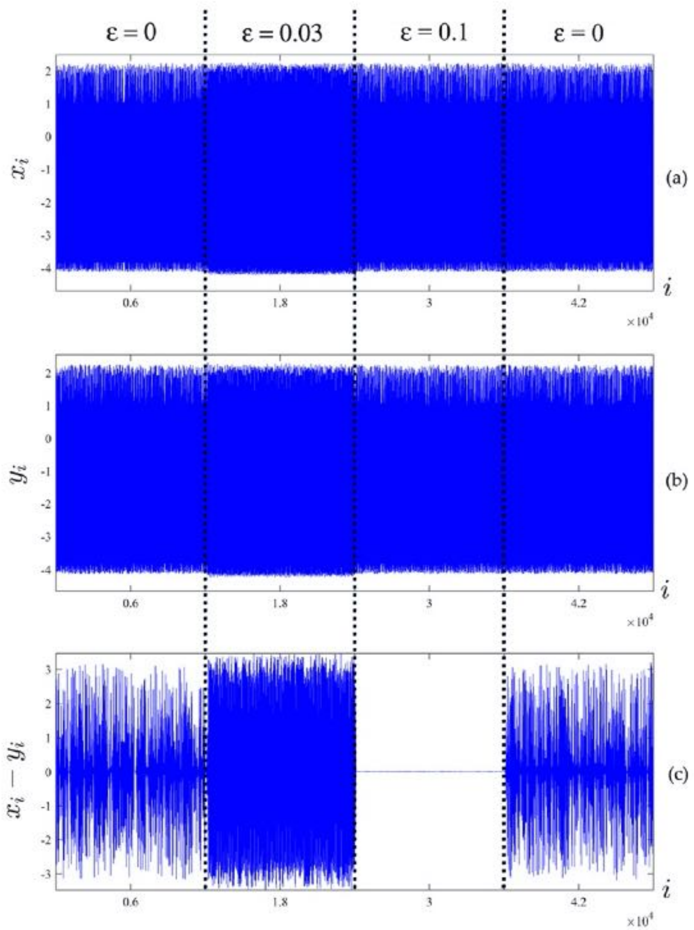


Figure 8. Time series X (**a**) and Y (**b**) and the difference $X - Y$ (**c**), obtained from numerical integration of the coupled nonlinear pendulum model (Equation (5)). Dotted lines separate time intervals with different values for the coupling parameters.

The time series are divided into $T = 160$ segments of size $m = 300$ according to the first step of **Algorithm C** (300 is a sufficient number of points to reconstruct a meaningful attractor). Next, the optimal time lags for each segment of both signals were computed using **Algorithm B**. The set of optimal time lags $\tau_{*j}^{(X)}, \tau_{*j}^{(Y)}$ ($j = \overline{1{,}160}$) is presented in Figure 9a,b.

Now, absolute differences between optimal time lag vectors $\tau_{*j}^{(X,Y)} = \left|\tau_{*j}^{(X)} - \tau_{*j}^{(Y)}\right|$ ($j = \overline{1{,}160}$) were computed. The obtained vector is divided into $F = 16$ segments of size $h = 10$, which results in the vector of mean absolute differences $A^{(X,Y)} = \left[\bar{\tau}_1^{(X,Y)} \bar{\tau}_2^{(X,Y)} \ \ldots \ \bar{\tau}_{16}^{(X,Y)}\right]$ illustrated in Figure 9c.

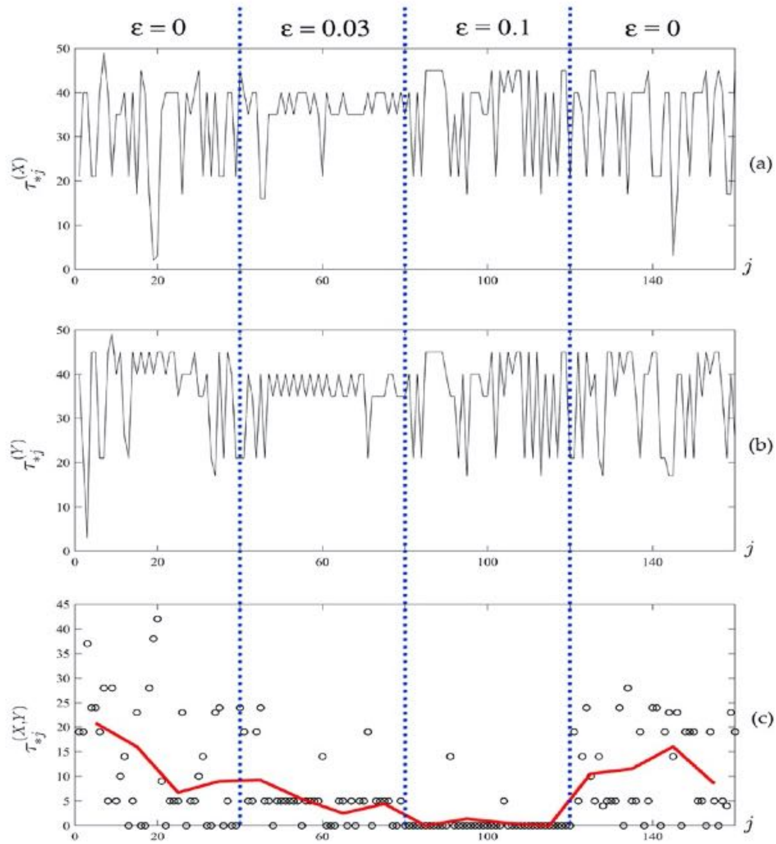


Figure 9. The sets of optimal time lags (**a**) $\tau_{*j}^{(X)}$ and (**b**) $\tau_{*j}^{(Y)}$ for the time series depicted in Figure 8. Circles in (**c**) denote the absolute differences $\tau_{*j}^{(X,Y)}$ between optimal time lags for X and Y. The solid red line in (**c**) corresponds to the averaged absolute differences $A^{(X,Y)} = \left[\bar{\tau}_1^{(X,Y)}\bar{\tau}_2^{(X,Y)} \ \ldots \ \bar{\tau}_{16}^{(X,Y)}\right]$.

This procedure allows us to identify and quantify the variable of geometrical synchronization in time. The numerical values on the *y*-axis in Figure 9 can be interpreted as follows. Smaller values of $\bar{\tau}_i^{(X,Y)}$ indicate a greater magnitude of synchronization in the respective segment. If $\bar{\tau}_i^{(X,Y)}$ is equal to 0, the corresponding synchronization can be considered as absolute synchronization. Analogously, the maximal possible value of $\bar{\tau}_i^{(X,Y)}$ (equal to 49 in this Example) corresponds to absolute desynchronization. For the algorithm parameters used in this example, the cut point for desynchronization is $\bar{\tau}_i^{(X,Y)} = 15$; i.e., the signals are considered poorly synchronized in the respective segment for the averaged absolute differences of optimal time lags exceeding this value.

The chaotic oscillators given in Equation (5) are nonsynchronized in the first quarter of data points ($\varepsilon = 0$), which results in an average absolute of differences of optimal time lags ranging from 6 to 21. When the coupling parameter is set to $\varepsilon = 0.03$, the chaotic oscillators are weakly synchronized, which is reflected by the decreased values of $A^{(X,Y)}$. Note that this effect is not obvious, and cannot be observed by simply considering the difference $X - Y$ (Figure 8c). Further, the coupling parameter $\varepsilon = 0.1$ results in an almost complete synchronization, as seen from both Figure 8c and the near-zero values of $A^{(X,Y)}$ in Figure 9c. In the last quarter of data points, oscillators are allowed to evolve in the uncoupled regime at $\varepsilon = 0$, which results in uncoupled chaotic oscillations.

2.6. Clusterization of Multivariate Time Series Based and Their Synchronization with a Master Time Series

Suppose a set of time series $X^{(k)} = (X_1^{(k)}, \dots, X_n^{(k)}), k = \overline{1,K}$ and a master time series $M = (M_1, \dots, M_n)$ are given. The objective of the following procedure is to compare and clusterize time series $X^{(k)}$ $(k = \overline{1,K})$ based on their synchronization in respect to the master time series M. The steps of **Algorithm D** read:

(1) Compute the vector of mean absolute differences $A^{(X^{(k)},M)} = [\bar{\tau}_1^{(X^{(k)},M)} \dots \bar{\tau}_F^{(X^{(k)},M)}]$, describing the relationship between $X^{(k)}$ and M as described in **Algorithm C**, for each $X^{(k)}, k = \overline{1,K}$.

(2) Calculate the Euclidean distance (the measure used to estimate the geometrical similarity of two data vectors) which represents the similarity between all K data signals, using the following formula:

$$\left\|A^{(X^{(i)},M)} - A^{(X^{(j)},M)}\right\|_2 = \sqrt{\left(\bar{\tau}_1^{(X^{(i)},M)} - \bar{\tau}_1^{(X^{(j)},M)}\right)^2 + \dots + \left(\bar{\tau}_F^{(X^{(i)},M)} - \bar{\tau}_F^{(X^{(j)},M)}\right)^2}\ , i,j = \overline{1,K}.$$

The above equation yields the symmetric matrix of Euclidean distances.

(3) Construct a dendrogram plot (UPGMA) [37] using the obtained matrix. The main goal of the dendrogram is to identify the clusters of similar time series, i.e., the clustering process involves grouping the analyzed time series based on the similarity of the slower rhythm dynamics of their synchronization with master time series M.

The procedure described above was utilized in subsequent analysis to identify the clusterization of a group of 20 people based on the synchronization of their HRV with the fluctuations in the Earth's local magnetic field. These fluctuations are reflected by the power of the local magnetic field data.

3. Results

3.1. The Application of the New Analysis Technique on HRV and Magnetic Field Data

3.1.1. Obtaining the Power of Local Magnetic Field during the Experiment

The local magnetic field power data was computed using the magnetic field intensity values (see **Algorithm A**) during the experiment (see Section 2.3.1). It is also important to note one specific feature of the acquisition process of the magnetometer data. The magnetometer values are uploaded to the central server at the end of each hour, and the time required for the upload is about one minute. Therefore, the magnetometer data contains one minute-long periods of missing data that occur at the end of each hour.

The local magnetic field power was calculated in the frequency range $\omega \in [0; 1]$ Hz, since the low-frequency fluctuations of the magnetic field have the most significant impact on human physiology, especially heart and brain activity [29].

The normal heart rate for healthy adults is approximately 60 beats per minute, which implies that the standard IBI is approximately one second. Thus, the power of the magnetic field was computed in one-second intervals, in order to match the time scales of HRV and the local magnetic field variability.

During the computation of the magnetic field power, the spectrogram was cropped using the cropping level $S_{crop} = 0.25$, since empirical observations indicated that this cropping level was most effective at removing the spike type noise from the spectrograms.

3.1.2. Identification of Clusters in the Groups Based on the Similarity/Synchronization between Participants' HRV and Magnetic Field Activity

Algorithm D was applied to the experimental data (Sections 2.1 and 3.1.1) in order to identify clusters of participants based on the slow dynamics of the synchronization between the participants' HRV and the power of the local magnetic field.

According to **Algorithm D**, the time series $X^{(k)}, k = \overline{1,20}$ represents the participants' HRV data collected during the experiment. The master time series M corresponds to the time series of the power of the local magnetic field measured during the time of the experiment.

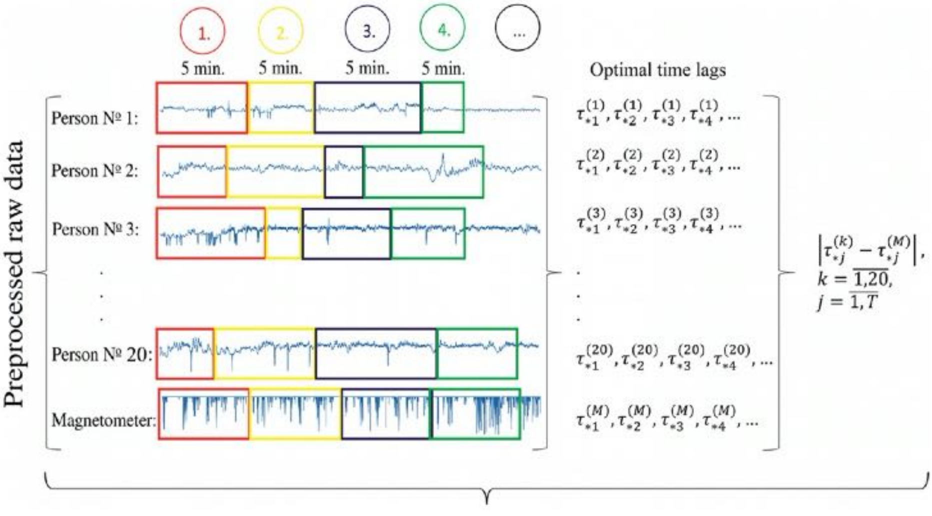
Since **Algorithm D** employs **Algorithms B** and **C**, the corresponding parameters for both of those algorithms had to be selected:

(1) One of the steps of **Algorithm C** is splitting the participants' HRV and local magnetic field power time series into segments. The standard length of analysis for HRV is five minutes [38]. Thus, inter-beat (RR) interval and magnetometer data was split into five-minute segments for analysis. Note that since HRV data consists of time intervals between each pair of heartbeats, the number of samples in the data vectors corresponding to each five-minute segment varies due to changes in the participants heart rate and other factors that influence HRV, such as stress and emotional states [39]. Since the power of the local magnetic field was computed for one-second time intervals, the resulting five-minute segments consisted of the same number of elements (300 data points). However, the difference in the size of the segments of HRV and the power of the local magnetic field time series did not impact the overall result of the study, since all of the segments represented the same concurrent five-minute time intervals.
(2) We selected the number of slices in **Algorithm B** to be 60 because it was empirically observed that a higher number would result in some empty slices.
(3) The maximal value of τ in **Algorithm B** was set to 50. Higher values of τ would generate too short trajectory matrices, because the five-minute segments consisted of approximately 300 elements.
(4) The value of the parameter h in **Algorithm C**, used for identification of slow dynamics of the synchronization between the two time series, was set to 48. This corresponded to a four-hour averaging of the difference of the optimal time lags. It was observed that this value of h produced the most meaningful averaging.
(5) As noted in Section 3.2 the magnetometer data contained one minute-long periods of missing data at the end of each hour. Since these periods in the time series did not contain any information, it was necessary to remove those periods in such a way that would not disrupt the timing between the HRV and magnetic field time series. The solution we implemented was to remove the missing data segments from both the five-minute magnetometer data and from the five-minute RR interval series. Since the cropped series obtained after this procedure fully defined the five-minute series, they were used in the data reduction step.

We applied the clusterization technique on two-day and two-week data sets collected during the experiment (see Section 3.2) in order to determine how the time span of the data set impacts the quality of the clusterization.

We firstly analyzed two days of data (2015/02/27 18:05:00 through 2015/03/01 18:05:00). Therefore, each individual's HRV and the magnetometer data consisted of 576 five-minute segments, i.e. $T = 576$.

According to the first step of **Algorithm D**, the vector of mean absolute differences $A^{(X^{(k)},M)}$ was computed as described in **Algorithm C**, for each $X^{(k)}, k = \overline{1,20}$. The execution of this step is demonstrated in Figure 10.



$$A^{(X^{(k)},M)} = \left[\bar{\tau}_1^{(X^{(k)},M)} \dots \bar{\tau}_F^{(X^{(k)},M)}\right]$$

$$\bar{\tau}_i^{(X^{(k)},M)} = \frac{1}{48}\sum_{j=1}^{48} \bar{\tau}_{*(48\cdot(i-1)+j)'}^{(X^{(k)},M)}$$

$$k = \overline{1,20}$$

Figure 10. The scheme of the application of **Algorithm C** on the experimental data. The horizontal axis of the depicted data corresponds to the indices of the time series.

The application of steps 2 and 3 of **Algorithm D** to the two-day (2015/02/27 18:05:00 through 2015/03/01 18:05:00) data resulted in the dendrogram plot depicted in Figure 11.

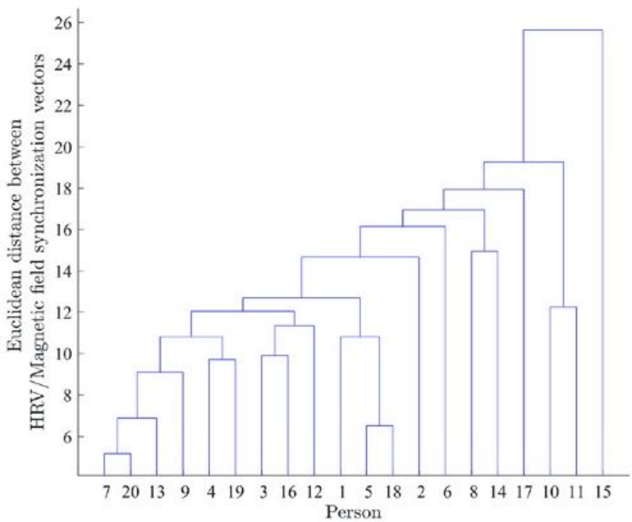


Figure 11. Dendrogram plot for the two-day (2015/02/27 18:05:00 through 2015/03/01 18:05:00) data. Numbers on the X axis represent participants (numbered from 1 to 20).

The dendrogram depicted in the Figure 11 is a visual representation of the geometrical synchronization between HRV and the magnetic field for all 20 participants. Numbers on the X axis represent participants. The height of the branches of the dendrogram is proportional to the Euclidean distance between HRV/Magnetic field synchronization vectors for corresponding participants.

It can be seen in Figure 11 that participants 7 and 20 are the closest (or most similar) in the sense of synchronization between their HRV and local magnetic field power time series. The Euclidean distance between the HRV and magnetic field synchronization for the pair of participants (7,20) is equal to 5.15. At the opposite end of the spectrum, the participant 15's synchronization with the magnetic field is least similar to any of the remaining participants.

The variation of the slow dynamics of the synchronization (**Algorithm C**) for two pairs of participants, (7,20) and (7,15), is also illustrated in Figures 12 and 13, respectively. It can be seen that there is a strong visible similarity between the synchronization dynamics for participants 7 and 20, meaning that they are similarly synchronized with the local magnetic field, and form a cluster in the dendrogram (Figure 11). On the other hand, there is no visible similarity in the synchronization dynamics of individuals (7,15), indicating that the relationship between HRV and magnetic field activity for those participants is unlikely (Figure 13). The Euclidean distance between the HRV and magnetic field synchronization for the pair of participants (7,15) is equal to 30.09.

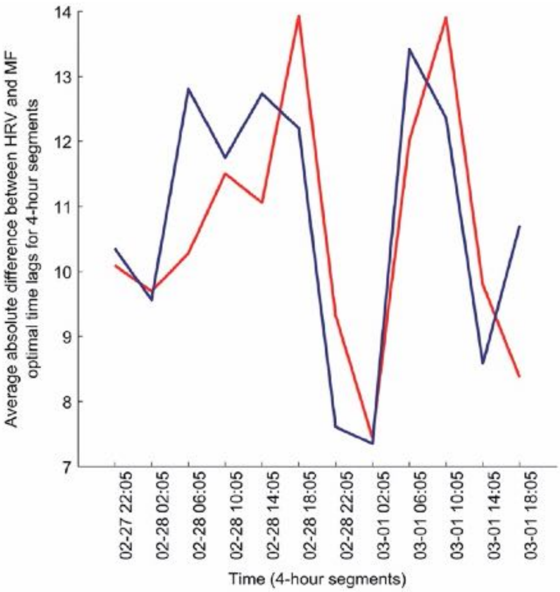


Figure 12. The variation of the slow dynamics of the geometrical synchronization constructed from optimal time lags for participant 7 (red line) and participant 20 (blue line) for the time period between 2015/02/27 18:05:00–2015/03/01 18:05:00.

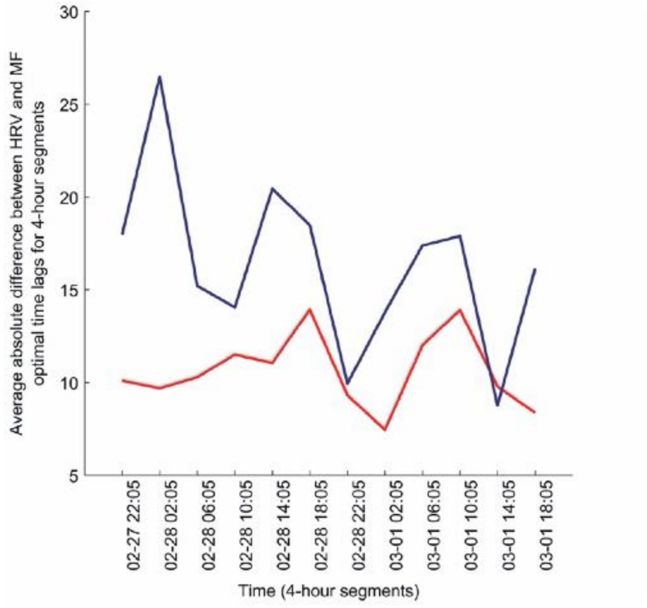


Figure 13. The variation of the slow dynamics of the geometrical synchronization constructed from optimal time lags for participant 7 (red line) and participant 15 (blue line) for the time period between 2015/02/27 18:05:00–2015/03/01 18:05:00.

Next, the dendrogram plot (Figure 14) for the entire two weeks ($T = 4032$) of the experiment was obtained in an identical manner. The comparison of the two-day (Figure 11) and two-week (Figure 14) clusterization results shows that the use of the data with the longer time span provides better quality of clusterization, since the distances between the identified clusters for two-week data (Figure 14) are greater.

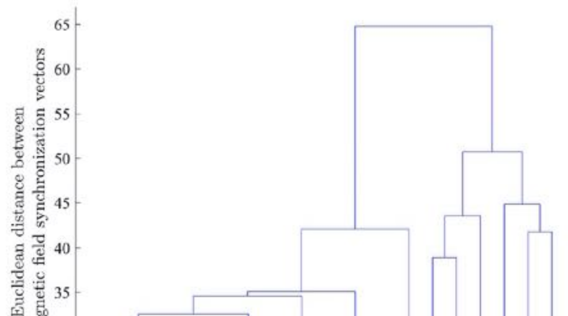


Figure 14. Dendrogram plot for the two-week data. Numbers on the X axis represent participants (numbered from 1 to 20).

3.2. The Relation between Synchnorization Results and the Psychological Interactions between Participants

3.2.1. Psychological Survey Data

In addition to the HRV data presented in Section 2.1, each person's physical and mental condition as well as the quality of interactions between the individuals during the two-week experiment were assessed. Each participant completed a questionnaire twice each day throughout the two-week period. The questionnaire consisted of questions concerning their physical, emotional, social, and general states (rating scale between 0 and 10). At the end of each day, each participant was also asked to make a list of other participating individuals who they had interacted with that day (if any) and rate whether the interaction had positively (+1) or negatively (−1) affected them and their survey responses. The quality of interaction data is shown in Table 1. The first column as well as the first row of the table show the participant number for each of the 20 volunteers. The numbers in the intersection rows and columns equal the sum of the row person ratings of the interaction with the column person ratings over the 14 days. If, for example, the row person specified four positive and two negative interactions with the column person during the two-week experiment, the overall interaction value will equal 2. It can be seen that the matrix is nonsymmetric, which means that if the column person positively or negatively affected the row person, this does not necessarily imply that the opposite is true. The matrix is also sparse, since participants did not complete this part of the survey if interactions did not occur.

Table 1. Interpersonal interaction data, gathered from all questionnaires.

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1			−1	−1						2		2					1			−1
2										1						2				
3																				
4			−1								4									
5																				
6																				
7																				3
8																				
9			2		1													6		
10		4				1	1					1			4					1
11				1																
12	2		1			1													−1	
13		1	4	2							8					1				3
14			2																	
15																	2			
16		2																		
17																				
18																				
19	1	1	2			1	2		1		1	2	1			1		1		
20			1	1			3				1									

In order to illustrate interaction data, the questionnaire matrix was visualized using the directed weighted graph visualization technique (Figure 15). A line with an arrow pointing from person a to person b (the pair (a, b)) represents that person a felt positive about person b. The width of the line is proportional to the number of times such an interaction did occur. The graph gives a clearer picture of "mutual affection" between the participants. Participants' pairs (7,20); (2,16); (4,11); (2,10); (1,12) can be clearly identified. However, it is important to note that the "mutual affection" for pairs (4,11) and (2,10) was not "balanced", since the thickness of lines (4,11) and (11,4) as well as lines between

(2,10) and (10,2) is substantially different. Consequently, only the pairs (7,20), (2,16), and (1,12) show bilateral "mutual positive interactions".

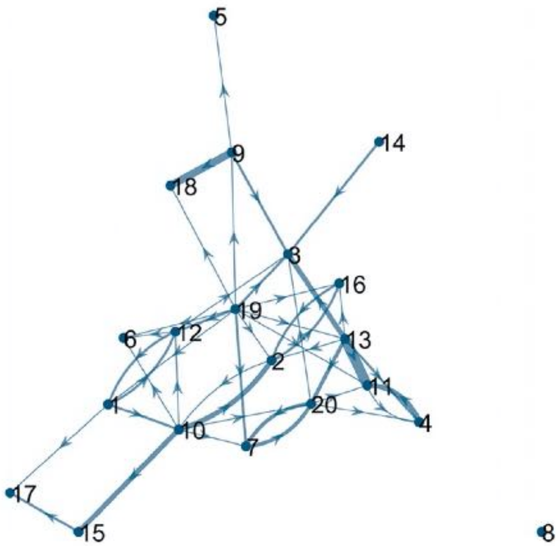


Figure 15. The graph of the evaluated interaction levels between participants. Nodes represent participants (numbered from 1 to 20). A line with an arrow pointing from person a to b (a, b), represents that person a feels positive about person b. The width of the line is proportional to the overall (a, b) interaction value (sum of a's ratings of the interaction with the b's ratings over the 14 days).

The data from the questionnaires (physical, emotional, social, and general state), was also analyzed and examined for the occurrences of changes in participants' conditions in each domain. Changes were most clearly evident in participant 15's survey data. (Figure 16). The figure shows that after feeling good for the first two days of the experimental period, there was a change in his physical, emotional, social, and general condition that drastically worsened and then recovered on the eighth day of the experiment.

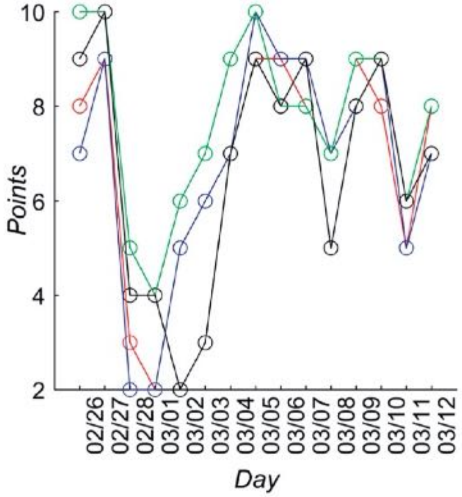


Figure 16. Participant 15's change of status during self-evaluation in points (max—10, min—0; Y axis) over the 14 days (X axis). The green, black, red, and blue lines correspond to the self-evaluation of social, general, physical, and emotional states, respectively.

3.2.2. Comparison of Survey Data and the HRV/Magnetic Field Synchronization Results

The results of the HRV geometrical synchronization with the magnetic field data (represented by cluster diagrams in Section 3.1.2) were compared with the survey data (Section 3.2) in order to determine if the two separate data sets (sociological and physiological) revealed similar trends.

The dendrogram in Figure 14 shows that the synchronization between HRV and local magnetic field power for participants 7 and 20 is mostly similar. On the other hand, the synchronization for participant 15 is mostly different when compared to all other participants.

It is interesting to observe that the pair of participants (7,20) is the mostly mutually positively oriented pair according to the questionnaire data (Figure 15). Remarkably, participant 15 has self-assessed his condition being the worst (out of all 20 participants) during the analyzed period of time.

It appears that the computational technique based on the identification of slow dynamics of the synchronization between HRV and local magnetic field can also reflect interpersonal relationships. Participants reporting more positive states and interactions were more similarly synchronized with the magnetic field. Note that the questionnaire data was not used in the proposed algorithm, and served only as a tool to assess psychological relationships within the group.

4. Discussion

This study developed and validated a novel computational approach using near-optimal chaotic attractor embedding techniques for the identification of physiological synchronization among individual group members' slow wave rhythms in heart rate variability and the degree of synchronization with changes in the local geomagnetic field. This approach allowed us to identify and quantify the degree of geometrical synchronization in time. This new analysis method was utilized to determine the degree of synchronization between locally obtained geomagnetic fields and to identify clusters of similar synchronization patterns in a group of 20 people whose HRV was continuously monitored over a two-week period as they went about their normal day-to-day lives.

Through comparing the two-day and two-week clusterization results, it can be seen that the two-week data provided better separation of the clusters of participants, i.e., the distances between the constructed clusters are greater. This demonstrates that the longer duration of the experiment positively impacts the ability to identify meaningful clusters of individuals. However, the comparison of the two-day dendrogram with the survey data showcased that a shorter time span of data provides a clearer detection of the changes in the participants' condition. This is because the changes in the participant's condition can average out over a long period of time. Thus, such investigations should be performed over both short and long time periods in order to obtain more complete results.

To the best of our knowledge, this is the first study to incorporate psychological data gathered throughout the experiment in the context of physiological synchronization to other group members and with the Earth's time-varying magnetic fields.

Interestingly, the synchronization between the groups' slow wave dynamics of RR intervals and the variation of the local magnetic field were consistent with the psychological data gathered throughout the experiment. When individual pairs reported more stress in their interpersonal relationships, they were less synchronized. This could imply that both the physiological and psychological variables were influenced by the time-varying magnetic fields in the environment. On the other hand, it may indicate that one's level of stress and emotional state modulates the capacity to synchronize to other group members and the Earth's magnetic field. Either way, this finding suggests that psychological states may be a factor in mediating the level of physiological synchronization between people and with the rhythms in the Earth's magnetic field.

Although the specific details for how geomagnetic fields influence human psychophysiology are not yet fully understood, a potential explanation is through a resonant coupling between the nervous system and filed line resonances (Alfvén waves), or standing waves in the Earth-ionosphere resonant cavity (Schumann resonances) that overlap with physiological rhythms [30]. However, a growing body of research strongly suggests that solar and magnetic influences affect a wide range of human health and behavioral processes with the cardiovascular and nervous systems being the most clearly affected.

Overall, the study demonstrated that the slow wave rhythms in heart rate variability can synchronize with local magnetic field data, and that the degree of synchronization is affected by the quality of interpersonal relationships. When two or more persons respond to some changing environmental factor in a similar way and are emotionally close as measured by an independent metric (such as the survey or a direct comparison of their HRV attractors over time), then their response patterns to the environmental factor are less likely to result from chance.

5. Conclusions

The results of this study are consistent with other studies showing that daily autonomic nervous system activity responds to changes in geomagnetic activity. It also confirms these findings in a larger group and by using a different analysis approach; i.e., the observation of slow wave dynamics occurring in people's heart rhythms over many hours to days. In addition, it also confirms the surprising degree of synchronized activity between the slow wave dynamics in heart rhythms and changes in the Earth's time-varying magnetic field in a frequency range that includes both Schumann resonances and geomagnetic field line resonances, which have similar frequencies as the rhythms produced by human brains and hearts.

Supplementary Materials: The following are available online at www.mdpi.com/1660-4601/14/9/998/s1, Ethical Statement: KAUNO REGIONINIS BIOMEDICINIU TYRIMU ETIKOS KOMITETAS.

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Author Contributions: The two-week experiment was conceived of by Rollin McCraty, Mike Atkinson, Alfonsas Vainoras, Abdullah A. Alabdulgader and Roza Joffe, who recruited its participants, and obtained their written consent. The remaining authors (Inga Timofejeva, Minvydas Ragulskis) contributed to the data analysis, the construction of the proposed algorithm for the identification of synchronization between participants' HRV and magnetic field activity, and the writing of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations:

EEG	Electroencephalogram
HRV	Heart rate variability
IBI	Inter-beat-interval
Pc	pulsations continuous
Pi	pulsations irregular

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ANNEXES

Annex 1

KAUNO REGIONINIS BIOMEDICININIŲ TYRIMŲ ETIKOS KOMITETAS

Lietuvos sveikatos mokslų universitetas, A. Mickevičiaus g. 9, LT 44307 Kaunas, tel. (+370) 37 32 68 89; el.paštas: kaunorbtek@lsmuni.lt

LEIDIMAS ATLIKTI BIOMEDICININĮ TYRIMĄ

2015-12-23 Nr. BE-2-51

Biomedicininio tyrimo pavadinimas: **"Psichofiziologinių žmogaus parametrų sąsajos su žemės magnetinio lauko svyravimais Lietuvoje"**	
Protokolo Nr.:	**Joffė-Vain-1**
Data:	**2015-12-16**
Versija:	**2**
Asmens informavimo forma	**Versija 2, 2015-12-16**
Pagrindinis tyrėjas:	**Prof. habil. dr. Alfonsas Vainoras**
Biomedicininio tyrimo vieta: Įstaigos pavadinimas: Adresas:	**Lietuvos sveikatos mokslų universitetas** **Sveikatos tyrimų institutas** Betonuotojų g. 4, Kaunas

Išvada:

Kauno regioninio biomedicininių tyrimų etikos komiteto posėdžio, įvykusio **2015 m. gruodžio mėn. 22 d.** (protokolo Nr. BE-10-12) sprendimu pritarta biomedicininio tyrimo vykdymui.

Mokslinio eksperimento vykdytojai įsipareigoja: (1) nedelsiant informuoti Kauno Regioninį biomedicininių Tyrimų Etikos komitetą apie visus nenumatytus atvejus, susijusius su studijos vykdymu, (2) iki sausio 15 dienos – pateikti metinį studijos vykdymo apibendrinimą bei, (3) per mėnesį po studijos užbaigimo, pateikti galutinį pranešimą apie eksperimentą.

Kauno regioninio biomedicininių tyrimų etikos komiteto nariai			
Nr.	Vardas, Pavardė	Veiklos sritis	Dalyvavo posėdyje
1.	Prof. Romaldas Mačiulaitis	Klinikinė farmakologija	taip
2.	Prof. Edgaras Stankevičius	Fiziologija, farmakologija	taip
3.	Doc. Eimantas Peičius	Filosofija	taip
4.	Dr. Ramunė Kasperavičienė	Kalbotyra	taip
5.	Med. dr. Jonas Andriuškevičius	Chirurgija	taip
6.	Agnė Krušinskaitė	Teisė	taip
7.	Prof. Skaidrius Miliauskas	Pulmonologija, vidaus ligos	taip
8.	Med. dr. Rokas Bagdonas	Chirurgija	ne
9.	Eglė Vaižgelienė	Visuomenės sveikata	ne

Kauno regioninis biomedicininių tyrimų etikos komitetas dirba vadovaudamasis etikos principais nustatytais biomedicininių tyrimų Etikos įstatyme, Helsinkio deklaracijoje, vaistų tyrinėjimo Geros klinikinės praktikos taisyklėmis.

Pirmininkas Prof. Romaldas Mačiulaitis

LR Asmens duomenų teisinės apsaugos įstatymo 10 str. 3 punktas numato, jog asmens duomenys apie asmens sveikatą automatiniu būdu, taip pat mokslinio **medicininio tyrimo tikslais** gali būti tvarkomi tik pranešus Valstybinei duomenų apsaugos inspekcijai. Šiuo atveju Valstybinė duomenų apsaugos inspekcija privalo atlikti išankstinę patikrą.

Pasibaigus tyrimui, tyrėjas ar tyrimo užsakovas privalo informuoti KRBTEK raštu apie tyrimo pabaigą bei pateikti tyrimo ataskaitos santrauką. Atliekant biomedicininio tyrimo pakeitimus būtina gauti Kauno regioninio biomedicininio tyrimo etikos komiteto pritarimą pakeitimams.

Reikalavimas pateikti pranešimą apie tyrimo pabaigą bei ataskaitos santrauką įsigaliojo nuo 2010 m. gegužės 6 d. Šį reikalavimą rasite Lietuvos Respublikos sveikatos apsaugos ministro įsakymo "Dėl leidimų atlikti biomedicininį tyrimą išdavimo tvarkos aprašo patvirtinimo" (Žin., 2008, Nr. 6-225; 2010, Nr. 55-2706; 2011, Nr. 233-1570; Nr. 67-3184) 18[1] punkte *„Leidimas atlikti biomedicininį tyrimą galioja iki biomedicininio tyrimo paraiškoje nurodytos tyrimo pabaigos datos. Biomedicininių tyrimų užsakovas, jo įgaliotas atstovas ir (ar) pagrindinis tyrėjas per 30 kalendorinių dienų privalo raštu pranešti leidimą atlikti biomedicininį tyrimą išdavusiai institucijai (Lietuvos bioetikos komitetui ar regioniniam biomedicininių tyrimų etikos komitetui) apie tyrimo pabaigą ir per 90 kalendorinių dienų pateikti tyrimo vykdymo ataskaitos santrauką"*.

Įsakymo nuostata taikoma visiems biomedicininiams tyrimams.

Annex 2

Kodas _________ Pildymo data: _________ Pildymo laikas: __ val. __ min.

Prašome atsakyti į žemiau pateiktus klausimus, pasirenkant Jums tinkamiausią atsakymą iš pateiktų, arba įrašant savo (kur prašoma įrašyti).

Jūsų šeimyninis statusas? Jūsų išsilavinimas? Jūsų amžius (įrašykite): ___

nevedęs/netekėjusi	*pagrindinis*	
vedęs/ištekėjusi	*vidurinis*	
išsiskyręs (-usi)	*profesinis*	*Jūsų lytis (pabraukite):*
turiu sugyventinį (-ę)	*aukštasis neuniversitetinis*	*vyras*
našlys (-ė)	*bakalauro laipsnis*	*moteris*
	magistro laipsnis	
	aukštesnis nei magistro laipsnis	

Ar reguliariai užsiimate	*Taip*
fizine veikla?	*Ne*

Įrašykite savo svorį: _________ Įrašykite savo ūgį: _________

Fizinis gyvybingumas – koks šiuo metu yra Jūsų fizinės energijos lygis?

1. Žemas energijos lygis (silpnumas, nuovargis)
2. Nei žemas, nei aukštas
3. Aukšas energijos lygis (stiprumas, energingumas)

Emocinis gyvybingumas – kokias emocijas šiuo metu jaučiate?

1. Neigiami jausmai (liūdesys, nerimas, pyktis)
2. Nei neigiami, nei teigiami
3. Teigiami jausmai (ramybė, laimė, entuziazmas)

Socialinis bendravimas – kokia šiuo metu yra Jūsų socialinių santykių kokybė?

1. Visai nebendrauju (vienišumas, konfliktai, atstūmimas)
2. Nei žemas, nei aukštas
3. Turiu stiprius socialinius santykius (abipusis priėmimas, harmonija)

Bendra gerovė – ką šiuo metu jaučiate galvodamas (-a) apie savo gyvenimą?

1. Gyvenimas yra sunkus (daug sukrėtimų)
2. Nei neigiami, nei teigiami
3. Gyvenimas yra puikus (savirealizacija, pilnatvės jausmas)

Normality

Table A3.1. *Distribution of health indicators*

	Mean	Median	Standard Deviation	Skewness	Kurtosis
Physical vitality	3.47	3	1.10	–0.31	–0.39
Emotional vitality	3.62	4	1.07	–0.37	–0.4
Social connectedness	3.88	4	1.06	–0.68	–0.21
Overall wellbeing	3.70	4	1.13	–0.66	–0.16
SF physical	53.64	55.42	7.01	–1.03	1.66
SF mental	44.79	45.33	10.44	–0.36	–0.13

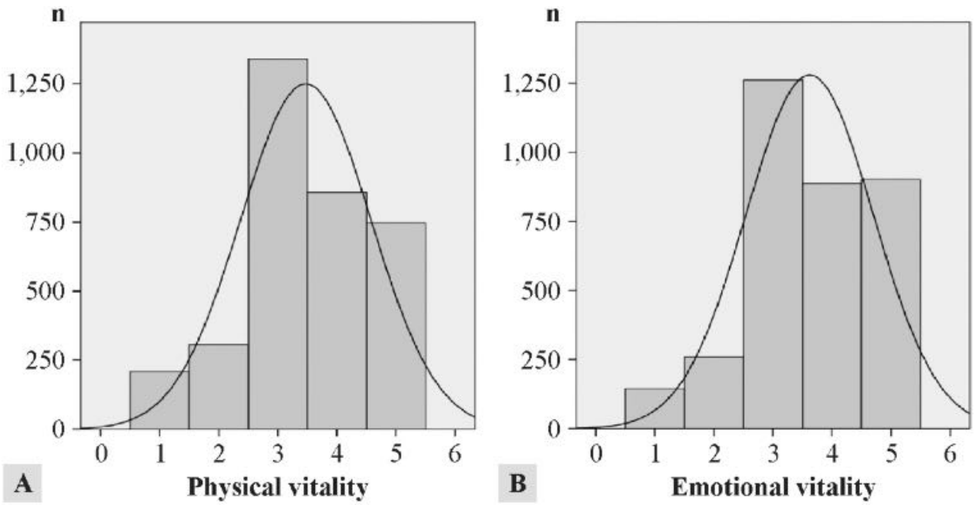

Fig. A3.2 (A–B). *Visual distribution of health indicators*

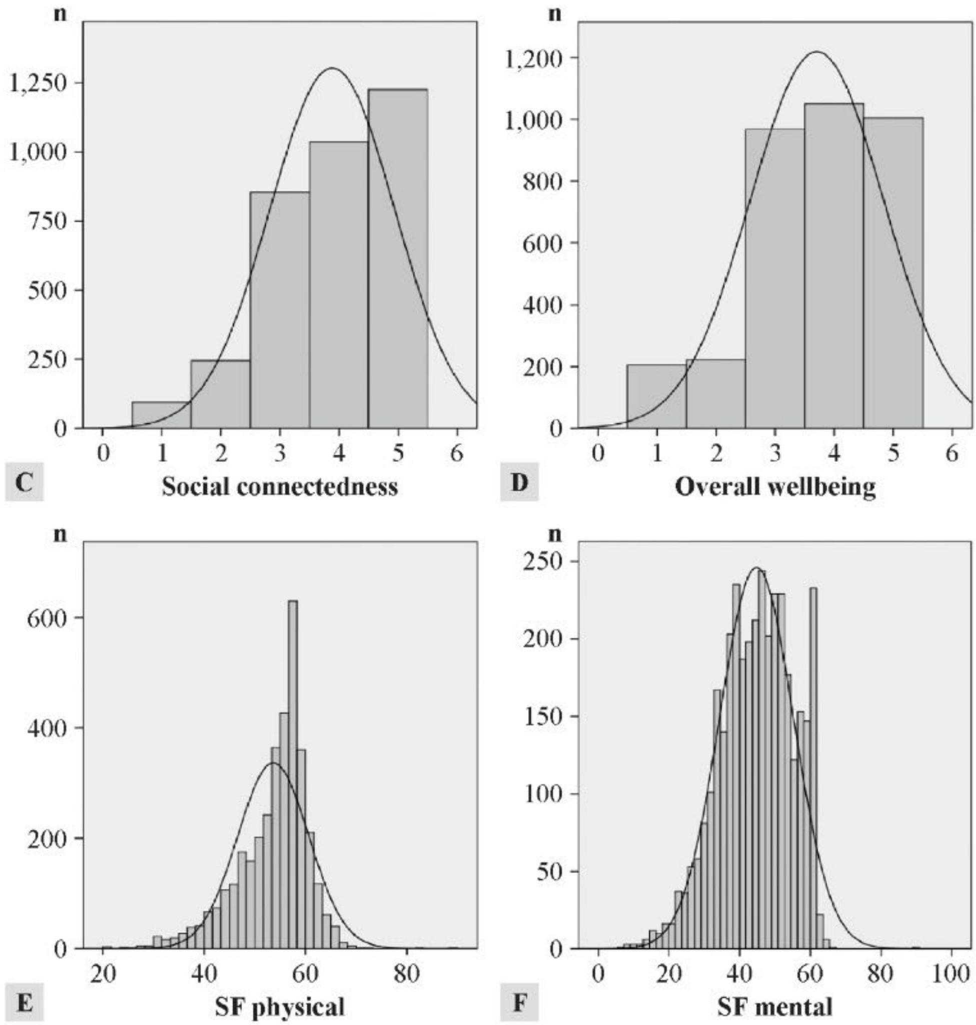

Fig. A3.2 (C–F). *Visual distribution of health indicators*

Table A3.3. *Distribution of GMF indicators*

Frequency	Mean	Median	Standard Deviation	Skewness	Kurtosis
0–3.5 Hz	69.34	66.44	19.91	0.9	1.24
3.5–7 Hz	33.03	31.2	18.21	2.43	9.48
7–15 Hz	72.13	72.25	35.39	2.71	13.33
15–32 Hz	115.44	108.34	61.08	4.19	26.14
32–66 Hz	557.38	560.22	119.27	0.54	2.46
0–66 Hz	847.32	832.31	215.52	2.36	12.62

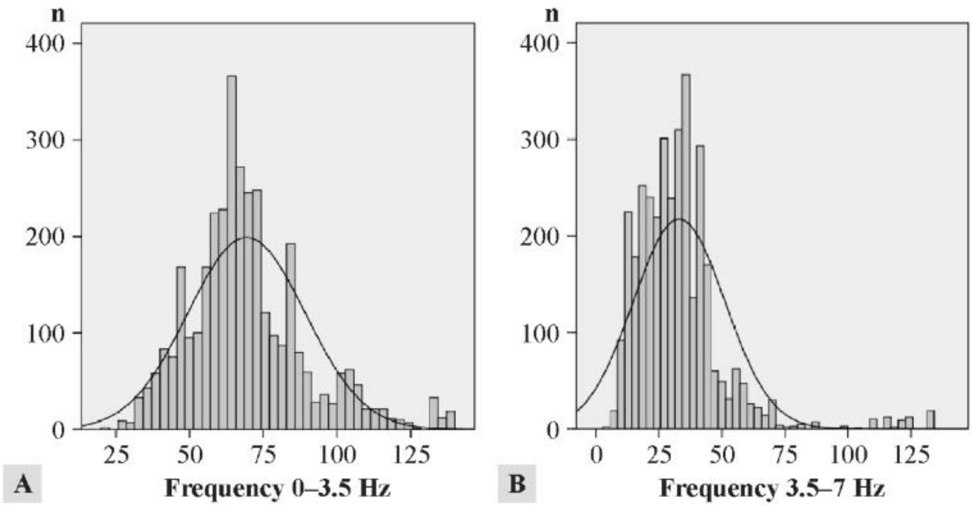

Fig. A3.4 (A–B). *Visual distribution of GMF indicators*

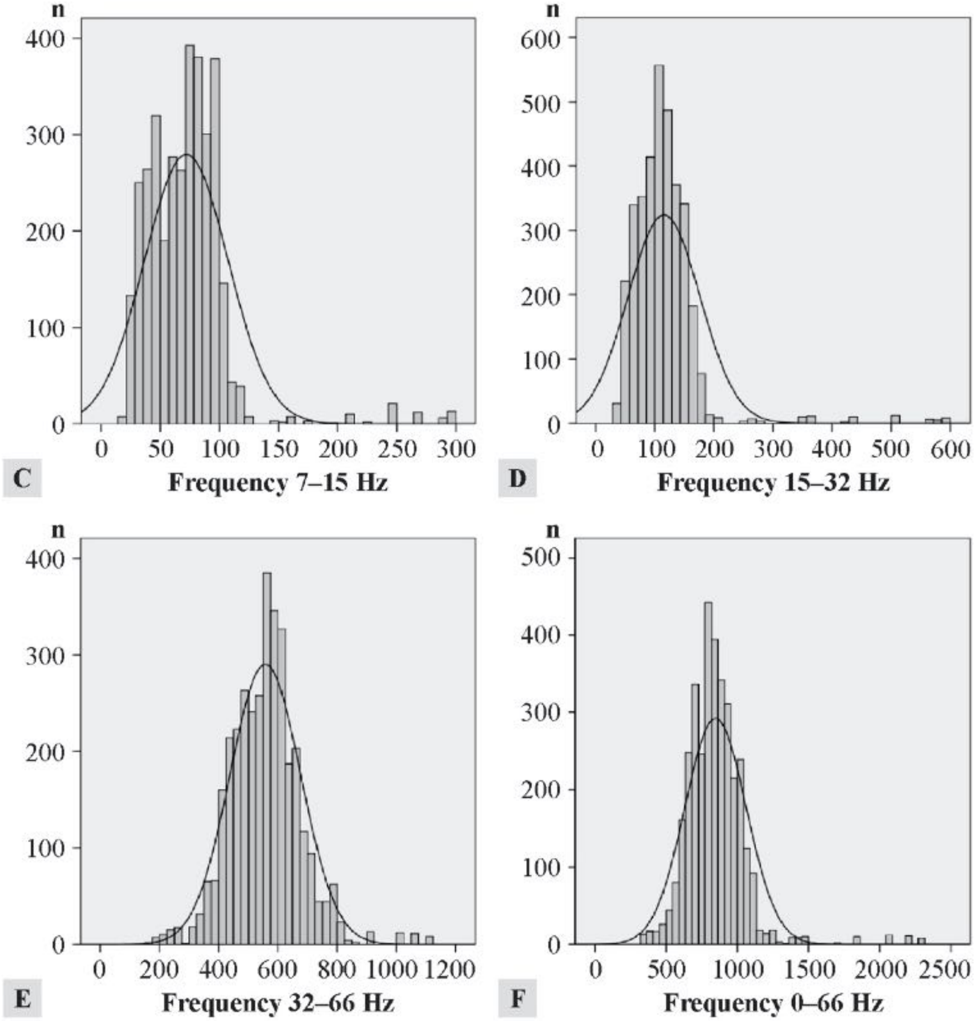

Fig. A3.4 (C–F). *Visual distribution of GMF indicators*

Table A4.1. *Health indicators and geomagnetic field at actual time and with lagging intervals. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.040*	0.039*	0.020	0.015	–0.005	0.014
		P	0.02	0.024	0.252	0.388	0.772	0.427
	Emotional vitality	rho	0.029	0.027	0.015	0.008	0.000	0.010
		P	0.093	0.111	0.391	0.619	0.998	0.541
	Social connectedness	rho	–0.016	–0.023	–0.036*	–0.022	0.012	–0.002
		P	0.342	0.176	0.033	0.206	0.49	0.885
	Overall wellbeing	rho	0.052*	0.047*	0.034*	0.030	0.007	0.027
		P	0.002	0.005	0.043	0.077	0.663	0.108
	SF physical	rho	0.029	0.036*	0.042*	0.050*	0.017	0.040*
		P	0.086	0.035	0.014	0.003	0.306	0.021
	SF mental	rho	0.048*	0.027	0.001	0.004	0.029	0.027
		P	0.005	0.111	0.949	0.834	0.089	0.108
12 h	Physical vitality	rho	0.034*	0.035*	0.035*	–0.003	–0.033	–0.018
		P	0.045	0.038	0.038	0.866	0.055	0.281
	Emotional vitality	rho	0.042*	0.052*	0.064*	0.034*	–0.008	0.012
		P	0.013	0.002	0	0.044	0.621	0.484
	Social connectedness	rho	0.038*	0.041*	0.058*	0.031	0.005	0.022
		P	0.024	0.015	0.001	0.07	0.787	0.188
	Overall wellbeing	rho	0.038*	0.037*	0.030	0.001	–0.015	–0.003
		P	0.026	0.03	0.074	0.935	0.383	0.877
	SF physical	rho	0.008	0.012	0.000	–0.022	–0.011	–0.012
		P	0.621	0.471	0.981	0.2	0.532	0.494
	SF mental	rho	0.102*	0.110*	0.119*	0.065*	–0.026	0.026
		P	0	0	0	0	0.127	0.124

__Table A4.1__. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
24 h	Physical vitality	rho	0.015	0.011	0.005	0.004	–0.002	0.000
		P	0.37	0.524	0.78	0.815	0.911	0.98
	Emotional vitality	rho	0	–0.007	–0.002	–0.004	–0.007	–0.008
		P	0.981	0.701	0.921	0.801	0.701	0.632
	Social connectedness	rho	–0.033	–0.038*	–0.048*	–0.034*	0.009	–0.018
		P	0.054	0.025	0.005	0.045	0.601	0.278
	Overall wellbeing	rho	0.018	0.021	0.02	0.015	–0.019	–0.004
		P	0.305	0.216	0.25	0.374	0.266	0.819
	SF physical	rho	0.026	0.039*	0.036*	0.044*	0.013	0.032
		P	0.125	0.021	0.034	0.01	0.456	0.064
	SF mental	rho	0.002	–0.012	–0.025	–0.029	–0.018	–0.027
		P	0.885	0.484	0.147	0.092	0.296	0.109
36 h	Physical vitality	rho	0.035*	0.042*	0.046*	0.009	–0.031	–0.014
		P	0.038	0.014	0.007	0.581	0.073	0.409
	Emotional vitality	rho	0.040*	0.053*	0.063*	0.037*	–0.006	0.009
		P	0.02	0.002	0	0.03	0.743	0.593
	Social connectedness	rho	0.016	0.033	0.054*	0.03	0.007	0.014
		P	0.353	0.051	0.002	0.077	0.703	0.399
	Overall wellbeing	rho	0.032	0.038*	0.038*	0.011	–0.014	–0.006
		P	0.063	0.025	0.028	0.519	0.423	0.741
	SF physical	rho	–0.028	–0.019	–0.02	–0.022	–0.004	–0.015
		P	0.107	0.269	0.246	0.203	0.798	0.375
	SF mental	rho	0.093*	0.107*	0.109*	0.050*	–0.015	0.026
		P	0	0	0	0.004	0.39	0.136

Table A4.1. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
48 h	Physical vitality	rho	0.019	0.02	0.006	0.006	–0.016	–0.007
		P	0.269	0.232	0.708	0.738	0.345	0.677
	Emotional vitality	rho	–0.005	–0.013	–0.023	–0.027	–0.036*	–0.042*
		P	0.747	0.459	0.18	0.109	0.036	0.014
	Social connectedness	rho	–0.041*	–0.043*	–0.058*	–0.051*	–0.036*	–0.055*
		P	0.017	0.012	0.001	0.003	0.033	0.001
	Overall wellbeing	rho	0.018	0.017	0.003	–0.011	–0.051*	–0.039*
		P	0.289	0.328	0.871	0.522	0.003	0.022
	SF physical	rho	0.03	0.045*	0.035*	0.031	-0.015	0.012
		P	0.075	0.008	0.043	0.071	0.392	0.479
	SF mental	rho	–0.013	–0.033	–0.049*	–0.043*	–0.009	–0.034*
		P	0.435	0.056	0.004	0.011	0.611	0.048

Note: * indicates $P<0.05$.

Table A4.2. *Health indicators and geomagnetic field during spring season. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.068*	0.071*	0.032	0.040*	0.038	0.052*
		P	0.001	0.000	0.108	0.047	0.060	0.009
	Emotional vitality	rho	0.059*	0.068*	0.041*	0.040*	0.037	0.053*
		P	0.003	0.001	0.039	0.043	0.066	0.008
	Social connectedness	rho	0.001	0.009	-0.018	0.009	0.046*	0.036
		P	0.954	0.666	0.362	0.655	0.020	0.070
	Overall wellbeing	rho	0.080*	0.086*	0.053*	0.055*	0.041*	0.061*
		P	0.000	0.000	0.008	0.006	0.038	0.002
	SF physical	rho	–0.038	–0.042*	–0.061*	–0.034	0.016	-0.010
		P	0.060	0.037	0.002	0.090	0.418	0.635
	SF mental	rho	0.096*	0.081*	0.039	0.055*	0.074*	0.081*
		P	0.000	0.000	0.054	0.006	0.000	0.000

Table A4.2. *Continued*

Health indicator			**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
12 h	Physical vitality	rho	0.058*	0.052*	0.051*	0.017	–0.016	0.007
		P	0.004	0.010	0.011	0.385	0.431	0.742
	Emotional vitality	rho	0.058*	0.065*	0.073*	0.047*	0.011	0.034
		P	0.003	0.001	0.000	0.019	0.596	0.091
	Social connectedness	rho	0.063*	0.053*	0.065*	0.036	0.013	0.039*
		P	0.001	0.008	0.001	0.072	0.504	0.048
	Overall wellbeing	rho	0.056*	0.047*	0.030	0.004	0.006	0.020
		P	0.005	0.017	0.131	0.856	0.746	0.323
	SF physical	rho	0.032	0.029	0.020	0.008	0.040*	0.039
		P	0.112	0.150	0.322	0.689	0.044	0.050
	SF mental	rho	0.132*	0.139*	0.143*	0.093*	–0.018	0.054*
		P	0.000	0.000	0.000	0.000	0.379	0.008
24 h	Physical vitality	rho	0.014	0.008	-0.013	-0.001	0.016	0.009
		P	0.496	0.686	0.529	0.946	0.414	0.653
	Emotional vitality	rho	0.007	0.004	0.002	0.013	0.019	0.020
		P	0.735	0.835	0.914	0.522	0.332	0.327
	Social connectedness	rho	–0.038	–0.032	–0.053*	–0.021	0.026	–0.003
		P	0.058	0.105	0.008	0.303	0.200	0.890
	Overall wellbeing	rho	0.027	0.031	0.019	0.030	0.017	0.024
		P	0.178	0.118	0.340	0.132	0.386	0.232
	SF physical	rho	–0.049*	–0.055*	–0.077*	–0.047*	0.011	–0.021
		P	0.015	0.006	0.000	0.020	0.572	0.295
	SF mental	rho	0.011	0.006	–0.015	–0.003	0.010	0.001
		P	0.582	0.754	0.446	0.870	0.635	0.943

Table A4.2. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
36 h	Physical vitality	rho	0.064*	0.066*	0.067*	0.027	–0.012	0.015
		P	0.001	0.001	0.001	0.175	0.564	0.461
	Emotional vitality	rho	0.064*	0.080*	0.087*	0.056*	0.014	0.036
		P	0.001	0.000	0.000	0.005	0.473	0.071
	Social connectedness	rho	0.035	0.042*	0.054*	0.029	0.012	0.024
		P	0.079	0.037	0.007	0.152	0.554	0.225
	Overall wellbeing	rho	0.047*	0.053*	0.048*	0.022	0.006	0.017
		P	0.020	0.008	0.016	0.268	0.750	0.390
	SF physical	rho	–0.003	0.008	0.009	0.014	0.046*	0.037
		P	0.876	0.694	0.644	0.487	0.021	0.066
	SF mental	rho	0.111*	0.124*	0.130*	0.062*	–0.003	0.043*
		P	0.000	0.000	0.000	0.002	0.870	0.031
48 h	Physical vitality	rho	0.020	0.028	–0.002	0.017	0.007	0.009
		P	0.323	0.154	0.912	0.408	0.709	0.668
	Emotional vitality	rho	–0.009	–0.006	–0.032	–0.024	–0.022	–0.034
		P	0.655	0.772	0.115	0.238	0.264	0.090
	Social connectedness	rho	–0.048*	–0.042*	–0.069*	–0.049*	–0.028	–0.049*
		P	0.017	0.034	0.001	0.014	0.159	0.013
	Overall wellbeing	rho	0.018	0.023	–0.012	–0.008	–0.033	–0.029
		P	0.378	0.246	0.545	0.698	0.100	0.152
	SF physical	rho	–0.035	–0.039	–0.073*	–0.052*	–0.012	–0.035
		P	0.079	0.053	0.000	0.010	0.542	0.081
	SF mental	rho	0.005	–0.010	–0.049*	–0.025	0.014	–0.011
		P	0.789	0.627	0.014	0.208	0.471	0.597

Note: * indicates $P<0.05$.

Table A4.3. *Health indicators and geomagnetic field during fall season. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	–0.027	–0.050	–0.011	–0.082*	–0.115*	–0.109*
		P	0.407	0.129	0.740	0.012	0.000	0.001
	Emotional vitality	rho	–0.050	–0.062	–0.033	–0.071*	–0.087*	–0.094*
		P	0.123	0.058	0.317	0.029	0.008	0.004
	Social connectedness	rho	0.009	–0.034	–0.011	–0.017	–0.059	–0.052
		P	0.790	0.297	0.732	0.593	0.071	0.113
	Overall wellbeing	rho	–0.015	–0.043	0.007	–0.030	–0.079*	–0.075*
		P	0.653	0.194	0.829	0.362	0.015	0.021
	SF physical	rho	0.034	0.005	0.082*	0.042	–0.037	–0.013
		P	0.297	0.877	0.012	0.202	0.252	0.697
	SF mental	rho	0.005	–0.005	0.036	–0.041	–0.072*	–0.059
		P	0.872	0.879	0.270	0.205	0.026	0.072
12 h	Physical vitality	rho	–0.045	–0.014	-0.007	–0.055	–0.080*	–0.076*
		P	0.168	0.659	0.825	0.090	0.014	0.021
	Emotional vitality	rho	–0.017	0.010	0.044	0.002	–0.070*	–0.048
		P	0.596	0.749	0.174	0.943	0.031	0.140
	Social connectedness	rho	–0.055	–0.020	0.013	–0.004	–0.044	–0.044
		P	0.090	0.533	0.684	0.893	0.176	0.179
	Overall wellbeing	rho	–0.022	0.011	0.045	0.001	–0.071*	–0.053
		P	0.509	0.729	0.170	0.968	0.030	0.105
	SF physical	rho	–0.016	0.028	0.017	–0.039	–0.077*	–0.067*
		P	0.630	0.396	0.596	0.236	0.018	0.039
	SF mental	rho	–0.030	–0.012	0.021	–0.041	–0.086*	–0.076*
		P	0.353	0.713	0.513	0.212	0.009	0.021

Table A4.3. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
24 h	Physical vitality	rho	0.024	0.002	0.046	0.006	–0.050	–0.029
		P	0.467	0.958	0.156	0.848	0.128	0.369
	Emotional vitality	rho	–0.015	–0.044	0.003	–0.035	–0.066*	–0.062
		P	0.653	0.181	0.926	0.291	0.043	0.059
	Social connectedness	rho	0.045	0.023	0.058	0.014	-0.023	-0.008
		P	0.169	0.474	0.077	0.671	0.483	0.806
	Overall wellbeing	rho	–0.016	–0.039	0.013	–0.052	–0.106*	–0.100*
		P	0.615	0.234	0.699	0.114	0.001	0.002
	SF physical	rho	0.076*	0.080*	0.117*	0.084*	–0.015	0.025
		P	0.019	0.014	0.000	0.010	0.654	0.439
	SF mental	rho	0.054	0.015	0.059	–0.029	–0.078*	–0.057
		P	0.101	0.643	0.072	0.383	0.017	0.080
36 h	Physical vitality	rho	–0.057	–0.024	–0.007	–0.022	–0.078*	–0.077*
		P	0.082	0.468	0.836	0.501	0.016	0.018
	Emotional vitality	rho	–0.048	–0.035	0.003	0.002	–0.066*	–0.060
		P	0.145	0.281	0.932	0.958	0.044	0.067
	Social connectedness	rho	–0.058	–0.005	0.039	0.030	–0.030	–0.025
		P	0.074	0.880	0.230	0.365	0.364	0.443
	Overall wellbeing	rho	–0.014	0.012	0.030	0.005	–0.064	–0.046
		P	0.675	0.706	0.354	0.888	0.052	0.161
	SF physical	rho	–0.053	–0.013	–0.009	–0.029	–0.066*	–0.067*
		P	0.103	0.688	0.781	0.374	0.042	0.041
	SF mental	rho	0.015	0.031	0.023	0.003	–0.079*	–0.053
		P	0.645	0.349	0.475	0.926	0.016	0.106

Table A4.3. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
48 h	Physical vitality	rho	0.002	–0.013	0.017	–0.028	–0.072*	–0.054
		P	0.956	0.690	0.594	0.397	0.028	0.101
	Emotional vitality	rho	0.003	–0.020	0.004	–0.038	–0.069*	–0.060
		P	0.917	0.550	0.899	0.246	0.034	0.065
	Social connectedness	rho	0.010	0.008	0.039	0.007	–0.052	–0.032
		P	0.748	0.807	0.233	0.833	0.108	0.327
	Overall wellbeing	rho	0.001	–0.020	0.021	–0.034	–0.093*	–0.075*
		P	0.964	0.543	0.524	0.301	0.004	0.023
	SF physical	rho	0.058	0.050	0.101*	0.032	–0.021	0.009
		P	0.078	0.129	0.002	0.324	0.519	0.789
	SF mental	rho	–0.011	–0.034	0.024	–0.025	–0.069*	–0.053
		P	0.741	0.303	0.455	0.439	0.036	0.102

Note: * indicates $P<0.05$.

Table A4.4. *Health indicators and geomagnetic field in men group. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.027	–0.009	–0.051	–0.037	0.002	–0.008
		P	0.378	0.759	0.100	0.228	0.943	0.801
	Emotional vitality	rho	–0.016	–0.029	–0.049	–0.052	0.016	–0.009
		P	0.608	0.342	0.114	0.091	0.597	0.779
	Social connectedness	rho	–0.024	–0.024	–0.051	–0.034	0.009	–0.008
		P	0.442	0.434	0.098	0.264	0.774	0.786
	Overall wellbeing	rho	0.011	0.003	–0.031	–0.036	–0.017	–0.017
		P	0.726	0.922	0.316	0.249	0.573	0.581
	SF physical	rho	0.054	0.023	–0.028	0.004	0.004	0.014
		P	0.079	0.452	0.362	0.893	0.886	0.652
	SF mental	rho	0.007	–0.025	–0.072*	–0.064*	0.016	–0.018
		P	0.810	0.422	0.020	0.038	0.610	0.565

Table A4.4. *Continued*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
12 h	Physical vitality	rho	0.088*	0.089*	0.099*	0.030	–0.050	–0.009
		P	0.004	0.004	0.001	0.326	0.106	0.767
	Emotional vitality	rho	0.083*	0.094*	0.131*	0.083*	–0.020	0.024
		P	0.007	0.002	0.000	0.007	0.518	0.444
	Social connectedness	rho	0.073*	0.074*	0.093*	0.039	–0.013	0.020
		P	0.018	0.016	0.003	0.204	0.666	0.525
	Overall wellbeing	rho	0.060	0.067*	0.077*	0.043	–0.015	0.017
		P	0.053	0.031	0.013	0.168	0.638	0.581
	SF physical	rho	0.083*	0.080*	0.060	–0.013	–0.048	–0.022
		P	0.007	0.009	0.051	0.672	0.119	0.486
	SF mental	rho	0.165*	0.176*	0.197*	0.125*	–0.043	0.050
		P	0.000	0.000	0.000	0.000	0.161	0.107
24 h	Physical vitality	rho	–0.055	–0.072*	–0.093*	–0.089*	–0.029	–0.062*
		P	0.075	0.020	0.002	0.004	0.345	0.043
	Emotional vitality	rho	–0.093*	–0.089*	–0.075*	–0.051	0.007	–0.029
		P	0.002	0.004	0.015	0.098	0.818	0.348
	Social connectedness	rho	–0.067*	–0.062*	–0.079*	–0.043	–0.005	–0.034
		P	0.030	0.043	0.011	0.164	0.879	0.271
	Overall wellbeing	rho	–0.049	-0.040	–0.040	–0.009	0.012	–0.004
		P	0.115	0.195	0.194	0.765	0.705	0.888
	SF physical	rho	0.024	–0.013	–0.059	–0.052	–0.053	–0.051
		P	0.440	0.670	0.056	0.094	0.089	0.099
	SF mental	rho	–0.070*	–0.083*	–0.096*	–0.062*	0.018	–0.029
		P	0.024	0.007	0.002	0.046	0.564	0.341

Table A4.4. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
36 h	Physical vitality	rho	0.097*	0.119*	0.152*	0.071*	–0.041	0.020
		P	0.002	0.000	0.000	0.021	0.181	0.511
	Emotional vitality	rho	0.080*	0.099*	0.134*	0.081*	–0.010	0.037
		P	0.009	0.001	0.000	0.009	0.756	0.229
	Social connectedness	rho	0.036	0.046	0.075*	0.033	–0.025	–0.002
		P	0.242	0.135	0.015	0.282	0.419	0.944
	Overall wellbeing	rho	0.056	0.082*	0.099*	0.078*	0.017	0.047
		P	0.068	0.008	0.001	0.012	0.578	0.124
	SF physical	rho	0.086*	0.105*	0.096*	0.042	–0.015	0.025
		P	0.005	0.001	0.002	0.172	0.625	0.415
	SF mental	rho	0.127*	0.145*	0.169*	0.085*	–0.019	0.050
		P	0.000	0.000	0.000	0.006	0.541	0.109
48 h	Physical vitality	rho	–0.015	–0.020	–0.067*	–0.032	0.021	–0.007
		P	0.617	0.512	0.029	0.299	0.489	0.828
	Emotional vitality	rho	–0.084*	–0.084*	–0.095*	–0.066*	–0.016	–0.061*
		P	0.006	0.006	0.002	0.032	0.602	0.046
	Social connectedness	rho	–0.056	–0.060	–0.084*	–0.052	–0.017	–0.049
		P	0.067	0.050	0.006	0.093	0.589	0.115
	Overall wellbeing	rho	–0.044	–0.045	–0.063*	–0.037	–0.021	–0.049
		P	0.155	0.148	0.042	0.235	0.491	0.112
	SF physical	rho	0.038	0.006	–0.035	–0.021	–0.025	–0.021
		P	0.224	0.837	0.264	0.488	0.421	0.501
	SF mental	rho	–0.052	–0.081*	–0.127*	–0.078*	0.010	–0.046
		P	0.094	0.009	0.000	0.011	0.743	0.138

Note: * indicates $P<0.05$.

Table A4.5. *Health indicators and geomagnetic field in women group. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.021	0.027	0.016	0.010	–0.007	0.009
		P	0.307	0.188	0.423	0.641	0.732	0.670
	Emotional vitality	rho	0.036	0.030	0.019	0.016	–0.005	0.010
		P	0.083	0.146	0.362	0.450	0.796	0.624
	Social connectedness	rho	–0.017	–0.031	–0.041*	–0.024	0.014	–0.003
		P	0.412	0.125	0.046	0.234	0.491	0.872
	Overall wellbeing	rho	0.053*	0.043*	0.036	0.036	0.022	0.036
		P	0.010	0.036	0.078	0.076	0.293	0.082
	SF physical	rho	0.001	0.020	0.046*	0.050*	0.022	0.038
		P	0.945	0.330	0.026	0.014	0.284	0.062
	SF mental	rho	0.044*	0.020	0.003	0.008	0.038	0.035
		P	0.033	0.339	0.882	0.692	0.065	0.090
12 h	Physical vitality	rho	0.007	0.011	0.012	–0.006	–0.011	–0.008
		P	0.745	0.595	0.562	0.775	0.584	0.705
	Emotional vitality	rho	0.022	0.033	0.037	0.019	0.003	0.014
		P	0.284	0.108	0.075	0.346	0.870	0.481
	Social connectedness	rho	0.023	0.028	0.045*	0.030	0.015	0.027
		P	0.261	0.171	0.029	0.141	0.462	0.183
	Overall wellbeing	rho	0.027	0.024	0.014	–0.009	–0.005	–0.001
		P	0.188	0.242	0.511	0.662	0.801	0.967
	SF physical	rho	–0.031	–0.021	–0.028	–0.021	0.014	–0.001
		P	0.127	0.298	0.174	0.317	0.495	0.949
	SF mental	rho	0.071*	0.081*	0.088*	0.051*	-0.003	0.032
		P	0.001	0.000	0.000	0.013	0.889	0.125

Table A4.5. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
24 h	Physical vitality	rho	0.022	0.015	0.011	0.015	0.012	0.012
		P	0.294	0.479	0.599	0.462	0.564	0.559
	Emotional vitality	rho	0.027	0.009	0.009	0.000	–0.010	–0.007
		P	0.183	0.665	0.650	0.987	0.620	0.729
	Social connectedness	rho	–0.025	–0.039	–0.047*	–0.039	0.017	–0.016
		P	0.226	0.056	0.022	0.060	0.421	0.447
	Overall wellbeing	rho	0.028	0.022	0.018	0.003	–0.029	–0.015
		P	0.178	0.282	0.370	0.874	0.165	0.473
	SF physical	rho	0.013	0.044*	0.052*	0.065*	0.041*	0.057*
		P	0.528	0.034	0.012	0.002	0.046	0.006
	SF mental	rho	0.012	–0.010	–0.023	–0.038	–0.032	–0.040
		P	0.554	0.621	0.267	0.063	0.120	0.055
36 h	Physical vitality	rho	0.006	0.007	0.004	–0.007	–0.013	–0.016
		P	0.783	0.741	0.849	0.718	0.516	0.426
	Emotional vitality	rho	0.021	0.032	0.035	0.025	0.002	0.005
		P	0.305	0.119	0.090	0.232	0.906	0.821
	Social connectedness	rho	0.006	0.028	0.046*	0.031	0.023	0.025
		P	0.755	0.169	0.024	0.131	0.272	0.223
	Overall wellbeing	rho	0.020	0.020	0.015	–0.011	–0.020	–0.020
		P	0.318	0.338	0.478	0.606	0.322	0.334
	SF physical	rho	–0.083*	–0.077*	–0.069*	–0.042*	0.010	–0.022
		P	0.000	0.000	0.001	0.041	0.624	0.280
	SF mental	rho	0.076*	0.091*	0.086*	0.044*	0.000	0.028
		P	0.000	0.000	0.000	0.033	0.981	0.171

Table A4.5. *Continued*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
48 h	Physical vitality	rho	0.009	0.008	0.004	–0.005	–0.032	–0.021
		P	0.645	0.682	0.860	0.824	0.122	0.311
	Emotional vitality	rho	0.014	–0.002	–0.015	–0.028	–0.045*	–0.042*
		P	0.505	0.928	0.473	0.176	0.029	0.041
	Social connectedness	rho	–0.041*	–0.047*	–0.060*	–0.060*	–0.046*	–0.062*
		P	0.046	0.021	0.004	0.003	0.025	0.003
	Overall wellbeing	rho	0.026	0.020	0.005	–0.021	–0.063*	–0.046*
		P	0.207	0.333	0.790	0.305	0.002	0.026
	SF physical	rho	0.014	0.043*	0.043*	0.036	–0.008	0.019
		P	0.491	0.037	0.038	0.077	0.698	0.367
	SF mental	rho	–0.021	–0.042*	–0.046*	–0.050*	–0.017	–0.041*
		P	0.311	0.043	0.025	0.015	0.415	0.047

Note: * indicates $P<0.05$.

Table A4.6. *Health indicators and geomagnetic field in 19–29-year-old group. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.059*	0.058*	0.036	0.033	0.006	0.031
		P	0.004	0.004	0.072	0.098	0.774	0.125
	Emotional vitality	rho	0.030	0.030	0.015	0.011	0.001	0.011
		P	0.134	0.132	0.451	0.598	0.964	0.574
	Social connectedness	rho	-0.007	-0.013	-0.024	-0.001	0.031	0.019
		P	0.741	0.510	0.233	0.944	0.126	0.360
	Overall wellbeing	rho	0.068*	0.064*	0.049*	0.052*	0.029	0.051*
		P	0.001	0.002	0.015	0.010	0.151	0.012
	SF physical	rho	0.082*	0.087*	0.086*	0.094*	0.028	0.073*
		P	0.000	0.000	0.000	0.000	0.163	0.000
	SF mental	rho	0.060*	0.033	0.004	0.008	0.025	0.029
		P	0.003	0.104	0.855	0.691	0.213	0.152

Table A4.6. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
12 h	Physical vitality	rho	0.041*	0.036	0.023	0.003	-0.001	0.007
		P	0.040	0.074	0.259	0.871	0.971	0.740
	Emotional vitality	rho	0.041*	0.049*	0.057*	0.034	0.010	0.027
		P	0.045	0.016	0.005	0.089	0.606	0.179
	Social connectedness	rho	0.040*	0.040*	0.048*	0.032	0.019	0.030
		P	0.048	0.047	0.019	0.108	0.346	0.135
	Overall wellbeing	rho	0.048*	0.039	0.012	-0.002	0.005	0.011
		P	0.017	0.051	0.560	0.933	0.823	0.580
	SF physical	rho	0.014	0.024	-0.001	-0.029	-0.025	-0.019
		P	0.497	0.231	0.947	0.148	0.225	0.347
	SF mental	rho	0.103*	0.104*	0.097*	0.051*	-0.011	0.031
		P	0.000	0.000	0.000	0.012	0.596	0.130
24 h	Physical vitality	rho	0.038	0.035	0.027	0.033	0.027	0.029
		P	0.059	0.087	0.174	0.098	0.187	0.146
	Emotional vitality	rho	-0.002	-0.004	0.002	0.007	0.021	0.009
		P	0.940	0.829	0.904	0.733	0.295	0.667
	Social connectedness	rho	-0.028	-0.033	-0.039	-0.014	0.050*	0.012
		P	0.162	0.099	0.055	0.501	0.014	0.554
	Overall wellbeing	rho	0.022	0.031	0.027	0.034	0.011	0.019
		P	0.285	0.126	0.174	0.095	0.583	0.340
	SF physical	rho	0.069*	0.084*	0.078*	0.088*	0.030	0.067*
		P	0.001	0.000	0.000	0.000	0.134	0.001
	SF mental	rho	0.005	-0.006	-0.020	-0.018	-0.005	-0.016
		P	0.813	0.756	0.333	0.367	0.809	0.438

Table A4.6. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
36 h	Physical vitality	rho	0.028	0.035	0.033	0.010	-0.013	-0.007
		P	0.162	0.080	0.101	0.622	0.505	0.741
	Emotional vitality	rho	0.038	0.048*	0.051*	0.044*	0.012	0.021
		P	0.058	0.017	0.011	0.031	0.555	0.299
	Social connectedness	rho	0.013	0.034	0.047*	0.038	0.019	0.023
		P	0.508	0.095	0.019	0.057	0.340	0.264
	Overall wellbeing	rho	0.040*	0.045*	0.025	0.015	0.006	0.009
		P	0.046	0.025	0.218	0.445	0.785	0.673
	SF physical	rho	-0.034	-0.021	-0.035	-0.038	-0.014	-0.028
		P	0.096	0.301	0.081	0.064	0.500	0.171
	SF mental	rho	0.089*	0.102*	0.092*	0.051*	-0.003	0.030
		P	0.000	0.000	0.000	0.011	0.896	0.138
48 h	Physical vitality	rho	0.046*	0.040*	0.024	0.024	0.003	0.013
		P	0.023	0.046	0.230	0.238	0.877	0.507
	Emotional vitality	rho	0.003	-0.003	-0.012	-0.007	-0.006	-0.016
		P	0.888	0.885	0.549	0.744	0.773	0.442
	Social connectedness	rho	-0.034	-0.031	-0.042*	-0.027	-0.018	-0.033
		P	0.090	0.129	0.037	0.177	0.361	0.105
	Overall wellbeing	rho	0.036	0.033	0.017	0.015	-0.019	-0.007
		P	0.073	0.106	0.394	0.466	0.337	0.733
	SF physical	rho	0.073*	0.084*	0.070*	0.066*	-0.008	0.040
		P	0.000	0.000	0.001	0.001	0.695	0.051
	SF mental	rho	-0.010	-0.025	-0.037	-0.025	0.010	-0.015
		P	0.626	0.219	0.066	0.227	0.607	0.472

Note: * indicates $P<0.05$.

Table A4.7. *Health indicators and geomagnetic field in 30–39-year-old group. P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	–0.079*	–0.072*	–0.084*	–0.064*	0.000	–0.034
		P	0.013	0.023	0.008	0.042	0.999	0.278
	Emotional vitality	rho	–0.054	–0.048	–0.051	–0.034	0.025	–0.001
		P	0.085	0.128	0.107	0.282	0.431	0.983
	Social connectedness	rho	–0.090*	–0.090*	–0.107*	–0.091*	–0.014	–0.055
		P	0.005	0.004	0.001	0.004	0.667	0.083
	Overall wellbeing	rho	–0.103*	–0.092*	–0.091*	–0.075*	0.005	–0.039
		P	0.001	0.004	0.004	0.018	0.876	0.213
	SF physical	rho	–0.114*	–0.103*	–0.085*	–0.066*	–0.002	–0.038
		P	0.000	0.001	0.007	0.038	0.957	0.228
	SF mental	rho	–0.064*	–0.060	–0.076*	–0.047	0.076*	0.017
		P	0.044	0.059	0.017	0.141	0.017	0.589
12 h	Physical vitality	rho	–0.054	–0.037	–0.009	–0.028	–0.010	–0.026
		P	0.090	0.248	0.777	0.379	0.759	0.419
	Emotional vitality	rho	–0.024	–0.009	0.016	0.029	0.040	0.030
		P	0.439	0.787	0.620	0.365	0.208	0.347
	Social connectedness	rho	–0.005	0.006	0.045	0.017	0.034	0.033
		P	0.886	0.858	0.157	0.589	0.288	0.291
	Overall wellbeing	rho	–0.087*	–0.071*	–0.032	–0.012	0.084*	0.037
		P	0.006	0.026	0.315	0.705	0.008	0.246
	SF physical	rho	–0.019	–0.028	–0.015	–0.005	0.045	0.019
		P	0.552	0.373	0.646	0.881	0.160	0.561
	SF mental	rho	0.024	0.051	0.098*	0.091*	0.053	0.083*
		P	0.451	0.107	0.002	0.004	0.098	0.009

Table A4.7. *Continued*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
24 h	Physical vitality	rho	–0.115*	–0.111*	–0.114*	–0.098*	–0.026	–0.071*
		P	0.000	0.000	0.000	0.002	0.417	0.025
	Emotional vitality	rho	–0.074*	–0.080*	–0.074*	–0.064*	–0.030	–0.049
		P	0.020	0.011	0.020	0.042	0.344	0.118
	Social connectedness	rho	–0.090*	–0.090*	–0.107*	–0.102*	–0.061	–0.092*
		P	0.004	0.004	0.001	0.001	0.054	0.004
	Overall wellbeing	rho	–0.108*	–0.100*	–0.088*	–0.078*	–0.036	–0.067*
		P	0.001	0.002	0.005	0.013	0.261	0.034
	SF physical	rho	–0.091*	–0.085*	–0.084*	–0.078*	–0.018	–0.056
		P	0.004	0.007	0.008	0.015	0.565	0.079
	SF mental	rho	–0.088*	–0.101*	–0.111*	–0.094*	–0.001	–0.056
		P	0.006	0.002	0.000	0.003	0.965	0.079
36 h	Physical vitality	rho	–0.022	–0.013	0.004	–0.005	0.024	0.021
		P	0.493	0.673	0.893	0.868	0.457	0.515
	Emotional vitality	rho	–0.023	0.000	0.021	0.008	0.038	0.027
		P	0.474	0.994	0.498	0.794	0.225	0.400
	Social connectedness	rho	–0.026	–0.016	0.019	–0.003	0.040	0.027
		P	0.405	0.617	0.544	0.929	0.208	0.401
	Overall wellbeing	rho	–0.097*	–0.085*	–0.046	–0.018	0.090*	0.036
		P	0.002	0.007	0.144	0.561	0.004	0.256
	SF physical	rho	–0.038	–0.036	–0.009	0.015	0.039	0.020
		P	0.239	0.253	0.781	0.647	0.219	0.529
	SF mental	rho	0.018	0.035	0.066*	0.034	0.059	0.072*
		P	0.577	0.269	0.039	0.282	0.066	0.024

Table A4.7. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
48 h	Physical vitality	rho	–0.113*	–0.087*	–0.093*	–0.067*	–0.018	–0.055
		P	0.000	0.006	0.003	0.033	0.565	0.081
	Emotional vitality	rho	–0.098*	–0.102*	–0.110*	–0.111*	–0.066*	–0.105*
		P	0.002	0.001	0.000	0.000	0.038	0.001
	Social connectedness	rho	–0.105*	–0.113*	–0.134*	–0.125*	–0.057	–0.105*
		P	0.001	0.000	0.000	0.000	0.074	0.001
	Overall wellbeing	rho	–0.131*	–0.114*	–0.117*	–0.117*	–0.072*	–0.117*
		P	0.000	0.000	0.000	0.000	0.023	0.000
	SF physical	rho	–0.088*	–0.067*	–0.069*	–0.063*	–0.026	–0.053
		P	0.006	0.036	0.031	0.048	0.411	0.098
	SF mental	rho	–0.110*	–0.129*	–0.151*	–0.126*	–0.010	–0.080*
		P	0.001	0.000	0.000	0.000	0.745	0.012

Note: * indicates $P<0.05$.

Table A4.8. *Health indicators and geomagnetic field in physically active group (regular). P values included*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	rho	0.018	0.032	0.017	0.013	0.027	0.033
		P	0.540	0.259	0.558	0.653	0.351	0.243
	Emotional vitality	rho	0.088*	0.101*	0.085*	0.069*	0.045	0.077*
		P	0.002	0.000	0.003	0.016	0.117	0.007
	Social connectedness	rho	–0.014	–0.021	–0.039	–0.020	0.036	0.017
		P	0.614	0.463	0.175	0.479	0.212	0.562
	Overall wellbeing	rho	0.025	0.043	0.035	0.032	0.027	0.038
		P	0.376	0.130	0.222	0.268	0.347	0.191
	SF physical	rho	0.015	0.037	0.053	0.053	0.021	0.049
		P	0.591	0.196	0.065	0.067	0.470	0.087
	SF mental	rho	0.043	0.027	–0.009	0.012	0.084*	0.064*
		P	0.134	0.344	0.751	0.688	0.003	0.025

Table A4.8. Continued

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
12 h	Physical vitality	rho	0.009	0.015	0.041	–0.009	–0.049	–0.038
		P	0.767	0.609	0.151	0.763	0.085	0.182
	Emotional vitality	rho	0.058*	0.074*	0.103*	0.034	–0.060*	–0.021
		P	0.042	0.010	0.000	0.240	0.035	0.467
	Social connectedness	rho	0.043	0.062*	0.115*	0.037	–0.024	0.006
		P	0.130	0.029	0.000	0.202	0.403	0.832
	Overall wellbeing	rho	0.028	0.054	0.093*	0.030	–0.021	0.002
		P	0.321	0.058	0.001	0.303	0.470	0.946
	SF physical	rho	–0.018	–0.016	–0.018	–0.030	–0.005	–0.018
		P	0.522	0.581	0.543	0.290	0.869	0.525
	SF mental	rho	0.121*	0.145*	0.180*	0.079*	–0.060*	0.013
		P	0.000	0.000	0.000	0.006	0.036	0.653
24 h	Physical vitality	rho	0.021	0.022	0.013	0.030	0.049	0.044
		P	0.463	0.453	0.638	0.291	0.090	0.127
	Emotional vitality	rho	0.079*	0.085*	0.090*	0.092*	0.055	0.089*
		P	0.006	0.003	0.002	0.001	0.056	0.002
	Social connectedness	rho	–0.013	–0.030	–0.053	–0.020	0.054	0.017
		P	0.661	0.291	0.062	0.495	0.059	0.560
	Overall wellbeing	rho	0.013	0.022	0.020	0.040	0.049	0.041
		P	0.649	0.440	0.481	0.162	0.089	0.153
	SF physical	rho	0.019	0.052	0.058*	0.061*	0.034	0.053
		P	0.514	0.070	0.045	0.034	0.241	0.064
	SF mental	rho	0.016	–0.010	–0.036	–0.012	0.054	0.027
		P	0.583	0.717	0.213	0.674	0.062	0.345

Table A4.8. *Continued*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
36 h	Physical vitality	rho	0.037	0.036	0.054	0.006	–0.055	–0.033
		P	0.199	0.206	0.057	0.839	0.055	0.243
	Emotional vitality	rho	0.083*	0.084*	0.110*	0.031	–0.067*	–0.026
		P	0.004	0.003	0.000	0.284	0.019	0.368
	Social connectedness	rho	0.039	0.054	0.096*	0.038	–0.014	0.012
		P	0.171	0.060	0.001	0.180	0.626	0.666
	Overall wellbeing	rho	0.045	0.066*	0.096*	0.059*	–0.008	0.017
		P	0.116	0.021	0.001	0.041	0.781	0.545
	SF physical	rho	–0.051	–0.034	–0.021	0.014	0.041	0.022
		P	0.075	0.242	0.467	0.627	0.153	0.437
	SF mental	rho	0.117*	0.127*	0.151*	0.048	–0.046	0.012
		P	0.000	0.000	0.000	0.092	0.112	0.687
48 h	Physical vitality	rho	0.023	0.027	0.011	0.027	0.019	0.026
		P	0.413	0.351	0.701	0.340	0.517	0.361
	Emotional vitality	rho	0.040	0.044	0.030	0.017	–0.031	–0.010
		P	0.166	0.123	0.302	0.560	0.278	0.734
	Social connectedness	rho	–0.037	–0.053	–0.075*	–0.050	–0.015	–0.044
		P	0.201	0.066	0.009	0.080	0.591	0.126
	Overall wellbeing	rho	0.008	0.006	–0.018	–0.021	–0.042	–0.037
		P	0.792	0.842	0.537	0.469	0.145	0.199
	SF physical	rho	0.011	0.053	0.037	0.035	–0.028	0.000
		P	0.698	0.066	0.195	0.231	0.323	0.998
	SF mental	rho	–0.012	–0.038	–0.067*	–0.051	0.009	–0.023
		P	0.667	0.189	0.019	0.076	0.747	0.433

Note: * indicates $P<0.05$.

Table A4.9. *Health indicators and geomagnetic field in physically passive group (not regular). P values included*

Health indicator			**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
0 h	Physical vitality	rho	0.020	0.004	–0.007	–0.009	–0.018	–0.009
		P	0.362	0.847	0.771	0.698	0.430	0.674
	Emotional vitality	rho	–0.033	–0.055*	–0.058*	–0.057*	–0.023	–0.044
		P	0.148	0.015	0.010	0.012	0.300	0.051
	Social connectedness	rho	–0.050*	–0.070*	–0.073*	–0.059*	–0.004	–0.035
		P	0.025	0.002	0.001	0.009	0.863	0.119
	Overall wellbeing	rho	0.035	0.008	0.004	–0.001	–0.003	0.005
		P	0.122	0.722	0.852	0.959	0.904	0.823
	SF physical	rho	0.011	0.017	0.023	0.036	0.012	0.023
		P	0.625	0.450	0.311	0.106	0.579	0.314
	SF mental	rho	0.009	–0.030	–0.043	–0.050*	–0.009	–0.023
		P	0.686	0.188	0.058	0.027	0.692	0.306
12 h	Physical vitality	rho	0.045*	0.044*	0.035	0.022	–0.002	0.011
		P	0.046	0.049	0.115	0.338	0.923	0.619
	Emotional vitality	rho	0.025	0.034	0.048*	0.057*	0.040	0.046*
		P	0.275	0.131	0.033	0.011	0.075	0.040
	Social connectedness	rho	0.040	0.036	0.043	0.051*	0.029	0.042
		P	0.074	0.106	0.053	0.024	0.197	0.061
	Overall wellbeing	rho	0.042	0.026	0.004	0.003	–0.001	0.004
		P	0.062	0.251	0.866	0.885	0.953	0.873
	SF physical	rho	0.020	0.019	0.006	–0.013	–0.010	–0.007
		P	0.370	0.387	0.803	0.574	0.655	0.758
	SF mental	rho	0.088*	0.089*	0.095*	0.078*	0.006	0.045*
		P	0.000	0.000	0.000	0.001	0.782	0.046

Table A4.9. *Continued*

Health indicator			0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
24 h	Physical vitality	rho	–0.013	–0.023	–0.017	–0.026	–0.020	–0.026
		P	0.561	0.305	0.457	0.249	0.371	0.248
	Emotional vitality	rho	–0.073*	–0.094*	–0.075*	–0.079*	–0.029	–0.067*
		P	0.001	0.000	0.001	0.000	0.198	0.003
	Social connectedness	rho	–0.071*	–0.081*	–0.072*	–0.070*	–0.011	–0.049*
		P	0.002	0.000	0.001	0.002	0.633	0.031
	Overall wellbeing	rho	–0.007	–0.013	–0.005	–0.023	–0.051*	–0.039
		P	0.770	0.577	0.831	0.297	0.023	0.085
	SF physical	rho	0.020	0.031	0.027	0.037	0.006	0.025
		P	0.372	0.164	0.231	0.104	0.777	0.276
	SF mental	rho	–0.046*	–0.064*	–0.056*	–0.075*	–0.057*	–0.077*
		P	0.041	0.005	0.012	0.001	0.012	0.001
36 h	Physical vitality	rho	0.029	0.040	0.039	0.022	–0.006	0.005
		P	0.197	0.074	0.079	0.334	0.788	0.837
	Emotional vitality	rho	0.009	0.025	0.030	0.045*	0.041	0.035
		P	0.679	0.273	0.189	0.043	0.067	0.116
	Social connectedness	rho	0.017	0.036	0.048*	0.044	0.023	0.027
		P	0.462	0.110	0.031	0.052	0.298	0.233
	Overall wellbeing	rho	0.025	0.021	0.008	–0.005	–0.004	–0.006
		P	0.258	0.345	0.734	0.825	0.857	0.795
	SF physical	rho	–0.017	–0.013	–0.017	–0.032	–0.031	–0.033
		P	0.457	0.553	0.458	0.160	0.170	0.138
	SF mental	rho	0.084*	0.102*	0.096*	0.068*	0.020	0.051*
		P	0.000	0.000	0.000	0.002	0.379	0.024

Table A4.9. *Continued*

Health indicator			**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
48 h	Physical vitality	rho	–0.014	–0.016	–0.021	–0.028	–0.023	–0.030
		P	0.522	0.471	0.353	0.216	0.304	0.184
	Emotional vitality	rho	–0.061*	–0.081*	–0.079*	–0.078*	–0.023	–0.065*
		P	0.007	0.000	0.000	0.000	0.302	0.004
	Social connectedness	rho	–0.072*	–0.077*	–0.081*	–0.083*	–0.034	–0.067*
		P	0.001	0.001	0.000	0.000	0.127	0.003
	Overall wellbeing	rho	–0.006	–0.016	–0.015	–0.035	–0.042	–0.047*
		P	0.791	0.482	0.511	0.122	0.060	0.038
	SF physical	rho	0.035	0.039	0.034	0.030	0.002	0.024
		P	0.124	0.086	0.128	0.189	0.917	0.289
	SF mental	rho	–0.060*	–0.083*	–0.078*	–0.075*	–0.007	–0.053*
		P	0.007	0.000	0.000	0.001	0.768	0.018

Note: * indicates P<0.05.

Table A5.1. *Wellbeing and health indicators and geomagnetic field during spring season*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	0.068*	0.071*	0.032	0.040*	0.038	0.052*
	Emotional vitality	0.059*	0.068*	0.041*	0.040*	0.037	0.053*
	Social connectedness	0.001	0.009	–0.018	0.009	0.046*	0.036
	Overall wellbeing	0.080*	0.086*	0.053*	0.055*	0.041*	0.061*
	SF physical	–0.038	–0.042*	–0.061*	–0.034	0.016	–0.010
	SF mental	0.096*	0.081*	0.039	0.055*	0.074*	0.081*
12 h	Physical vitality	0.058*	0.052*	0.051*	0.017	–0.016	0.007
	Emotional vitality	0.058*	0.065*	0.073*	0.047*	0.011	0.034
	Social connectedness	0.063*	0.053*	0.065*	0.036	0.013	0.039*
	Overall wellbeing	0.056*	0.047*	0.030	0.004	0.006	0.020
	SF physical	0.032	0.029	0.020	0.008	0.040*	0.039
	SF mental	**0.132***	**0.139***	**0.143***	0.093*	–0.018	0.054*
24 h	Physical vitality	0.014	0.008	-0.013	–0.001	0.016	0.009
	Emotional vitality	0.007	0.004	0.002	0.013	0.019	0.020
	Social connectedness	-0.038	-0.032	–0.053*	–0.021	0.026	–0.003
	Overall wellbeing	0.027	0.031	0.019	0.030	0.017	0.024
	SF physical	–0.049*	–0.055*	–0.077*	–0.047*	0.011	–0.021
	SF mental	0.011	0.006	-0.015	-0.003	0.010	0.001
36 h	Physical vitality	0.064*	0.066*	0.067*	0.027	–0.012	0.015
	Emotional vitality	0.064*	0.080*	0.087*	0.056*	0.014	0.036
	Social connectedness	0.035	0.042*	0.054*	0.029	0.012	0.024
	Overall wellbeing	0.047*	0.053*	0.048*	0.022	0.006	0.017
	SF physical	–0.003	0.008	0.009	0.014	0.046*	0.037
	SF mental	**0.111***	**0.124***	**0.130***	0.062*	–0.003	0.043*
48 h	Physical vitality	0.020	0.028	–0.002	0.017	0.007	0.009
	Emotional vitality	–0.009	–0.006	–0.032	–0.024	–0.022	–0.034
	Social connectedness	–0.048*	–0.042*	–0.069*	–0.049*	–0.028	–0.049*
	Overall wellbeing	0.018	0.023	–0.012	–0.008	–0.033	–0.029
	SF physical	–0.035	–0.039	–0.073*	–0.052*	–0.012	–0.035
	SF mental	0.005	–0.010	–0.049*	–0.025	0.014	–0.011

Note: **grey** indicates ϱ>0.10; * indicates $P<0.05$.

Table A5.2. *Wellbeing and health indicators and geomagnetic field during fall season*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	–0.027	–0.050	–0.011	–0.082*	–0.115*	–0.109*
	Emotional vitality	–0.050	–0.062	–0.033	–0.071*	–0.087*	–0.094*
	Social connectedness	0.009	–0.034	–0.011	–0.017	–0.059	–0.052
	Overall wellbeing	–0.015	–0.043	0.007	–0.030	–0.079*	–0.075*
	SF physical	0.034	0.005	0.082*	0.042	–0.037	–0.013
	SF mental	0.005	–0.005	0.036	–0.041	–0.072*	–0.059
12 h	Physical vitality	–0.045	–0.014	–0.007	–0.055	–0.080*	–0.076*
	Emotional vitality	–0.017	0.010	0.044	0.002	–0.070*	–0.048
	Social connectedness	–0.055	–0.020	0.013	–0.004	–0.044	–0.044
	Overall wellbeing	–0.022	0.011	0.045	0.001	–0.071*	–0.053
	SF physical	–0.016	0.028	0.017	–0.039	–0.077*	–0.067*
	SF mental	–0.030	–0.012	0.021	–0.041	–0.086*	–0.076*
24 h	Physical vitality	0.024	0.002	0.046	0.006	–0.050	–0.029
	Emotional vitality	–0.015	–0.044	0.003	–0.035	–0.066*	–0.062
	Social connectedness	0.045	0.023	0.058	0.014	–0.023	–0.008
	Overall wellbeing	–0.016	–0.039	0.013	–0.052	**–0.106***	**–0.100***
	SF physical	0.076*	0.080*	**0.117***	0.084*	–0.015	0.025
	SF mental	0.054	0.015	0.059	–0.029	–0.078*	–0.057
36 h	Physical vitality	–0.057	–0.024	–0.007	–0.022	–0.078*	–0.077*
	Emotional vitality	–0.048	–0.035	0.003	0.002	–0.066*	–0.060
	Social connectedness	–0.058	–0.005	0.039	0.030	–0.030	–0.025
	Overall wellbeing	–0.014	0.012	0.030	0.005	–0.064	–0.046
	SF physical	–0.053	–0.013	–0.009	–0.029	–0.066*	–0.067*
	SF mental	0.015	0.031	0.023	0.003	–0.079*	–0.053
48 h	Physical vitality	0.002	–0.013	0.017	–0.028	–0.072*	–0.054
	Emotional vitality	0.003	–0.020	0.004	–0.038	–0.069*	–0.060
	Social connectedness	0.010	0.008	0.039	0.007	–0.052	–0.032
	Overall wellbeing	0.001	–0.020	0.021	–0.034	–0.093*	–0.075*
	SF physical	0.058	0.050	**0.101***	0.032	–0.021	0.009
	SF mental	–0.011	–0.034	0.024	–0.025	–0.069*	–0.053

Note: **grey** indicates ϱ>0.10; * indicates $P<0.05$.

Table A5.3. *Wellbeing and health indicators and geomagnetic field in men group*

Lag	**Health indicator**	**0–3.5 Hz**	**3.5–7 Hz**	**7–15 Hz**	**15–32 Hz**	**32–66 Hz**	**0–66 Hz**
0 h	Physical vitality	0.027	–0.009	–0.051	–0.037	0.002	–0.008
	Emotional vitality	–0.016	–0.029	–0.049	–0.052	0.016	–0.009
	Social connectedness	–0.024	–0.024	–0.051	–0.034	0.009	–0.008
	Overall wellbeing	0.011	0.003	–0.031	–0.036	–0.017	–0.017
	SF physical	0.054	0.023	–0.028	0.004	0.004	0.014
	SF mental	0.007	–0.025	–0.072*	–0.064*	0.016	–0.018
12 h	Physical vitality	0.088*	0.089*	0.099*	0.030	–0.050	–0.009
	Emotional vitality	0.083*	0.094*	**0.131***	0.083*	–0.020	0.024
	Social connectedness	0.073*	0.074*	0.093*	0.039	–0.013	0.020
	Overall wellbeing	0.060	0.067*	0.077*	0.043	–0.015	0.017
	SF physical	0.083*	0.080*	0.060	–0.013	–0.048	–0.022
	SF mental	**0.165***	**0.176***	**0.197***	**0.125***	–0.043	0.050
24 h	Physical vitality	–0.055	–0.072*	–0.093*	–0.089*	–0.029	–0.062*
	Emotional vitality	–0.093*	–0.089*	–0.075*	–0.051	0.007	–0.029
	Social connectedness	–0.067*	–0.062*	–0.079*	–0.043	–0.005	–0.034
	Overall wellbeing	–0.049	–0.040	–0.040	–0.009	0.012	–0.004
	SF physical	0.024	–0.013	–0.059	–0.052	–0.053	–0.051
	SF mental	–0.070*	–0.083*	–0.096*	–0.062*	0.018	–0.029
36 h	Physical vitality	0.097*	**0.119***	**0.152***	0.071*	–0.041	0.020
	Emotional vitality	0.080*	0.099*	**0.134***	0.081*	–0.010	0.037
	Social connectedness	0.036	0.046	0.075*	0.033	–0.025	–0.002
	Overall wellbeing	0.056	0.082*	0.099*	0.078*	0.017	0.047
	SF physical	0.086*	**0.105***	0.096*	0.042	–0.015	0.025
	SF mental	**0.127***	**0.145***	**0.169***	0.085*	–0.019	0.050
48 h	Physical vitality	–0.015	–0.020	–0.067*	–0.032	0.021	–0.007
	Emotional vitality	–0.084*	–0.084*	–0.095*	–0.066*	–0.016	–0.061*
	Social connectedness	–0.056	–0.060	–0.084*	–0.052	–0.017	–0.049
	Overall wellbeing	–0.044	–0.045	–0.063*	–0.037	–0.021	–0.049
	SF physical	0.038	0.006	–0.035	–0.021	–0.025	–0.021
	SF mental	–0.052	–0.081*	–0.127*	–0.078*	0.010	–0.046

Note: **grey** indicates $\varrho>0.10$; * indicates $P<0.05$.

__Table A5.4.__ Wellbeing and health indicators and geomagnetic field in women group

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	0.021	0.027	0.016	0.010	–0.007	0.009
	Emotional vitality	0.036	0.030	0.019	0.016	–0.005	0.010
	Social connectedness	–0.017	–0.031	–0.041*	–0.024	0.014	–0.003
	Overall wellbeing	0.053*	0.043*	0.036	0.036	0.022	0.036
	SF physical	0.001	0.020	0.046*	0.050*	0.022	0.038
	SF mental	0.044*	0.020	0.003	0.008	0.038	0.035
12 h	Physical vitality	0.007	0.011	0.012	–0.006	–0.011	–0.008
	Emotional vitality	0.022	0.033	0.037	0.019	0.003	0.014
	Social connectedness	0.023	0.028	0.045*	0.030	0.015	0.027
	Overall wellbeing	0.027	0.024	0.014	–0.009	–0.005	–0.001
	SF physical	–0.031	–0.021	–0.028	–0.021	0.014	–0.001
	SF mental	0.071*	0.081*	0.088*	0.051*	–0.003	0.032
24 h	Physical vitality	0.022	0.015	0.011	0.015	0.012	0.012
	Emotional vitality	0.027	0.009	0.009	0.000	–0.010	–0.007
	Social connectedness	–0.025	–0.039	–0.047*	–0.039	0.017	–0.016
	Overall wellbeing	0.028	0.022	0.018	0.003	–0.029	–0.015
	SF physical	0.013	0.044*	0.052*	0.065*	0.041*	0.057*
	SF mental	0.012	–0.010	–0.023	–0.038	–0.032	–0.040
36 h	Physical vitality	0.006	0.007	0.004	–0.007	–0.013	–0.016
	Emotional vitality	0.021	0.032	0.035	0.025	0.002	0.005
	Social connectedness	0.006	0.028	0.046*	0.031	0.023	0.025
	Overall wellbeing	0.020	0.020	0.015	–0.011	–0.020	–0.020
	SF physical	–0.083*	–0.077*	–0.069*	–0.042*	0.010	–0.022
	SF mental	0.076*	0.091*	0.086*	0.044*	0.000	0.028
48 h	Physical vitality	0.009	0.008	0.004	–0.005	–0.032	–0.021
	Emotional vitality	0.014	–0.002	–0.015	–0.028	–0.045*	–0.042*
	Social connectedness	–0.041*	–0.047*	–0.060*	–0.060*	–0.046*	–0.062*
	Overall wellbeing	0.026	0.020	0.005	–0.021	–0.063*	–0.046*
	SF physical	0.014	0.043*	0.043*	0.036	–0.008	0.019
	SF mental	–0.021	–0.042*	–0.046*	–0.050*	–0.017	–0.041*

Note: * indicates $P<0.05$.

Table A5.5. *Wellbeing and health indicators and geomagnetic field among 19–29-year-old subjects*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	0.059*	0.058*	0.036	0.033	0.006	0.031
	Emotional vitality	0.030	0.030	0.015	0.011	0.001	0.011
	Social connectedness	–0.007	–0.013	–0.024	–0.001	0.031	0.019
	Overall wellbeing	0.068*	0.064*	0.049*	0.052*	0.029	0.051*
	SF physical	0.082*	0.087*	0.086*	0.094*	0.028	0.073*
	SF mental	0.060*	0.033	0.004	0.008	0.025	0.029
12 h	Physical vitality	0.041*	0.036	0.023	0.003	–0.001	0.007
	Emotional vitality	0.041*	0.049*	0.057*	0.034	0.010	0.027
	Social connectedness	0.040*	0.040*	0.048*	0.032	0.019	0.030
	Overall wellbeing	0.048*	0.039	0.012	–0.002	0.005	0.011
	SF physical	0.014	0.024	–0.001	–0.029	–0.025	–0.019
	SF mental	**0.103***	**0.104***	0.097*	0.051*	–0.011	0.031
24 h	Physical vitality	0.038	0.035	0.027	0.033	0.027	0.029
	Emotional vitality	–0.002	–0.004	0.002	0.007	0.021	0.009
	Social connectedness	–0.028	–0.033	–0.039	–0.014	0.050*	0.012
	Overall wellbeing	0.022	0.031	0.027	0.034	0.011	0.019
	SF physical	0.069*	0.084*	0.078*	0.088*	0.030	0.067*
	SF mental	0.005	–0.006	–0.020	–0.018	–0.005	–0.016
36 h	Physical vitality	0.028	0.035	0.033	0.010	–0.013	–0.007
	Emotional vitality	0.038	0.048*	0.051*	0.044*	0.012	0.021
	Social connectedness	0.013	0.034	0.047*	0.038	0.019	0.023
	Overall wellbeing	0.040*	0.045*	0.025	0.015	0.006	0.009
	SF physical	–0.034	–0.021	–0.035	–0.038	–0.014	–0.028
	SF mental	0.089*	**0.102***	0.092*	0.051*	–0.003	0.030
48 h	Physical vitality	0.046*	0.040*	0.024	0.024	0.003	0.013
	Emotional vitality	0.003	–0.003	–0.012	–0.007	–0.006	–0.016
	Social connectedness	–0.034	–0.031	–0.042*	–0.027	–0.018	–0.033
	Overall wellbeing	0.036	0.033	0.017	0.015	–0.019	–0.007
	SF physical	0.073*	0.084*	0.070*	0.066*	–0.008	0.040
	SF mental	–0.010	–0.025	–0.037	–0.025	0.010	–0.015

Note: **grey** indicates ϱ>0.10; * indicates *P*<0.05.

Table A5.6. *Wellbeing and health indicators and geomagnetic field among 30–39-year-old subjects*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	–0.079*	–0.072*	–0.084*	–0.064*	0.000	–0.034
	Emotional vitality	–0.054	–0.048	–0.051	–0.034	0.025	–0.001
	Social connectedness	–0.090*	–0.090*	**–0.107***	–0.091*	–0.014	–0.055
	Overall wellbeing	**–0.103***	–0.092*	–0.091*	–0.075*	0.005	–0.039
	SF physical	**–0.114***	**–0.103***	–0.085*	–0.066*	–0.002	–0.038
	SF mental	–0.064*	–0.060	–0.076*	–0.047	0.076*	0.017
12 h	Physical vitality	–0.054	–0.037	–0.009	–0.028	–0.010	–0.026
	Emotional vitality	–0.024	–0.009	0.016	0.029	0.040	0.030
	Social connectedness	–0.005	0.006	0.045	0.017	0.034	0.033
	Overall wellbeing	–0.087*	–0.071*	–0.032	–0.012	0.084*	0.037
	SF physical	–0.019	–0.028	–0.015	–0.005	0.045	0.019
	SF mental	0.024	0.051	0.098*	0.091*	0.053	0.083*
24 h	Physical vitality	**–0.115***	**–0.111***	**–0.114***	–0.098*	–0.026	–0.071*
	Emotional vitality	–0.074*	–0.080*	–0.074*	–0.064*	–0.030	–0.049
	Social connectedness	–0.090*	–0.090*	**–0.107***	**–0.102***	–0.061	–0.092*
	Overall wellbeing	**–0.108***	**–0.100***	–0.088*	–0.078*	–0.036	–0.067*
	SF physical	–0.091*	–0.085*	–0.084*	–0.078*	–0.018	–0.056
	SF mental	–0.088*	**–0.101***	**–0.111***	–0.094*	–0.001	–0.056
36 h	Physical vitality	–0.022	–0.013	0.004	–0.005	0.024	0.021
	Emotional vitality	–0.023	0.000	0.021	0.008	0.038	0.027
	Social connectedness	–0.026	–0.016	0.019	–0.003	0.040	0.027
	Overall wellbeing	–0.097*	–0.085*	–0.046	–0.018	0.090*	0.036
	SF physical	–0.038	–0.036	–0.009	0.015	0.039	0.020
	SF mental	0.018	0.035	0.066*	0.034	0.059	0.072*
48 h	Physical vitality	**–0.113***	–0.087*	–0.093*	–0.067*	–0.018	–0.055
	Emotional vitality	–0.098*	**–0.102***	**–0.110***	**–0.111***	–0.066*	**–0.105***
	Social connectedness	**–0.105***	**–0.113***	**–0.134***	**–0.125***	–0.057	**–0.105***
	Overall wellbeing	**–0.131***	**–0.114***	**–0.117***	**–0.117***	–0.072*	**–0.117***
	SF physical	–0.088*	–0.067*	–0.069*	–0.063*	–0.026	–0.053
	SF mental	**–0.110***	**–0.129***	**–0.151***	**–0.126***	–0.010	–0.080*

Note: **grey** indicates ϱ>0.10; * indicates P<0.05.

Table A5.7. *Wellbeing and health indicators and geomagnetic field in physically active group*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	0.018	0.032	0.017	0.013	0.027	0.033
	Emotional vitality	0.088*	**0.101***	0.085*	0.069*	0.045	0.077*
	Social connectedness	–0.014	–0.021	–0.039	–0.020	0.036	0.017
	Overall wellbeing	0.025	0.043	0.035	0.032	0.027	0.038
	SF physical	0.015	0.037	0.053	0.053	0.021	0.049
	SF mental	0.043	0.027	–0.009	0.012	0.084*	0.064*
12 h	Physical vitality	0.009	0.015	0.041	–0.009	–0.049	–0.038
	Emotional vitality	0.058*	0.074*	**0.103***	0.034	–0.060*	–0.021
	Social connectedness	0.043	0.062*	**0.115***	0.037	–0.024	0.006
	Overall wellbeing	0.028	0.054	0.093*	0.030	–0.021	0.002
	SF physical	–0.018	–0.016	–0.018	–0.030	–0.005	–0.018
	SF mental	**0.121***	**0.145***	**0.180***	0.079*	–0.060*	0.013
24 h	Physical vitality	0.021	0.022	0.013	0.030	0.049	0.044
	Emotional vitality	0.079*	0.085*	0.090*	0.092*	0.055	0.089*
	Social connectedness	–0.013	–0.030	–0.053	–0.020	0.054	0.017
	Overall wellbeing	0.013	0.022	0.020	0.040	0.049	0.041
	SF physical	0.019	0.052	0.058*	0.061*	0.034	0.053
	SF mental	0.016	–0.010	–0.036	–0.012	0.054	0.027
36 h	Physical vitality	0.037	0.036	0.054	0.006	–0.055	–0.033
	Emotional vitality	0.083*	0.084*	**0.110***	0.031	–0.067*	–0.026
	Social connectedness	0.039	0.054	0.096*	0.038	–0.014	0.012
	Overall wellbeing	0.045	0.066*	0.096*	0.059*	–0.008	0.017
	SF physical	–0.051	–0.034	–0.021	0.014	0.041	0.022
	SF mental	**0.117***	**0.127***	**0.151***	0.048	–0.046	0.012
48 h	Physical vitality	0.023	0.027	0.011	0.027	0.019	0.026
	Emotional vitality	0.040	0.044	0.030	0.017	–0.031	–0.010
	Social connectedness	–0.037	–0.053	–0.075*	–0.050	–0.015	–0.044
	Overall wellbeing	0.008	0.006	–0.018	–0.021	–0.042	–0.037
	SF physical	0.011	0.053	0.037	0.035	–0.028	0.000
	SF mental	–0.012	–0.038	–0.067*	–0.051	0.009	–0.023

Note: **grey** indicates ϱ>0.10; * indicates *P*<0.05.

Table A5.8. *Wellbeing and health indicators and geomagnetic field in physically passive group*

Lag	Health indicator	0–3.5 Hz	3.5–7 Hz	7–15 Hz	15–32 Hz	32–66 Hz	0–66 Hz
0 h	Physical vitality	0.020	0.004	–0.007	–0.009	–0.018	–0.009
	Emotional vitality	–0.033	–0.055*	–0.058*	–0.057*	–0.023	–0.044
	Social connectedness	–0.050*	–0.070*	–0.073*	–0.059*	–0.004	–0.035
	Overall wellbeing	0.035	0.008	0.004	–0.001	–0.003	0.005
	SF physical	0.011	0.017	0.023	0.036	0.012	0.023
	SF mental	0.009	–0.030	–0.043	–0.050*	–0.009	–0.023
12 h	Physical vitality	0.045*	0.044*	0.035	0.022	–0.002	0.011
	Emotional vitality	0.025	0.034	0.048*	0.057*	0.040	0.046*
	Social connectedness	0.040	0.036	0.043	0.051*	0.029	0.042
	Overall wellbeing	0.042	0.026	0.004	0.003	–0.001	0.004
	SF physical	0.020	0.019	0.006	–0.013	–0.010	–0.007
	SF mental	0.088*	0.089*	0.095*	0.078*	0.006	0.045*
24 h	Physical vitality	–0.013	–0.023	–0.017	–0.026	–0.020	–0.026
	Emotional vitality	–0.073*	–0.094*	–0.075*	–0.079*	–0.029	–0.067*
	Social connectedness	–0.071*	–0.081*	–0.072*	–0.070*	–0.011	–0.049*
	Overall wellbeing	–0.007	–0.013	–0.005	–0.023	–0.051*	–0.039
	SF physical	0.020	0.031	0.027	0.037	0.006	0.025
	SF mental	–0.046*	–0.064*	–0.056*	–0.075*	–0.057*	–0.077*
36 h	Physical vitality	0.029	0.040	0.039	0.022	–0.006	0.005
	Emotional vitality	0.009	0.025	0.030	0.045*	0.041	0.035
	Social connectedness	0.017	0.036	0.048*	0.044	0.023	0.027
	Overall wellbeing	0.025	0.021	0.008	–0.005	–0.004	–0.006
	SF physical	–0.017	–0.013	–0.017	–0.032	–0.031	–0.033
	SF mental	0.084*	**0.102***	0.096*	0.068*	0.020	0.051*
48 h	Physical vitality	–0.014	–0.016	–0.021	–0.028	–0.023	–0.030
	Emotional vitality	–0.061*	–0.081*	–0.079*	–0.078*	–0.023	–0.065*
	Social connectedness	–0.072*	–0.077*	–0.081*	–0.083*	–0.034	–0.067*
	Overall wellbeing	–0.006	–0.016	–0.015	–0.035	–0.042	–0.047*
	SF physical	0.035	0.039	0.034	0.030	0.002	0.024
	SF mental	–0.060*	–0.083*	–0.078*	–0.075*	–0.007	–0.053*

Note: **grey** indicates ϱ>0.10; * indicates P<0.05.

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