SYMPTOMATIC RESPONSE OF THE ELDERLY WITH CARDIOVASCULAR DISEASE DURING A HEAT WAVE IN SLOVENIA

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SUMMARY

Objective: The aim of this study is to analyse the symptomatic response of elderly people to heat burden and indoor air quality exposure, and to create an index, the basis on which healthcare workers could react and prevent heat-related illnesses when the first symptoms appear.

Methods: The impact of the indoor thermal environment was studied with regards to Humidex and indoor air quality by CO_2 concentrations on elderly people's symptomatic response. It was a natural experiment in which two different groups of elderly people (> 65 years) were observed: the first group had a diagnosed cardiovascular disease, and the second group did not have the disease.

Results: The results show that the expression and aggravation of symptoms are related to an increase of heat burden and low indoor air quality. The symptoms under analysis do not have the same frequency distribution of intensity and, therefore, cannot be interpreted as a single universal symptom index. Instead, two indices must be created separately for both general and specific symptoms.

Conclusions: Healthcare workers should be educated about the interactive influences of the thermal environment and the air quality on health. Unsuitable conditions could be ascertained by the nursing home occupants' symptomatic response.

Key words: heat burden, air quality, cardiovascular disease, symptoms, elderly

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INTRODUCTION

In developed parts of the world, the average life span is increasing, therefore, issues related to population ageing impact many facets of human life (1, 2). Furthermore, the environment is also changing, heat waves have direct and immediate effects on elderly mortality and morbidity (3, 4). In addition, air quality increases the possibility of cardiovascular events. All these facts suggest that the indoor thermal environment and air quality should become priorities in nursing homes.

With ageing, the ability to regulate body temperature tends to decrease. This is a multi-factorial process involving many physiological systems with an impact on the cardiovascular system. Typically, these changes lead to reduced sweating capacity and ability to transport heat from the body core to the skin, and lower cardiovascular stability in the elderly. Heat illnesses may be induced by exposure to environmental heat stress, body dehydration, or salt depletion (5), causing the expression of heat-related symptoms. All these effects will put elderly people at a higher risk of morbidity and mortality (6). Several authors have reported that the elderly in nursing homes, the disabled, and those that live alone have higher risk of dying during a heat wave (7–9). Experiences from the 2003 heat wave reveal excess mortality, especially in nursing homes (10). Therefore, the training and education of healthcare workers and improvements in housing can represent long-term interventions that are necessary to combat heat burden in nursing homes.

Symptomatic Response to Thermal Environment

Heat-related illnesses include minor conditions, such as heat syncope, to the more severe condition known as heat stroke. Heat syncope appears as a short period of unconsciousness that can be detected by patients as symptoms of nausea and fatigue. Heat exhaustion can be the precursor of heatstroke. Heatstroke occurs when thermoregulatory mechanisms are overwhelmed, resulting in abnormally high body temperature and can lead to death (5, 11). Healthcare workers in nursing homes should know the risks related to high indoor temperature exposure, along with early recognition of symptoms and treatment of milder forms of heat-related illness. These measures may contribute to the prevention of heat-related illnesses (5). To assess indoor thermal environments in nursing homes, it may be necessary to monitor the temperature and to interpret the values obtained in terms of the health and comfort of elderly people.

In addition to basic meteorological variables, bio-meteorological indices such as Humidex should be included in the assessment, since it takes into account that the environment has several impacts on elderly people's response (12, 13). Humidex is an indicator of the perceived thermal comfort conditions combining effect of excessive humidity and high temperature (14).

In addition to heat burden, air quality can also cause adverse health effects due to responses to chemical pollutants. Moreover, the combination of heat burden and air quality can have a fatal impact on elderly people with cardiovascular diseases.

Symptomatic Response to Indoor Air Quality

Humans produce carbon dioxide (CO_2) in proportion to their metabolic rate, which is especially increased by heat burden. By quantity, CO_2 is the most important non-specific human bio-effluent. At the concentrations typically occurring indoors, CO_2 is harmless and not perceived by humans (15). In nursing homes, concentrations are typically between 400 and 1,200 ppm (16). The SIST EN 13779:2005 standard states that indoor air quality (IAQ) can be categorised according to CO_2 concentration and that CO_2 is a good indicator for the emission of human bio-effluents SIST EN 13779 (17). This standard defines four classes of indoor air quality (IDA) based on CO_2 concentrations (<400-IDA1; 400-600-IDA2; 600-1000-IDA3; >1000-IDA4 ppm). Epidemiological studies show that excess morbidity and mortality among the elderly is related to their exposure to different air pollutants, such as particles, ozone, nitrogen oxide, sulphurous oxides, etc. (18, 19). Nevertheless, requirements for building ventilation design are based on CO_2 levels, especially when occupants are the only source of pollution. Nursing homes are usually located in environments with good outdoor air quality and green spaces (20, 21). Since elderly people in nursing homes spend more than 90% of their time in indoor environments (22), the impact of indoor air quality should also be included in assessments. A study in Sweden showed a relationship between the concentration of CO_2 and expression of symptoms related to respiratory illnesses (23). Apte et al. (24) found that respiratory disorders and chest pain can be connected to the concentrations of CO_2 above 800 ppm. Fisk et al. (20) also report that lower ventilation rates per person have statistically significant prevalence rates of sick building syndrome.

The aim of this study is to analyse the symptomatic response of elderly people to heat burden and IAQ exposure in the period of heat wave. We also intend to create indices of symptomatic response taking into account both indoor heat exposure and air quality. Based on such indices healthcare workers could react and prevent heat-related illnesses when the first symptoms appear.

MATERIALS AND METHODS

Subjects

The subjects of this study were residents of a nursing home in the urban area of Ljubljana, the capital city of Slovenia. We studied two groups at the same time. In the first group were people with cardio-vascular diseases (CVD), aged over 65 years, and CVD diagnosed in accordance with the International Classification of Diseases (CVD group). This group included 50 persons, both males (46%) and females (54%) with an average age of 84 years and average Body Mass Index (BMI) of 24. The second group comprised 27 elderly people without a significant cardio-vascular diagnosis and was therefore called "no-CVD group", 52% were females and 48% males, with an average age of 83 years and average BMI of 23. None of the subjects was diagnosed for cognitive disorders.

Study Design

The study groups were observed for 80 days in the period from 17th June to 4th September 2011. Daily observation of symptoms expression was obtained between 12 a.m. and 3 p.m., when the microclimatic conditions were the most burdensome. Measurements were taken before 12 o'clock and during the heat burden period (3 p.m.), when temperatures were above 30 °C, to allow assessment of the impact on health in a wider temperature range.

Thermal Environment and Air Quality Measurements

The nursing home has no mechanical ventilation, nor air cooling or conditioning. Heat burden was determined as indoor air temperature (T) and indoor relative humidity (RH) and IAQ as CO_2 concentrations.

Measurement of T and RH were provided via automatic measurements using iButton® devices. The range for T measurement was between −40 °C and +85 °C, and accuracy of 0.1 °C. The range for RH measurement was 0–100%, and accuracy of 1% of RH. Meanwhile, CO_2 concentrations were measured using Almemo® 220-4 devices with a range between 0 ppm and 10,000 ppm, and accuracy of 2%. The devices used in this research were calibrated and were selected due to the practical application in building and the health profession.

On the basis of T and RH, the Humidex index (HI) was calculated; this is a measure of perceived heat from surroundings, which results from the combined effect of excessive humidity and high temperature (14). In this study, the HI classification proposed by Conti et al. (25) was used: (HI 1 <27: negligible heat burden; HI 2 27–30: minor heat burden; HI 3 30–40: major heat burden; HI 4 40–55: dangerous heat burden; HI 5 >55: extremely dangerous heat burden), since it is made for the general population and not for acclimatized workers, as proposed by Masterton and Richardson (14).

Observation of Symptoms

The analysis included the symptoms that are related to CVD and heat-related illnesses and are used in clinical medicine for diagnostic processes. Nine symptoms were monitored: pain behind the breastbone (S1), heart rate dropping (S2), nausea and fatigue (S3), shortness of breath (S4), cold hands and feet (S5), swelling of the ankles (S6), tinnitus (S7), depletion in case of less physical effort (S8), and general malaise (S9). All anamnesis variables were daily evaluated with a five-step scale by respondents, from "no" to "highly expressed" symptom (value 0 for "no symptom – symptom is not present"; 1 for "little – symptoms are present but manageable"; 2 for "medium – symptoms are tolerable"; 3 for "major – symptoms are barely tolerable": 4 for "highly expressed – symptoms are intolerable”). For statistical analysis, R software and Principal Component Analysis (PCA) method was used, which allows analysing the interdependency of variables with the aim of decreasing their number.

Ethics approval was provided by the National Medical Ethic Committee of the Republic of Slovenia, No. 42/03/11.

RESULTS

Environmental risk factors, such as heat burden and air quality, have an impact on health in terms of physiological responses to environmental changes. However, these factors also affect the sensation of the physical environment, which results in the detection of symptoms by the subjects. The analysis of symptoms shows that the relative frequency and magnitude of expressed symptoms is significantly higher in the CVD group in comparison to the no-CVD group (Table 1), although none of the residents included in the research reported pain behind the breastbone (S1). The results also show that the frequency of the symptoms’ expression is similar within the group, which indicates that symptoms are correlated with each other and that one symptom can induce others. The most predominant symptom in the CVD group was general malaise, followed by cold hands and feet and shortness of breath, which corresponds to the clinical status of cardiovascular patients. In the CVD group, all the symptoms are expressed with the highest magnitude of sensation in about 2% of the respondents. Meanwhile in the no-CVD group, none of the respondents reported the sensation of symptoms with the highest frequency.

A more detailed analysis of the frequency and insensitivity of expressed symptoms was performed using principal component analysis. First, we analysed whether age, gender or BMI have impact on the expression of symptoms, but no statistically significant impact has been found ($p > 0.05$).

The principal component analysis of all eight variables expressing symptoms for both groups (CVD and no-CVD) showed that all variables were strongly correlated (the first principal component explains 80.6% of total variation). The analysis revealed that the pattern of expressed symptoms S3 – nausea and fatigue, S8 – depletion in case of less physical effort and S9 – general malaise is different than the pattern of symptoms S2 – heart rate dropping, S4 – shortness of breath, S5 – cold hands and feet, S6 – swelling of ankles, S7 – tinnitus (the second principal component explains 4.7% of total variation, positive coefficients for S3, S8 and S9 and negative coefficients for the others). The results show that all analysed symptoms do not have the same frequency distribution of intensity of their expression. Therefore, they cannot be interpreted as single universal symptom index, but two indices have to be created separately: for symptoms S3, S8, and S9, we name the index “general symptoms and symptoms”; for S2, S4, S5, S6, and S7, we named the index specific symptoms for CVD.

In the next step, two indices based on the intensity of symptoms were created: I_{gs} for the general symptoms (ranging from 0 to 12 index points) and I_{ss} for the specific symptoms related to cardio-vascular disease (ranging from 0 to 20 index points). The resultant scale was assessed for reliability using Cronbach’s alpha (0.965; CI 0.963–0.967). We also calculated Pearson’s correlation coefficient among each symptom and I_{gs}, I_{ss} (S2 – 0.88, S3 – 0.89, S4 – 0.90, S5 – 0.91, S6 – 0.91, S7 – 0.90, S8 – 0.90, S9 – 0.88).

The results show an increase in the I_{gs} index in both CVD and no-CVD groups by increasing the HI and IDA categories (Fig. 1a, c). Similar results can be seen in case of I_{ss}, although the frequency in the no-CVD group is apparently lower (Fig. 1b, d).

Throughout the study period, indoor T was between 22 °C and 33.6 °C. Two heat waves occurred: the first between 7 and 14 July, and the other between 17 and 26 August; the latter was particularly pronounced (Fig. 2). The results show that in both heat waves major heat burden (HI 3) persisted for 25 days and was combined with moderate or low air quality (IDA 3 and IDA 4) for 42 days. The mean indoor T in the first heat wave was 29 °C and mean indoor RH 49% (T_{max} = 30.8 °C, RH_{max} = 63.7%). Meanwhile in the second heat wave T mean was 31 °C and RH 43% (T_{max} = 33.6 °C, RH_{max} = 58.5%).

The heat wave was defined according to (Souch and Grimmond, 2004) as five consecutive days with maximum temperature of 5 °C above the 1961–1990 daily normal maximum.

During both heat waves, there was low indoor air quality because windows were closed to prevent overheating in the rooms; however, this caused increased carbon dioxide concentrations, especially in the second heat wave. The results show that heat-related symptoms are in both groups (CVD and no-CVD) expressed in the period of heat wave, especially in the second

Table 1. *Relative frequency and magnitude of expressed symptoms (S2–S9) among the CVD and no CVD groups*

	CVD					no CVD				
Magnitude of sensation	0	1	2	3	4	0	1	2	3	4
Frequency of sensation	%	%	%	%	%	%	%	%	%	%
S2	63.2	18.1	13.1	3.9	1.5	98.8	1.0	0.1	0.0	0.0
S3	61.8	17.3	12.2	6.6	2.0	92.3	4.2	3.1	0.3	0.0
S4	61.0	19.8	11.8	5.6	1.7	99.1	0.5	0.3	0.0	0.0
S5	61.3	17.5	12.9	6.2	2.0	99.4	0.2	0.2	0.0	0.0
S6	61.4	18.9	11.9	5.7	1.9	99.6	0.2	0.1	0.0	0.0
S7	63.6	18.4	10.4	5.6	1.8	95.4	2.4	1.9	0.0	0.0
S8	64.7	15.1	12.1	5.8	2.0	89.1	6.5	3.7	0.6	0.0
S9	54.9	18.4	16.7	6.8	3.0	81.2	11.6	5.7	1.3	0.0

Heart rate dropping (S2), nausea and fatigue (S3), shortness of breath (S4), cold hands and feet (S5), swelling of the ankles (S6), tinnitus (S7), depletion in case of less physical effort (S8), general well-being (S9); magnitude of expressed symptoms: 0 – no, 1 – little, 2 – medium, 3 – major, 4 – highly

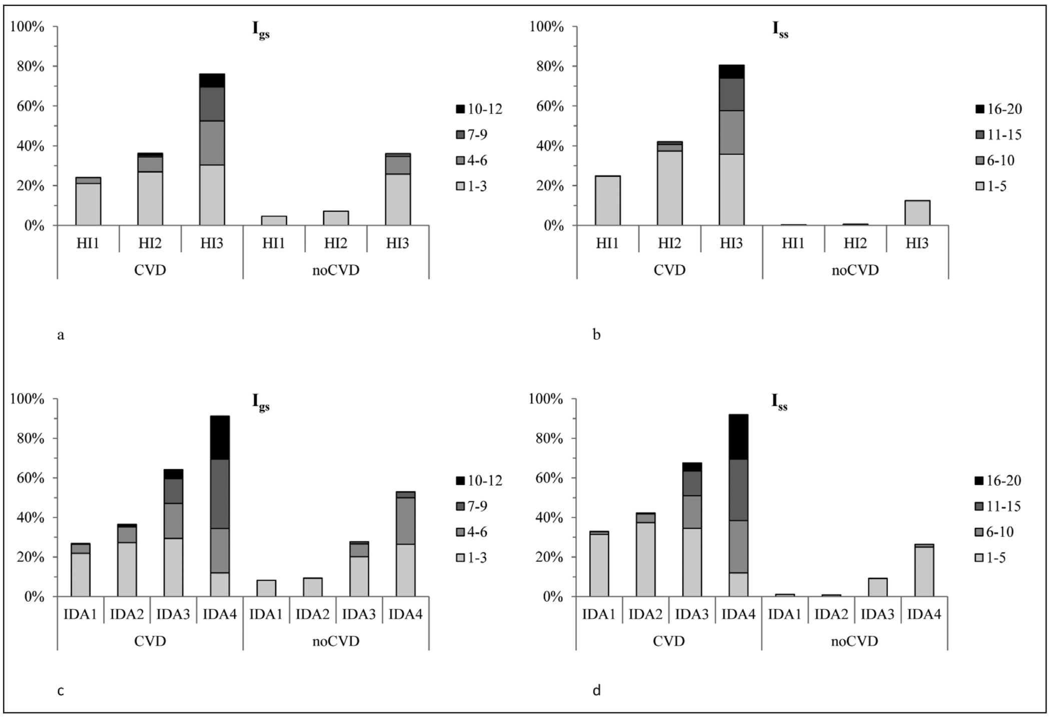

Fig. 1. General relative frequencies of index I_{gs} (general symptoms, top) and I_{ss} (CVD specific symptoms, bottom) according to HI classes and CO_2 (IDA) classes.

one that was more burdensome. According to the symptomatic response, the CVD group responses to the environmental stress are more intense than those of the no-CVD group (Fig. 2). In the CVD group index of specific symptoms (I_{ss}) was more expressed than the index of general symptoms (I_{gs}) and vice versa for the no-CVD group. The results also show that increasing both heat burden and CO_2 concentrations increase the expression of symptoms.

DISCUSSION

Risk groups like the elderly with chronic diseases can be at particularly greater risk, as thermo-regulation is directly dependent on cardiovascular response. The aim of this study is to analyse the symptomatic response to heat burden and low air quality in groups of elderly people with and without CVD.

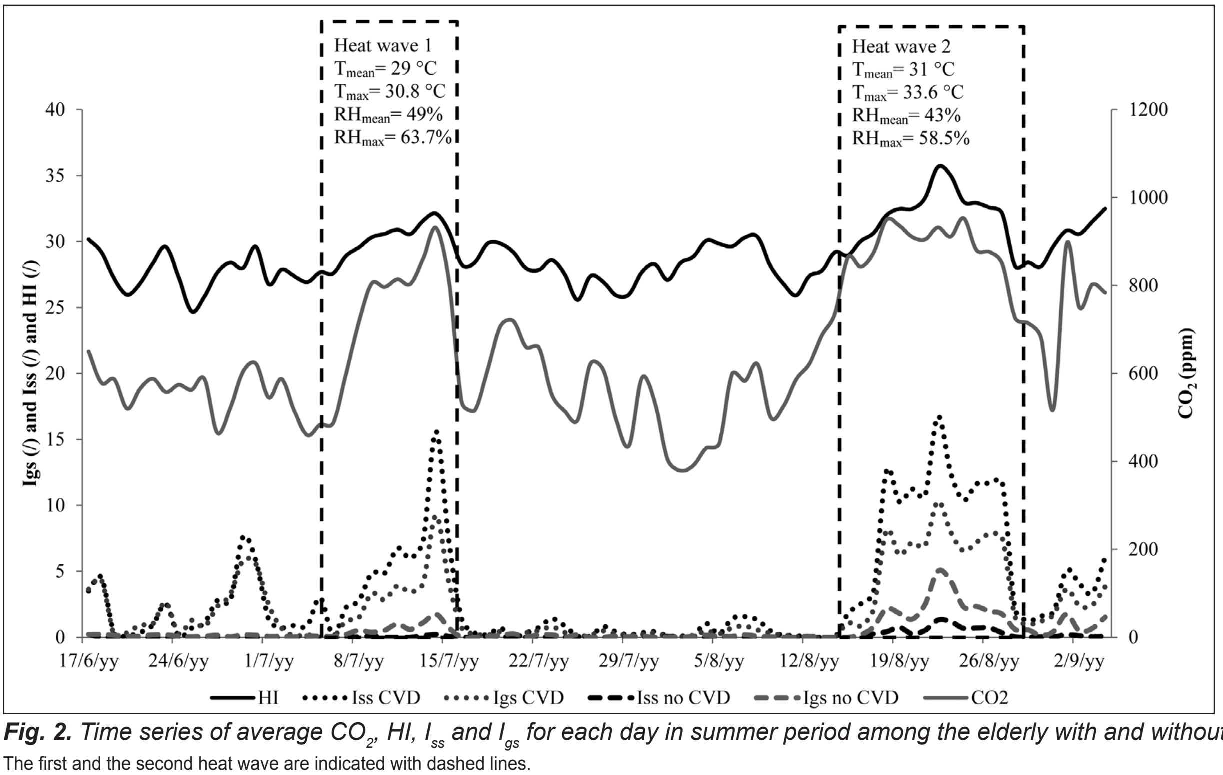

Fig. 2. Time series of average CO_2, HI, I_{ss} and I_{gs} for each day in summer period among the elderly with and without CVD.
The first and the second heat wave are indicated with dashed lines.

We found notable differences in symptoms among the groups: the frequency and magnitude of the expressed symptoms were more pronounced in the CVD group than in the no-CVD group. Similar to our study, Inaba and Mirbod (26) analysed heat stress symptoms among construction and traffic workers, and found significant differences regarding the frequency of ankle swelling. These symptoms were more abundant in the group of traffic workers that have more standing work. Contrary to this study and our study as well, Coris et al. (27) found no swelling ankles among athletes, which indicates that CVD and a lack of mobility have an impact on the frequency of this symptom. Ankle swelling appears when blood from the lower limbs cannot be pumped by the heart due to chronic heart disease or a lack of muscle movement. If the circulatory system is loaded by heat and attempts to dissipate heat by vasodilatation, this action exceeds the capability and results in ankle swelling.

A comparison of the symptomatic response to increased heat burden and low air quality between the CVD and no-CVD groups shows significant differences. Since the groups were similar to each other regarding BMI, age, and gender distribution, we can assume that the CVD group response is related to illness status. We found significant combined effects of heat burden and IAQ on a symptomatic response. In both groups, increases in I_{gs} can be observed due to heat burden and low indoor air quality. For the CVD group, up to 11 index points can be seen; meanwhile, in the no-CVD group, this figure is up to 5. Increases in I_{ss} as an indicator of heart disease can be observed in the CVD group ($I_{ss,max}$ = 17); however, in the no-CVD group these symptoms are less expressed ($I_{ss,max}$ = 2). In particular, HI has significant impact on symptomatic responses, although CO_2 as an indicator of IAQ also has noticeable effects on human response. Based on a comparison of symptoms, we can conclude that both heat burden and indoor air quality have an impact on the symptomatic response of the elderly in nursing homes.

The general symptoms are more dominant (80.59%) and can hide the specific ones (4.72%), which may be one of the reasons that the heat-related illnesses are underdiagnosed. Therefore, two indices were created; for general symptoms (I_{gs}) and symptoms specific to CVD (I_{ss}); this is in contrast to Coris et al. (27), who had a single index for athletes.

We have demonstrated that symptomatic variables are influenced by the heat burden (HI) and non-specific indoor air quality indicator (CO_2). Although CO_2 as an indoor air quality indicator can be used for air exchange requirements, no specific air pollutants can be related to human response. The results show that not only does the CVD group respond to the selected environmental factors more intensively than the no-CVD group, but also that specific symptoms should be monitored. The healthcare workers in nursing homes should be aware of the importance of monitoring responses of the human body and preventing heat-related illnesses before the first symptoms appear. Elderly people with diagnosed cardiovascular disease must stay indoors with air conditioning on days with poor air quality. Air conditioning is the leading protective factor against heat-related illnesses (12). Other suggestions for preventive measures include drinking water or non-alcoholic fluids frequently, electrolyte replacement, wearing lightweight, light-coloured loose-fitting clothing, and reducing strenuous activities during the hottest times of the day (26, 27). General and specific symptoms indices can be used as tools for health care workers to predict symptoms when elderly people are exposed to heat and low air quality. Health care decision makers should recognize that, in addition to thermal environment, indoor air quality must be monitored in elderly nursing homes. To prevent illness, suffering, and death caused by excessive heat, nursing homes should be well ventilated and comfortable, and safe temperature levels should be maintained at all times. Night air to cool down the room is one thermal comfort measure. Furthermore, electric fans can provide relief form heat burden. Windows and shutters should be open during the night and early morning, when temperatures are lower. Windows that receive morning or afternoon sun should be shaded. The results of our research show that comfort measures should provide HI below 29 and the concentration of CO_2 below 600 ppm to prevent general and specific heat-related symptoms.

CONCLUSIONS

Throughout the world, health in the twenty-first century is being shaped by demographic and environmental forces. Extreme climate changes expected in the future will affect the majority of people. At greater risk will be social groups that cannot mitigate the changes. Based on our research, we can conclude that not only heat burden, but also non-specific indoor air quality indicators should be taken into account when assessments are made. The results show that simultaneous exposure of a risk group to major heat burden and low air quality has an interactive effect on symptomatic responses. The frequency distribution of analysed symptoms is not universal in the CVD group and cannot be interpreted as a single index; two indices must be created, separately for general and specific symptoms. Regarding population trends, an increasing proportion of the elderly will live in organized institutions, which will require healthy environments, especially for those at greater health risks.

Adherence to Ethical Recommendations

The protocol for the research project has been approved by the Republic of Slovenia National Medical Ethics Committee No. 42/3/11. The research conforms to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh 2000). All participants gave informed consent for the research and their anonymity was preserved.

Conflict of Interests

None declared

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