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PhD THESIS

**RESEARCH ON THE PULSE WAVE VELOCITY AND
BURNOUT AS EFFECTS OF STRESS AND COPING
MECHANISMS OF HEALTHCARE WORKERS DURING THE
COVID-19 PANDEMIC**

– A B S T R A C T –

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ABSTRACT

Medical personnel provide essential services crucial in saving lives and improving the quality of life globally. Most of them work in an extremely demanding environment, characterized by long hours, complex tasks, and emotionally intense situations. Their work often involves making critical decisions, maintaining constant vigilance, and dealing with the emotional impact associated with patient suffering and death. These factors lead to a high level of occupational stress, which affects healthcare workers' physical and mental health.

The COVID-19 pandemic has significantly amplified the stress factors faced by healthcare workers, placing unprecedented demands on them. The rapid spread of the virus, coupled with high mortality rates, has considerably intensified the level of stress experienced by these professionals. Many have faced the constant fear of contracting the virus or transmitting it to their loved ones while managing overwhelming volumes of patients and dealing with severe resource limitations. This period has highlighted the imperative need to prioritize addressing occupational stress as a critical public health issue [1, 2, 3].

While the COVID-19 pandemic is a global crisis, its impact on healthcare workers varies across different regions and healthcare systems. A comparative examination of Romanian legislation regarding framing burnout as an occupational disease with other European states shows that in Europe, in 2018 only two European states enlisted burnout as an occupational disease (OD) on the OD list, whilst in 14 (38% of the other countries) burnout can be acknowledged as an OD [4]. In Romania, such regulations are still awaited. Meanwhile, studies show that the level of burnout of HW increases in the

pandemic period, for instance in Spain, from 33,6% before March 2020, it reaches 49,3% during the pandemic [5].

This doctoral research aimed to evaluate stress levels and, for the first time, to measure pulse wave velocity (PWV) and the components of burnout syndrome among healthcare workers from various university clinics in Timișoara, and to correlate these with their coping strategies. Another goal of the research was to find a non-invasive method of assessing PWV, a useful tool for evaluating cardiovascular risk.

In the first part of the thesis, called the general section, the fundamental concepts regarding stress, burnout syndrome, coping mechanisms, and PWV (pulse wave velocity) are concisely presented through four chapters. Additionally, this first part provides a summary of the main international advances, as well as national research relevant to the research topic addressed in this doctoral thesis.

Burnout, officially recognized as a professional phenomenon in the 11th revision of the International Classification of Diseases (ICD-11) in 2019, is a direct consequence of chronic workplace stress that has not been effectively managed. It manifests in three main dimensions: emotional exhaustion, depersonalization, and a diminished sense of personal accomplishment [6]. Healthcare professionals affected by burnout may experience a state of exhaustion, detachment from their work, and a reduced perception of their effectiveness in their roles, often accompanied, to varying degrees, by cognitive impairment.

Burnout has significant implications for both healthcare workers and the patients they care for. It can be correlated with a higher incidence of medical errors, decreased patient satisfaction, as well as an increase in absenteeism and turnover among medical staff [7, 8]. Furthermore, burnout can lead to severe mental health issues such as depression and anxiety, exacerbating the challenges these professionals face.

Coping is a complex concept involving a variety of cognitive, emotional, and behavioral strategies that individuals use to manage stress, adversity, and challenging situations. People often resort to different strategies, either consciously or unconsciously, sequentially or simultaneously, to deal with the stressors of daily life.

To reduce the impact of occupational stress and prevent burnout, healthcare workers need to adopt effective coping strategies. These strategies can be classified into

two main categories: individual and organizational approaches. On an individual level, healthcare workers can practice stress management techniques such as mindfulness, physical exercise, and time management. These practices can help reduce stress levels, improve resilience, and promote overall well-being.

Organizational approaches are equally important, involving the creation of a work environment that supports the mental and physical health of healthcare workers. This can include ensuring adequate staffing levels, providing mental health support services, and promoting a culture of open communication and mutual support. Additionally, regular monitoring of health indicators, such as pulse wave velocity (PWV), can facilitate the early identification of workers at risk of cardiovascular diseases, allowing for timely and effective interventions.

The COVID-19 pandemic has exacerbated the issue of burnout, as healthcare workers have been subjected to extreme pressures. High and persistent levels of stress, coupled with insufficient rest and recovery, have created a favorable context for widespread exhaustion in the healthcare sector. This situation has highlighted the need for systemic reforms to address the root causes of burnout and promote the well-being of healthcare workers [9].

Cardiovascular diseases (CVD) are the leading cause of mortality worldwide, and stress is a risk factor for cardiovascular diseases [10], contributing to the development of atherosclerosis, hypertension, and other cardiovascular conditions. Healthcare workers, due to the high levels of occupational stress they endure, are at an increased risk of developing cardiovascular diseases.

One of the key indicators of cardiovascular health is pulse wave velocity (PWV), which reflects arterial stiffness. Higher PWV values are associated with an increased risk of major adverse cardiovascular events, including myocardial infarction and stroke.

Given the high levels of stress that can lead to burnout among medical staff and the complex relationship with cardiovascular diseases, the research conducted for this doctoral thesis aimed to study pulse wave velocity (PWV) and burnout as effects of stress and coping mechanisms among healthcare workers during the COVID-19 pandemic.

In the special section, the original contributions are structured into three research studies. The **first study: „ Pulse wave velocity as a predictor of major adverse**

cardiovascular events and its correlation with general stress levels among healthcare workers during the COVID-19 pandemic”, is presented in Chapter 6 of the thesis.

Our aime was to evaluate the impact of the COVID-19 pandemic on the general stress levels of healthcare workers from two departments of a medical unit that was converted into a COVID-19 support unit. The study was conducted during the third pandemic wave in Romania, both during the period when healthcare workers were caring for a large number of patients with mild cases of COVID-19 and at the end of the pandemic wave when the number of hospitalized patients had significantly decreased. Twenty-six healthcare workers (doctors, nurses, nursing assistants, and cleaning staff) voluntarily participated in the study, based on informed consent. The participants were aged between 26 and 58 years (with an average of 45.61 years +/- 10.20 years).

The assessment of stress levels was conducted using a general stress questionnaire taken from Julian Melgosa's book *A New Lifestyle: Without Stress*, published in Romania by “Viață și Sănătate” Publishing House in 2000. The questionnaire consisted of 96 questions, along with an additional score for various aspects of life. The items were categorized into areas that contribute to stress: symptoms, environment, lifestyle, work, relationships, and personality. Responses were measured on a four-point Likert scale (“never,” “rarely,” “frequently,” and “almost always”), with scores ranging from 0 to 3. The results were interpreted using five stress levels: Level 1 (≤ 48 points, very low), Level 2 (49–72 points, low), Level 3 (73–120 points, normal), Level 4 (121–144 points, high), and Level 5 (≥ 145 points, dangerously high).

During the periods when the stress questionnaires were administered, the PWV values of the subjects were also measured using the Arteriograph Tensiomed device. The main objective was to analyze the potential correlation between general stress levels and PWV values among healthcare workers during these periods.

Based on the analysis of the stress questionnaire scores at the beginning and end of the study, the subjects were classified into two groups: those with normal stress (Level 3) and those with high stress (Level 4). The stress questionnaire results at the beginning of the study showed that 73.07% of healthcare workers experienced normal stress levels, while 26.93% had high-stress levels during periods of high patient load with COVID-19.

At the end of the study, during the period with fewer COVID-19 patients, 84.61% of healthcare workers had normal stress levels (Level 3), while 15.39% maintained a high-stress level (Level 4).

Additionally, the average pulse wave velocity (PWV) of healthcare workers was higher during the period with a large number of COVID-19 patients (9.12 m/s) than during the period with fewer patients (8.64 m/s). Given that the primary variable affecting the lives of healthcare workers during the study was related to their working conditions, the observed decrease in the average PWV values is attributed to the reduction in workplace stress.

The correlation analysis, expressed by Pearson's correlation coefficients (r), indicated a weak to moderate correlation between PWV values and stress scores both at the beginning ($r = 0.348$) and at the end of the study ($r = 0.403$) [11].

The personal contributions to this study were:

- we evaluated the stress levels of healthcare staff during the COVID-19 pandemic and correlated them with PWV values;

- we demonstrated that caring for COVID-19 patients increased the stress levels of healthcare workers, with implications for increased PWV values;

- we found that there is a weak to moderate correlation between stress levels and PWV among healthcare staff.

The **second study: „Analyzing burnout, coping mechanisms and pulse wave velocity among healthcare workers and possible connection with the workplace”**, is presented in the special part in Chapter 7.

We aimed to investigate, for the first time, the influence of the workplace on burnout levels, coping strategies, and pulse wave velocity among healthcare workers, as well as the potential correlations between burnout, coping, and PWV values [12].

The study was conducted at the end of the third wave of the COVID-19 pandemic, in university clinics in the western country (Cardiology, Intensive Care Unit, Oncology, and Occupational Medicine). It included 154 participants (specialist doctors, nurses, nursing assistants, and resident doctors) aged between 25 and 64 years, of whom 83.76% were women. The statistical analysis considered the division of subjects into five study groups: Cardiology, ICU, Oncology, Occupational Medicine, and Resident Doctors.

To assess burnout levels, we used the Burnout Assessment Tool (BAT-23), recently developed by Schaufeli et al, which contains 23 items. This questionnaire includes questions related to the four subscales of burnout syndrome: "exhaustion," "mental distancing," "cognitive impairment," and "emotional impairment," evaluated on a 5-point Likert scale, ranging from 1 (never) to 5 (always). For the analysis of results, we used the cutoff values established for the European population, which define three possible situations: "no burnout," "prone to burnout," and "burnout," for each subscale.

Thus, on the "exhaustion" subscale, a score below 3.06 signifies the absence of burnout syndrome, a score between 3.06 and 3.30 indicates a predisposition to burnout, and a score of 3.31 or higher indicates the presence of burnout. On the "mental distancing" subscale, according to the limits established by Schaufeli and colleagues, a score below 2.10 means that there is no burnout syndrome, a score between 2.10 and 3.29 indicates a predisposition to burnout, and a score of 3.30 or higher indicates the presence of burnout. The "cognitive impairment" subscale is classified as follows: a score below 2.70 means there is no burnout syndrome, a score between 2.70 and 3.09 indicates a predisposition to burnout, and a score of 3.10 or higher indicates the presence of burnout. The "emotional impairment" subscale classifies scores as follows: below 2.30 signifies the absence of burnout syndrome, between 2.30 and 3.09 indicates a predisposition to burnout, and 3.10 or higher indicates the presence of burnout.

To assess coping methods, we used the COPE questionnaire (Carver Coping Orientation to Problems Experienced), and for measuring PWV values, we used a Tensiomed arteriograph, with participants following expert recommendations for these measurements.

The study results regarding the "exhaustion" subscale indicate a susceptibility to burnout across all groups, except for cardiology healthcare workers, who are predisposed to burnout in terms of "exhaustion."

On the "mental distancing" subscale, also known as "depersonalization," all studied groups demonstrated a predisposition to burnout.

The results related to the "cognitive impairment" subscale show that most groups are not affected by burnout, except for the occupational medicine group, which is

predisposed to burnout on this subscale. This group has the highest average age and the longest average work tenure, suggesting that age may contribute to the increased levels of burnout observed on the "cognitive impairment" subscale. Therefore, implementing measures such as reducing long shifts or night shifts could be particularly beneficial for older healthcare workers.

On the "emotional impairment" subscale, the results show that all groups are predisposed to burnout.

To identify a potential effect of the workplace or department (oncology, cardiology, intensive care unit, occupational medicine, and resident group) on the BAT subscales (exhaustion, mental distancing, cognitive impairment, and emotional impairment), a multivariate analysis of variance (MANOVA) was conducted. Here, the independent variable was the department, and the dependent variables were the BAT subscales.

Our results showed that the department does not have a significant effect on "exhaustion" ($p = 0.72$) or "emotional impairment" ($p = 0.76$). However, the department has a significant effect on "mental distancing" ($p = 0.03$) with a medium effect size ($F = 2.71$) and on "cognitive impairment" ($p = 0.002$) with a medium effect size ($F = 4.36$). These effects of the department/workplace on "mental distancing" and "cognitive impairment" are attributed to the occupational medicine group. The observed effects on the "mental distancing" and "cognitive impairment" subscales are likely related to the age and work tenure of the subjects in the occupational medicine group, which are the highest among all study groups (specifically, the average age is 50.30 ± 6.51 years, and the average work tenure is 27.39 ± 9.14 years).

Another objective of the research was to identify a possible effect of the work department (oncology, cardiology, intensive care unit, occupational health, and resident group) on the scales of the COPE questionnaire. Thus, a multivariate analysis of variance (MANOVA) was conducted, in which the independent variable was the work department, and the dependent variables were the COPE scales. The analysis showed that the work department has a significant effect ($p = 0.03$) on "positive reinterpretation and growth," with a medium effect size ($F = 2.77$). Notably, the resident group had the highest score and significantly differed from the other groups on this scale. The department also has a significant effect on "emotional discharge" ($p = 0.02$), with a medium effect size ($F = 2.88$).

On this scale, the cardiology group had the lowest score and significantly differed from the other groups. We also found a significant effect on "behavioral disengagement" ($p = 0.004$), with a medium effect size ($F = 4.08$). On this scale, the resident group had the lowest score, while the occupational medicine group had the highest score. On the other COPE scales, the department does not have a statistically significant effect ($p > 0.05$).

Despite the varying susceptibility to burnout across different groups, common coping strategies frequently used by healthcare personnel include "positive reinterpretation and growth," "planning," and "active coping." Less frequently used coping mechanisms are "denial," "mental disengagement," and "substance/alcohol abuse," which do not appear to be influenced by the specific nature of the workplace.

The pulse wave velocity (PWV) values of healthcare workers in all our study groups (including the resident doctor's group) exceed the European average for corresponding age cohorts [13]. This suggests that elevated PWV values may be associated with the medical profession itself, rather than specific departments or units within the healthcare sector.

A multivariate analysis of variance (MANOVA), in which the independent variable was the workplace department and the dependent variable was PWV, showed that the workplace department has a significant effect ($p < 0.001$), but with a small effect size ($F = 11.36$). The highest PWV values were recorded in the cardiology and occupational medicine groups.

An analysis by age decades across the groups shows that the relative variation of PWV is higher than the European normal average of PWV (according to "The Reference Values for Arterial Stiffness' Collaboration"), with the highest percentage observed in the cardiology and intensive care groups (34%).

The correlation analysis conducted in the study indicated a weak to moderate correlation between pulse wave velocity and certain components (subscales) of the burnout assessment tool (BAT-23). PWV shows a stronger correlation with age ($p < 0.001$, $r = 0.552$) and body mass index ($p < 0.001$, $r = 0.362$).

Personal contributions in the second study were:

- for the first time, we applied a new burnout assessment tool, the 23-item Burnout Assessment Tool (BAT-23), to healthcare workers at the end of the COVID-19 pandemic.

Notably, most previous burnout studies have used the Maslach Burnout Inventory – Human Service Survey (MBI-HSS);

- we investigated for the first time in Romania the impact of the workplace (specific departments and units) on the burnout subscales among healthcare personnel;

- we identified the coping strategies used by healthcare workers;

- we measured pulse wave velocity (PWV) in healthcare workers and explored potential correlations with the work environment and components of the burnout assessment tool BAT-23;

- our findings indicate that the elevated PWV values observed among healthcare personnel are more closely associated with the medical profession itself than with specific workplaces (departments), noting that the average PWV values of the healthcare workers in the study were higher than the European average for each age decade;

- we demonstrated that PWV values correlate more strongly with age and body mass index (BMI) than with burnout, suggesting that arterial stiffness is primarily influenced by age and lifestyle factors, in line with other international findings.

In the **third study** named: „**A method to evaluate pulse wave velocity using a heart rate step function response**”, is presented in Chapter 8,

The goal of this study was to identify a non-invasive method for assessing arterial stiffness, specifically PWV, which is useful in medical consultations where specialized devices like arteriographs are not available.

The objectives of this study were: a) To identify potential correlations between pulse wave velocity measured with an arteriograph and certain parameters that can be obtained from the heart rate response following sudden moderate physical exertion or after the abrupt cessation of such exertion; b) To facilitate the development of a preliminary PWV evaluation method that could be available in any primary care setting, thereby aiding in the early detection of predisposition to cardiovascular diseases.

We selected a study group of 36 young, healthy subjects, consisting of 27 resident doctors and 9 medical students doing their summer internship in a university hospital. Among the subjects, 12 (33.3%) were men, and 24 (66.7%) were women, with an average age of 26.27 years \pm 3.23 years. The study involved two sequential types of measurements for each participant: (a) measurements with an arteriograph, in a supine

position (systolic blood pressure, diastolic blood pressure, heart rate, and PWV), and (b) measurements using a treadmill exercise testing system, in an upright position (systolic blood pressure, diastolic blood pressure, heart rate, and PWV). The parameters used in the study were: resting heart rate (HR-Rest), PWV, heart rate in an upright position before physical exertion, with the subject on the treadmill (HR-Pre), heart rate (HR-4min) measured after standardized exertion (walking for 4 minutes at a speed of 2.7 km/h), and heart rate 6 minutes after the physical exertion ceased (HR-6min), measured in a supine position.

The time dependence of heart rate after the cessation of physical exertion, referred to as the step response function to physical exertion, was fitted with a decreasing exponential function $y(t) = y_0 + A \cdot \exp(-t/\tau)$, where the parameters y_0 , A , and τ were determined from the fit (y_0 represents the resting heart rate after physical exertion; A is the difference between the heart rate at the beginning of the recovery period after physical exertion and the resting heart rate after relaxation; and τ is called the relaxation time and represents the time after which the deviation of $y(t)$ from the steady-state value, y_0 , decreases by $e = 2.71$ times).

The conclusions of this study allow us to delineate several thresholds that, if exceeded, may be associated with elevated pulse wave velocity (PWV) values:

- after moderate physical exercise and a rest period of at least 6 minutes, the heart rate at 6 minutes (FC-6min) remains above 80 beats per minute.
- the relaxation time (τ) following moderate physical exercise exceeds 1 minute.
- the heart rate measured after transitioning from a supine to a standing position exceeds 100 beats per minute.
- the resting heart rate is above 80 beats per minute.

This study demonstrates that using standardized physical exercise (as a stimulus) and recording the time-dependent heart rate (as a response to physical exercise) can be used for the preliminary assessment of PWV in the absence of dedicated medical devices (arteriograph, sphygmograph).

For the preliminary evaluation of PWV, the following formulas can be used [14]:

$$\text{PWV} = 3.353 + 0.057 \times \text{resting heart rate in supine position}$$

$PWV = 2.932 + 0.052 \times \text{heart rate (pre-exercise)}$ after transitioning from supine to standing position

$PWV = 3.774 + 0.049 \times \text{heart rate measured at 6 minutes after standardized physical exercise in supine position}$

The **primary personal contribution** in the third study is the demonstration that the heart rate response function after sudden physical exertion can be used for the preliminary evaluation of pulse wave velocity. Additionally, based on heart rate measurements, we established threshold values for some of the evaluated parameters, whose exceeding is correlated with increased PWV values, and we found equations that allow the determination of PWV from the measured heart rate values, as seen above.

The thesis concludes with a chapter on conclusions and personal contributions, references, and appendices.

Considering that our findings show the tendency towards burnout and the increase with a significant percentage of PWV (34%), compared to normal values in some medical workers, we emphasize the preventive importance of regular periodic medical check-ups performed by the occupational health physician, psychologist, and psychiatrist of medical units; they can identify early signs of burnout and stress, as well as cardiovascular impairment before they become severe.

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