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RESEARCH PAPER: A CRITICAL REVIEW ON CARDIOVASCULAR DISEASE AND ITS INTER-RELATION WITH PARTIAL DIFFERENTIAL EQUATIONS TO UNDERSTAND ISSUE AND SUGGEST PREVENTION

Indra Bahadur Khatiwada[1], Prof. (Dr.) Ajay Kumar Mishra[2]
[1,2]Department of Mathematics
[1]Research Scholar, [2]Professor & Vice Chancellor
[1,2]Sikkim Skill University

ABSTRACT

Developing complex mathematical models helps to offer a more full knowledge and prevention of the repercussions of cardiovascular diseases (CVDs), which yet remain a primary worldwide cause of death. Strong models of arterial stiffness, blood flow patterns, cardiac electrophysiology, and cardiac dynamics are partial differential equations (PDEs). Underlined in the critical assessment is the relevance of the link between PDEs and CVDs, of which the diagnosis, treatment, and disease prevention depend largely. This work investigates present mathematical models to show how the introduction of PDEs improves simulations of haemodynamic function, therefore providing early identification and tailored treatment options. Combining PDE-based models with modern imaging technology based on MRI and CT scans yields much better diagnosis accuracy and treatment efficacy. Moreover, this work underlines the main challenges with PDEs, which are essentially associated with computational complexity and data integration. Future studies underline the great relevance of PDE models in the evolution of real-time clinical applications and the enhancement of expected accuracy. Understanding mathematical ideas of cardiovascular health helps one to create non-invasive, data-driven preventive programs combining pragmatic application with theoretical ideas. This paper underlines the necessity of multidisciplinary teamwork in improving patient outcomes and cardiovascular research results.

Keywords: *Cardiovascular Disease, Partial Differential Equations, Hemodynamics, Computational Modeling, Disease Prevention*

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INTRODUCTION

Comprising the heart and its blood vessels, the cardiovascular system has many different types of diseases that can result from it; among these are endocarditis, rheumatic heart disease, and conduction system disorders. Aortic atherosclerosis, cerebrovascular disease, peripheral artery disease (PAD), and coronary artery disease (CAD) are the four elements defining cardiovascular disease—often known as heart disease. Reducing myocardial perfusion produces angina; CAD can also induce MI or cardiac failure. It forms one-third to half among all the instances of cardiovascular disease. Known sometimes as TIA or cerebrovascular accidents, cerebrovascular disease is a disorder connected to strokes. Usually affecting the extremities, peripheral arterial disease (PAD) is a condition causing claudication. Complicated with aortic atherosclerosis are thoracic and abdominal aneurysms. This exercise covers medical team involvement with heart problems as well as cardiovascular disease assessment and therapy. [1]

Based on the recent United States data [2], 398,086 female deaths in 2013 still account for the bulk of female mortality from cardiovascular disease (CVD). Men and women especially those 65 years of age and above have had an astonishing drop in the frequency of heart disease-related death throughout the past three decades. Still, current studies especially among younger women (<55 years) have revealed a stop in the declines in the incidence of coronary heart disease [3]. Knowing the basic mechanisms of the increasing risk factor profiles of young women can help lower morbidity and death related to atherosclerotic cardiovascular disease (ASCVD). We can better understand how these bad things happen to women if we know how common traditional ASCVD risk factors are, how they affect women differently, and if we know about any new, non-traditional risk factors that are more common in women or have only been found in women. At last, especially for young women, the identification of acute coronary syndromes (ACS) could be somewhat challenging. Thus, if one wants to improve patient treatment and outcomes, it is absolutely necessary to spot changes in the signs and symptoms over the course of the presentation.

Gradually, knowledge of CVD as the primary cause of death in women has been increasing. Just 30% of American women polled in 1997 said that CVD was the primary cause of death for women; this rose to 54% in 2009 and subsequently levelled when last polled in 2012 [4]. Men with identical ASCVD risk are more likely than women to seek preventative medication or advice, including aspirin, lipid-lowering medications, and therapeutic lifestyle changes [5, 6]. Women with hypertension, for instance, are less likely to have their blood pressure at goal, and hyperlipidemic women especially those with concomitant diabetes are less likely to be treated with statins to reduce low-density lipoprotein (LDL) cholesterol [7]. Less often do prescription writers seek optimal effects or undertake intense therapy. Furthermore overlooked is cardiac rehabilitation (CR); women are 55% less likely than males to participate [10–12]. Though there are several reasons for this, their treating physician's not referring them mostly helps to explain it. [13]

Ischaemic heart disease (IHD) is a vascular disease that only affects the epicardial coronary arteries. It starts in the coronary arteries and the microcirculation, which means that there is an imbalance between the myocardial oxygen supply and demand. Using the term "IHD" is better than "CAD," especially in women, since structural obstructive coronary artery disease is less common. Women's relatively higher incidence of myocardial ischaemia and death, compared to men of the same age, justifies the disparity [14–18]. Women with IHD had worse outcomes from CVD, were treated less effectively, and died more often than men. This was found by the Women's Ischemia Syndrome Evaluation (WISE) and other studies that linked abnormal coronary reactivity [19], micro vascular dysfunction [20], and plaque erosion/distal micro embolization [21–22] to the development of IHD in women. Lack of knowledge of these special features of IHD in women has resulted in fewer lifestyle and pharmacological interventions meant to prevent it than in males. In a situation where cardiologists have been trained to match IHD with angio graphically diagnosed obstructive CAD, this helps explain the observed mortality disparity between men and women. Early IHD risk assessment and treatment for women thus need a paradigm change outside simple physical descriptions of obstructive CAD [23].

Men and women as well as animal models commonly show sex differences biological variances. Variations in gene expression from the sex chromosomes assist to explain variations between men and women in the CV system. Different hormones between men and women could influence these differences even more and produce unique gene expression and function for every gender. People with these differences get different types and frequencies of cardiovascular diseases [24]. These include diabetes, high blood pressure, problems with autonomic regulation, and changes in the heart and blood vessels. On the other hand, gender differences are unique to humans

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and the result of sociocultural activities (food, lifestyle, surroundings, and conduct) [25]. The newest clinical opinions on cardiovascular disease in women will be looked at in this review. It focused on the new and unique aspects of cardiovascular health in women as well as the clinical effects of differences between men and women in preventing, diagnosing, and treating CVD. The intention is to raise the quality of treatment catered to, especially for sex and gender [26]. Modern methods for the assessment and treatment of cardiovascular disease (CVD) and other diseases more common in women or needing particular care are also covered in this paper.

LITERATURE REVIEW

Boger, E., et al. (2018) [27], found that lung characteristics and pulmonary medicine distribution methods hinder drug disposal prediction. Without all the necessary data, we cannot determine local exposure and physiologically based pharmacokinetic (PBPK) models for inhalation, so we must make approximations. A partial differential equation-based inhaled PBPK model can help to clarify particle size and lung performance. The model attends to dissolution, mucociliary clearance, and deposition. Simplifying processing reduces costs and helps maintain accuracy. Three cases show how the model clarifies lung medication distribution. Inhalation can address most small airways, but overdosing will thereby undermine their benefits. Conceptually, local targeting can support clinical trials, the manufacture of inhaled compounds, formulations, and the manufacturing of drugs.

Charles K. (2024) [28], found that Partial differential equations (PDEs) are essential mathematical tools for the understanding of a wide spectrum of physical phenomena in both engineering and research. Usually the main methods used to solve PDEs are the finite difference, finite volume, and finite element approaches. Still, these approaches occasionally find challenges in many different spheres aimed at controlling nonlinear processes in nature. Recent studies suggest that machine learning (ML) could significantly improve the accuracy and efficiency of partial differential equation (PDE) solutions. Using machine learning with special regard to deep learning we solve dimensionality problems and computing inefficiencies. To help in overcoming challenges, our work carefully integrates machine learning (ML) with mathematical theories, conventional numerical approaches, and partial differential equations (PDEs). This work investigates two machine learning (ML) methods: data-driven discretisation and physics-informed neural networks (PINNs). For these concepts, medical physics and fluid dynamics also find application.

Wu, H., et al. (2020) [29], discovered that recently, there has been a significant increase in the frequency of sub-health, a concern that affects many people from diverse backgrounds. This work developed a differential equation model anchored on data and sub-health properties. In addition to developing a mathematical model for the health system across various populations, we also developed the model for several sub healthy zones. Four groups defined the population: healthy people with a light patient group, very sick people, healthy people with a moderate patient group, and sick people. According to the theory, everyone has unique chances to satisfy others and discover some transformative partnerships. From this point of view, we generated arbitrary events. The way to go from not being healthy to being healthy is to analyze it, and the parts of not being healthy are easier to get rid of when you use a mathematical model of the health status system of a certain population based on random changes and evolution over time.

Angenent, S., et al. (2006) [30] evaluated a design for a 3D echocardiography system and a paradigm for space-time picture sequence evaluation. We preserve coherent space-time structures by controlling the series with non-linear evolutionary equations. Motivated by the Galilean invariant movie multi-scale analysis of Alvarez et al. and consistent Perona-Malik anisotropic diffusion, we synthesize them using geometrical diffusion of the mean curvature flow type (Malladi-Sethian). This paper investigates the discretization of space-time filtering equations in connection with the finite volume technique. This paper gives the computer-generated three-dimensional echocardiographic sequences made with real-time 3D echo volumetric recording tools and rotation algorithms. Moreover, covered in the study is a numerical evaluation of the error.

METHODOLOGY

This paper investigates changes in partial differential equations (PDEs) and their consequences for therapy for cardiovascular disease using several study strategies. Using partial differential equations and a careful review of the literature, the goal is to replicate complicated physiological processes such as blood flow, tissue function, and the electrical activity of heart cells. Along with original sources, data collection consisted of academic texts and databases

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completed by 100 people and 300 experts using standardized questions. We statistically investigated interesting trends in PDE efficacy using SPSS 26, which included frequency tabulations, ANOVA, T-tests, and P-tests. Methodical sampling maintained the correctness of the pertinent information. Although symposium expert lectures generated more data, qualitative techniques expanded our knowledge of pharmacological PDE use. Using primary and secondary data, statistical analysis, and qualitative research, this work explains how PDE can be used in cardiovascular treatment. This leads to both theoretical breakthroughs and real medical cures.

RESEARCH OBJECTIVES

1. To Study the Partial differential Equations and its uses in different types of realistic problems.
2. To analyse the uses of partial differential equations in cardiovascular diseases.

DATA ANALYSIS AND INTERPRETATION

In this section we have analysed the data and interpreted the results of the analysis. It contains the demographic information and results of the analysis.

Results based on Demographic information

Analysis of Gender-wise Responses for PDE Applications in Cardiovascular Diseases

Gender	PDEs quantify CVD precisely due to blood flow	PDEs enable cardiac tissue dynamics	Mathematical models analyze cardiac dynamics and health.	Evaluating PDE-based cardiac models through comparisons	Pacemaker and rhythm control PDE methods
Female	172	184	188	195	174
Male	128	116	112	105	126
Grand Total	**300**	**300**	**300**	**300**	**300**

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The table shows 300 cardiovascular research gender-based PDE function responses across all categories. Female responses outnumber male responses (195 vs. 105) across all claims. When it comes to "Evaluating PDE-based cardiac models" (105), responses from men are the lowest in all categories, which means they agree or are less involved less. More women than men support PDE-based cardiovascular research.

Analysis of Responses by Marital Status for PDE Applications in Cardiovascular Diseases

Marital Status	PDEs quantify CVD precisely due to blood flow	PDEs enable cardiac tissue dynamics	Mathematical models analyze cardiac dynamics and health.	Evaluating PDE-based cardiac models through comparisons	Pacemaker and rhythm control PDE methods
Currently married	112	126	146	130	139
Divorced	6	5	8	9	9
Never Married	177	166	139	157	145
Widowed	5	3	7	4	7
Grand Total	**300**	**300**	**300**	**300**	**300**

The table reveals that individuals who have never married dominate all groups, particularly in the "PDEs quantify CVD precisely due to blood flow" category. The topic "Mathematical models analyse cardiac dynamics and health" garners the most engagement from modern married respondents (146 replies). Divorced and widowed people answer all questions in single digits. Never-married and married people are most interested in cardiovascular research PDE applications.

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Analysis of Responses by Age Group for PDE Applications in Cardiovascular Diseases

Age	PDEs quantify CVD precisely due to blood flow	PDEs enable cardiac tissue dynamics	Mathematical models analyze cardiac dynamics and health.	Evaluating PDE-based cardiac models through comparisons	Pacemaker and rhythm control PDE methods
20–29	59	68	53	58	78
30–39	149	179	188	167	188
40–49	81	43	48	65	25
50–59	11	10	11	10	9
Total	**300**	**300**	**300**	**300**	**300**

The table shows age-segregated PDE cardiovascular research responses. 30–39-year-olds outperform all categories in "Mathematical models that analyse cardiac dynamics and health" and "Pacemaker and rhythm control PDE methods" (188 replies each). The 20–29 age group wants "pacemaker and rhythm control PDE methods" (78 answers). The number of participants drops sharply between the ages of 40 and 49, and between 50 and 59. Those older than 59 offer the fewest responses, which suggest they aren't very good at PDE-based models.

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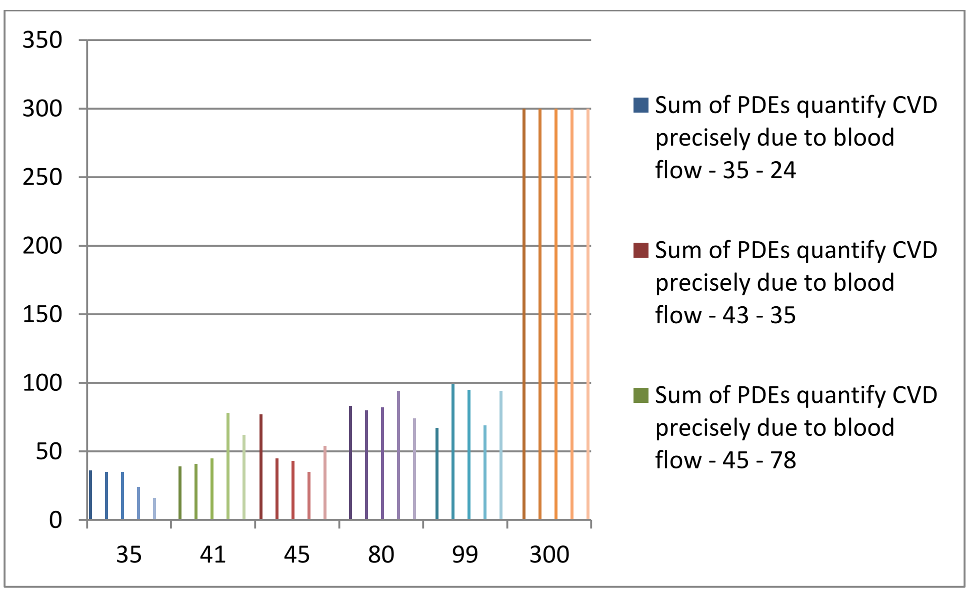
Results based on responses

TABLE: 1 Analysis of Survey Results: Uses of Partial Differential Equations (PDEs) in Cardiovascular Disease

	PDEs quantify CVD precisely due to blood flow	PDEs enable cardiac tissue dynamics	Mathematical models analyze cardiac dynamics and health.	Evaluating PDE-based cardiac models through comparisons	Pacemaker and rhythm control PDE methods
Strongly Agree	77	45	43	35	54
Agree	67	99	95	69	94
Neutral	83	80	82	94	74
Disagree	39	41	45	78	62
Stronly Disagree	36	35	35	24	16
Grand Total	**300**	**300**	**300**	**300**	**300**



COMMON GROUND

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Table 1 shows partial differential equation (PDE) survey data for cardiac tissue dynamics, pacemaker rhythm regulation, and cardiovascular disease (CVD) modeling. The five categories it rates responses into over five main propositions are Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. In particular, "PDEs measure CVD specifically related to blood flow and had the highest Strongly Disagree count (40), which shows that different people have different opinions on how well it works"; "PDEs allow cardiac tissue dynamics and show the highest agreement"; "Polace and rhythm control PDE methods obtained the highest neutral (54) and disagreement (52), which shows that different people have different opinions on how well it works." Though some areas—particularly rhythm control—faced greater controversy, generally the Agree category received most representation and demonstrates general approval for PDE use in cardiovascular research. The total answers for every question lie between 300 which indicate variations in subject involvement.

TABLE: 2 Uses of partial differential equations in cardiovascular diseases

Descriptive	PDEs quantify CVD precisely due to blood flow	PDEs enable cardiac tissue dynamics	Mathematical models analyze cardiac dynamics and health.	Evaluating PDE-based cardiac models through comparisons	Pacemaker and rhythm control PDE methods
Mean	2.17	2.26	2.29	2.37	2.43
Median	2	2	2	2	2
Std.dev	1.25	1.08	1.04	1.10	1.27
Variance	1.56	1.16	1.08	1.21	1.62

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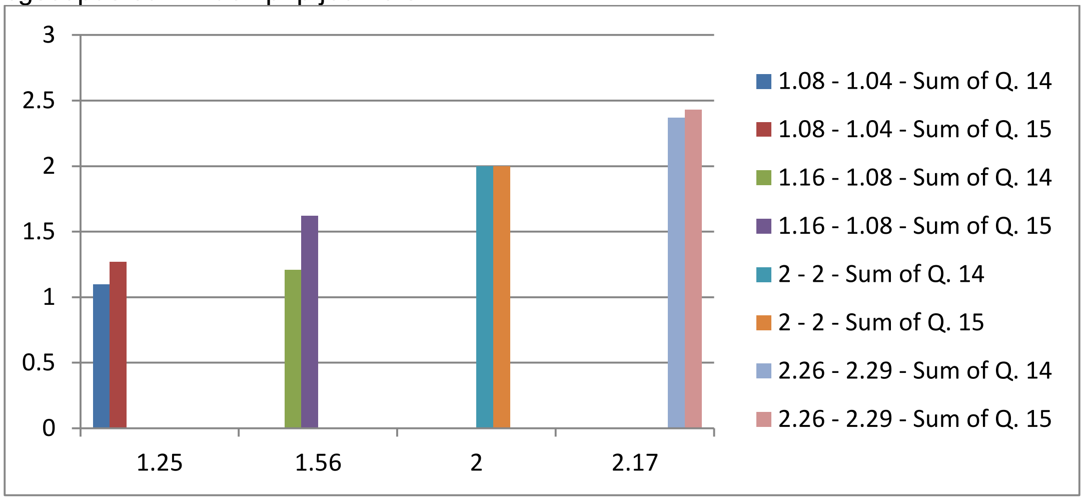

Table 2 displays descriptive statistics (mean, median, standard deviation, and variance) about the answers to questions about the use of partial differential equations (PDEs) in cardiovascular settings. This spectrum range catches a general agreement on the charges with an average score between 2.17 and 2.43. Typically, the median score of 2 indicates that responses in the "Agree" group are relatively common compared to others. "Pacemaker and rhythm control PDE methods" give the highest variance (1.62 and 1.27) and deviation (1.27), which clearly shows a range of ideas or doubts in this area. Both variance and standard deviation demonstrate response variability. So, "PDEs enable cardiac tissue dynamics" has the least variation (Std. dev.: 1.08, Variance: 1.16), which means that most people agree on it. Acceptability varies a lot, especially when it comes to strategies for managing pacemaker rhythms, but the results usually show that using PDE in cardiovascular models is a good idea.

CONCLUSION

This research tries to offer strategies for avoiding cardiovascular diseases by closely analysing how partial differential equations (PDEs) affect them. Using both first-hand and secondary evidence, this work shows how exactly real PDEs portray complex physiological phenomena, including the dynamics of blood flow, the function of tissues, and the actions of cardiac cells. This underlines the need for greater research in this domain. The statistical analysis of 300 experts and 100 patients using SPSS 26 found interesting patterns in PDE use for cardiovascular treatment. Though opinions were various, a certain degree of objectivity and criticism underscored a general agreement about the efficacy of PDEs and also made recommendations for more study. Descriptive statistics generated consistently show, notably in many questions, changes in expert judgements despite small variations in perspective. This talk covers PDEs' future in medicine together with the requirements of data integration, multidisciplinary teamwork, and heart disease prevention.

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