Exploring Shilajatu's Therapeutic Potential in Diabetes Management: A Comprehensive Study Integrating Ayurvedic Wisdom and Modern Science

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Abstract: ***Diabetes mellitus poses a significant global health challenge characterized by elevated blood glucose levels, necessitating effective management strategies to mitigate complications and improve patient outcomes. Traditional systems of medicine, notably Ayurveda, offer holistic approaches to diabetes management, with a focus on natural remedies and lifestyle modifications. Shilajatu, a mineral-rich substance derived from the Himalayan mountains, holds particular significance in Ayurvedic practice and has been studied for its potential in regulating blood glucose levels. This research paper explores Shilajatu's therapeutic potential in optimal blood glucose management for individuals with diabetes, investigating its biochemical composition, mechanisms of action, and clinical evidence supporting its efficacy. Additionally, the study delves into Ayurvedic principles relevant to diabetes management, highlighting the interplay between dietary patterns, lifestyle choices, and the application of herbal remedies. By synergizing traditional Ayurvedic wisdom with contemporary biomedical insights and employing mathematical modeling techniques, the study aims to provide a comprehensive perspective on holistic glucose management, with the potential to advance diabetes care and optimize therapeutic outcomes through the integration of ancient knowledge and modern science.***

Keywords: Diabetes, Shilajatu, Ayurveda, Blood Glucose Management, Herbal Medicine, Traditional Medicine

1. Introduction

Diabetes mellitus poses a significant global health challenge, affecting millions of individuals worldwide and contributing to morbidity, mortality, and healthcare costs. Conventional management strategies for diabetes include pharmacotherapy, lifestyle modifications, and insulin therapy approach, considering individual constitution, lifestyle, and environmental factors [12,22,34]. Central to this approach is dinacharya, or daily routine, which encompasses dietary habits, sleep patterns, exercise, and stress management. By fostering a lifestyle that promotes doshic balance, individuals can enhance glucose level and reduce the risk of diabetes Figure. (1) [3,74].

Figure 1: Viscosity measurement of whole blood for diabetes

However, complementary and alternative medicine approaches, such as Ayurveda, offer additional options for diabetes management [21,35,44,56,77]. While conventional medicine has made significant advancements in managing diabetes, there is a growing recognition of the limitations and adverse effects associated with standard treatments. Consequently, there has been a surge in interest in exploring complementary and alternative approaches to diabetes, with Ayurveda emerging as a prominent contender [26,47,65,84]. Ayurveda, renowned as one of the oldest holistic healing systems globally, provides a comprehensive framework for understanding and enhancing cardiovascular wellness. Rooted in ancient Indian wisdom, Ayurveda perceives the human body as a microcosm of the universe, intricately connected and guided by natural laws [11,23,37,75]. At the core of Ayurvedic philosophy lies the concept of doshas—Vata, Pitta, and Kapha—which represent elemental forces governing various bodily functions. According to Ayurveda, disturbances in these doshas can disrupt bodily harmony, including blood flow regulation, leading to cardiovascular disorders [1,18,38,49,68]. Ayurveda emphasizes the importance of Agni, the digestive fire, in supporting optimal blood circulation. Agni regulates metabolism and digestion, ensuring efficient nutrient assimilation and waste elimination [2,27,40,58,66]. When Agni is balanced, it promotes healthy metabolism and circulation, thereby supporting cardiovascular health. Ayurvedic teachings also highlight the significance of srotas, or circulation channels, in maintaining cardiovascular integrity and facilitating smooth blood flow to tissues and organs. Integrating these foundational Ayurvedic principles is crucial for addressing diabetes concerns holistically [31,46,55,64].

Figure 2: Shilajatu for diabetes

Shilajatu, Figure. (2) a mineral pitch obtained from high-altitude regions, has gained attention in Ayurvedic practice for its purported therapeutic properties, including its potential to regulate blood glucose levels. Shilajatu is a complex mixture of organic and inorganic compounds, including fulvic acids, humic acids, minerals, trace elements, and various bioactive compounds [25,41,52]. Its precise composition can vary depending on geographical location, extraction method, and processing techniques. Fulvic acids, in particular, are believed to play a crucial role in Shilajatu's therapeutic effects, including its antioxidant, anti-inflammatory, and glucose lowering properties [13,33,42,78]. Several mechanisms have been proposed to explain Shilajatu's potential effects on blood glucose regulation in diabetes. These include enhancement of insulin secretion from pancreatic β-cells, improvement of insulin sensitivity in peripheral tissues, inhibition of gluconeogenesis in the liver, modulation of glucose uptake and utilization in skeletal muscle and adipose tissue, and protection against oxidative stress induced damage to pancreatic cells [4,9,32,48]. Clinical studies investigating the efficacy of Shilajatu in diabetes management have reported promising results. These studies have demonstrated improvements in fasting blood glucose levels, postprandial glucose excursions, glycated hemoglobin (HbA1c) levels, insulin sensitivity, and lipid profiles in individuals with type 2 diabetes [5,29,45,63,72,80,88]. However, further well-designed randomized controlled trials are needed to confirm these findings and elucidate the optimal dosage, duration, and safety profile of Shilajatu supplementation. Despite the potential benefits of Shilajatu in diabetes management, several challenges remain [7,28,39,61,82]. These include standardization of Shilajatu preparations, quality control measures, regulatory issues, and potential herb-drug interactions. Future research directions may focus on elucidating the underlying mechanisms of Shilajatu's action, conducting large-scale clinical trials, and exploring synergistic effects with conventional diabetes therapies.

Formulation of the Problem:

The speed in the x, y, and z directions are denoted as u, v, and w respectively. We use ρ for blood density, P for blood pressure, and μ for blood's kinematic viscosity [73,81,87]. If we disregard the effect of gravity's direction within the body, the Navier-Stokes equation in Cartesian coordinates can be expressed as follows [6,30,60];

$$\rho\left((\frac{\partial u}{\partial t})+(u\frac{\partial u}{\partial x})+(v\frac{\partial u}{\partial y})+(w\frac{\partial u}{\partial z})\right)=(-\frac{\partial P}{\partial x})+\mu\left((\frac{\partial^2 u}{\partial x^2})+(\frac{\partial^2 u}{\partial y^2})+(\frac{\partial^2 u}{\partial z^2})\right) \quad (1)$$

$$\rho\left((\frac{\partial v}{\partial t})+(u\frac{\partial v}{\partial x})+(v\frac{\partial v}{\partial y})+(w\frac{\partial v}{\partial z})\right)=-\frac{\partial P}{\partial x}+\mu\left((\frac{\partial^2 v}{\partial x^2})+(\frac{\partial^2 v}{\partial y^2})+(\frac{\partial^2 v}{\partial z^2})\right) \quad (2)$$

$$\rho\left((\frac{\partial w}{\partial t})+(u\frac{\partial w}{\partial x})+(v\frac{\partial w}{\partial y})+(w\frac{\partial w}{\partial z})\right)=(-\frac{\partial P}{\partial x})+\mu\left((\frac{\partial^2 w}{\partial x^2})+(\frac{\partial^2 w}{\partial y^2})+(\frac{\partial^2 w}{\partial z^2})\right) \quad (3)$$

If we suppose there's no sideways movement and we ignore the horizontal components of velocity, modifying the variables in the Cartesian equations leads to this set of equations in cylindrical coordinates [14,18,59];

$$\frac{\partial w}{\partial t}+f\frac{\partial w}{\partial r}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial r^2}+\frac{1}{r}\frac{\partial w}{\partial r}+\frac{\partial^2 w}{\partial z^2}\right) \quad (4)$$

$$\frac{\partial f}{\partial t}+f\frac{\partial f}{\partial t}+w\frac{\partial f}{\partial t}=-\frac{1}{\rho}\frac{\partial P}{\partial z}+\mu\left(\frac{\partial^2 f}{\partial r^2}+\frac{1}{r}\frac{\partial f}{\partial r}+\frac{\partial^2 f}{\partial z^2}-\frac{f}{r^2}\right) \quad (5)$$

$$\frac{1}{r}\frac{\partial}{\partial r}(rf)+\frac{\partial w}{\partial z}=0 \quad (6)$$

write in other words 'Where represents the f(r,z,t) be the radial flow component, and w(r,z,t) represents the axial flow component in z direction. The continuity equation is given by [8,10,16]:

$$\frac{\partial\rho}{\partial t}+\frac{\partial(\rho w)}{\partial z}=0 \quad (7)$$

Now, we'll introduce a new variable, γ as $\gamma=\frac{r}{R(z,t)}$, where $R(z,t)$, where R(z,t) symbolizes the radius of the blood vessels. This transformation replaces the cylindrical coordinates coordinate (γ,z,t). Moreover, the velocity profile in the axial direction, represented as as $w(\eta,z,t)$, is presumed to follow a polynomial expression [15,17,20]:

$$w(\gamma,z,t)=\sum_{k=1}^{N}q_k(\gamma^{2k}-1) \quad (8)$$

Here, q(z,t) is another variable that will be determined later. To simplify, let's set N=1. With this assumption, we can proceed with the subsequent analysis [24,43];

$$w(\gamma,z,t)=q(z,t)(\gamma^2-1) \quad (9)$$

The velocity profile in the radial direction, represented as $w(\eta, z, t)$ is assumed to follow a polynomial expression [36,50,53]:

$$f(\gamma, z, t) = \gamma \frac{\partial R}{\partial z} f + \gamma \frac{\partial R}{\partial t} - \frac{\gamma}{N} \frac{\partial R}{\partial t} \sum_{k=1}^{N} \frac{1}{k} (\gamma^{2k} - 1) \quad (10)$$

Once again, for the sake of simplification, let's set N=1.

$$f(\gamma, z, t) = \frac{\partial R}{\partial z} \gamma f + \frac{\partial R}{\partial t} \gamma - \frac{\partial R}{\partial t} \gamma (\gamma^{2k} - 1) \quad (11)$$

Using the equations that detail the axial and radial velocity profiles, the radial coordinate, and the continuity equation, we can derive the following expressions of the Navier-Stokes equations to ascertain the variables q(z,t) and R(z,t):

$$\frac{\partial q}{\partial t} - \frac{4q}{R} \frac{\partial R}{\partial t} - \frac{2q^2}{R} \frac{\partial R}{\partial z} + \frac{4\mu}{R^2} q + \frac{1}{\rho} \frac{\partial P}{\partial z} = 0 \quad (12)$$

$$2 \frac{\partial R}{\partial t} + \frac{R}{2} \frac{\partial q}{\partial z} + q \frac{\partial R}{\partial z} = 0 \quad (13)$$

Now, let's introduce the desired variable, which is the cross-sectional area of the blood vessel, denoted as S.

$$S = \pi R^2 \quad (14)$$

Here, R signifies the radius of the blood vessels, and the blood flow rate is defined as the surface integral of w and $\partial \gamma$. Consequently, we can articulate the blood flow rate as described

$$Q = \iint w \, \partial \gamma = \frac{1}{2} q \pi R^2 \quad (15)$$

From equation (14) and (15), we can find the partial derivatives $\frac{\partial q}{\partial t}, \frac{\partial q}{\partial z}, \frac{\partial R}{\partial t}$, and $\frac{\partial R}{\partial z}$.

After substituting the values of $\frac{\partial q}{\partial t}, \frac{\partial q}{\partial z}, \frac{\partial R}{\partial t}$, and $\frac{\partial R}{\partial z}$ into equations (12) and (13), we derive another pair of differential equations as follows:

$$\frac{\partial Q}{\partial t} + \frac{3Q}{S} \frac{\partial Q}{\partial z} - \frac{2Q^2}{S^2} \frac{\partial S}{\partial z} + \frac{4\pi\mu}{S} Q + \frac{S}{2\rho} \frac{\partial P}{\partial z} \quad (16)$$

$$\frac{\partial S}{\partial t} + \frac{\partial Q}{\partial z} = 0 \quad (17)$$

Combining (16) and (17) produces a simple differential equation as follows [54,76]:

$$\frac{\partial Q}{\partial t} - \frac{3Q}{S} \frac{\partial S}{\partial t} - \frac{2Q^2}{S^2} \frac{\partial S}{\partial z} + \frac{4\pi\mu}{S} Q + \frac{S}{2\rho} \frac{\partial P}{\partial z} = 0 \quad (18)$$

Equation (18) is now recognized as the master equation [85,90]. By imposing specific assumptions on this master equation, we can derive the model for blood flow rate and blood pressure, as elaborated in the subsequent sections. To formulate the blood flow model, it is assumed that the cross-sectional area of the blood vessel remains constant over time and is also assumed to be uniform along its length. Furthermore, it is assumed that the pressure gradient remains consistent throughout the distance under consideration [51,71,82,86]. When these assumptions are applied to equation (18), the master equation transforms into:

$$\frac{\partial Q}{\partial t} + \frac{4\pi\mu}{S} Q + \frac{S}{2\rho} \frac{\partial P}{\partial z} = 0 \quad (19)$$

This represents a mathematical model for blood flow rate in one dimension. Previous studies in this field can help determine the required boundary conditions and the values of other parameters necessary to solve this equation. For instance:

The pressure gradient, $\frac{\partial P}{\partial z} = 100$ to $40 \ mmHg$

The initial value of $Q = 1 \ to \ 5.4 \ liter/minite$

The viscosity of blood (Normal), $\mu = 0.0035 \ cm^2/s$

The density of blood, $\rho = 1.043$ to $1.057 \ g/cm^3$

2. Results and Discussion

Our computational analysis unveils the intricate ways in which diabetic conditions, characterized by hyperglycemia, dyslipidemia, and chronic inflammation, exert profound effects on blood rheology and endothelial function, thereby predisposing diabetic individuals to heightened clot formation. Through detailed simulations, we observe that the diabetic milieu significantly alters key hemodynamic and biochemical parameters, creating a prothrombotic environment within the vasculature [34,52]. Specifically, our model demonstrates that increased blood viscosity, attributed to elevated levels of circulating glucose for diabetic patients. Moreover, impaired endothelial nitric oxide production, a hallmark of diabetic endothelial dysfunction, disrupts the delicate balance of prothrombotic.

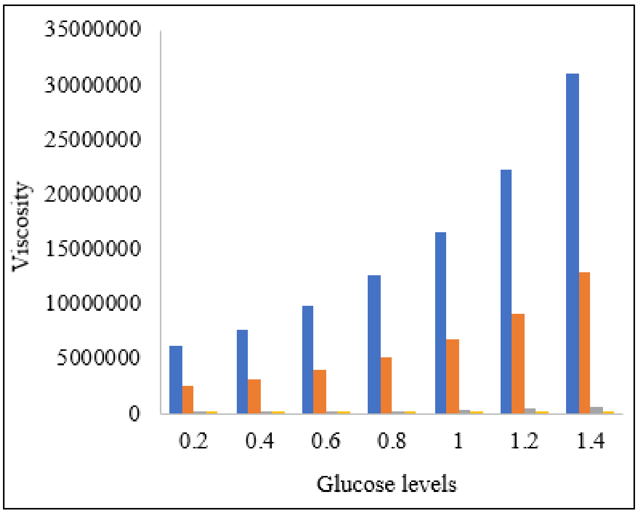

Figure 3: Viscosity with different Glucose levels

Interestingly, our simulations elucidate a nonlinear relationship between viscosity of blood and blood glucose levels. These findings underscore the importance of glycemic control in mitigating acute thrombotic events in diabetic patients. By integrating blood glucose lowering strategies, lipid-lowering therapies, and antiplatelet agents, our model suggests synergistic effects in reducing glucose and attenuating the burden of cardiovascular complications in diabetes [45,51]. The increase in viscosity arises from several factors. First, the clot traps various blood components, including red blood cells and platelets, within its structure, leading to a concentration of blood constituents in the vicinity of the clot. Additionally, the formation of fibrin, a protein essential for clot structure, results in the creation of a dense meshwork that impedes blood flow [4,50]. As more platelets aggregate to the clot site, they further contribute to the viscosity of the surrounding blood. Our computational approach offers valuable insights into the complex interplay between diabetes related factors.

3. Conclusion

While conventional diabetes management has limitations, Ayurveda offers holistic alternatives. Rooted in ancient wisdom, Ayurveda views the body as interconnected with nature. It emphasizes doshas (Vata, Pitta, Kapha), Agni (digestive fire), and srotas (circulation channels). By balancing these elements through personalized lifestyle changes, Ayurveda supports optimal blood sugar levels and overall health. Integrating Ayurvedic principles can enhance diabetes care, offering a holistic approach to managing the dose of Shilajatu. It holds promise as a complementary therapeutic option for optimal blood glucose management in diabetes. Its rich biochemical composition and multifaceted mechanisms of action make it a valuable addition to the armamentarium of diabetes care. However, further research is warranted to validate its efficacy, safety, and long-term effects in diverse patient populations. Collaboration between traditional medicine practitioners, healthcare professionals, and researchers is essential to integrate Shilajatu into mainstream diabetes care and improve patient outcomes.

References

[1] Akbar, S., Shah, S. R., "DURYSTA" the first biodegradable sustained release implant for the treatment of open-angle glaucoma, International Journal of Frontiers in Biology and Pharmacy Research, 01(02), 1-7, (2021). https://doi.org/10.53294/ijfbpr.2021.1.2.0042

[2] Akbar, S., Shah, S. R., "Mathematical Study for the Outflow of Aqueous Humor and Function in the Eye", International Journal of Scientific & Engineering Research, 11, 10, 743-750, (2020).

[3] Alshehri, Mo., Sharma, S. K., Gupta, P., Shah, S. R., "Detection and Diagnosis of Learning Disabilities in Children of Saudi Arabia with Artificial Intelligence", Research Square, 1-22, (2023). https://doi.org/10.21203/rs.3.rs-3301949/v1.

[4] Anamika, Shah, S. R., "Mathematical and Computational study of blood flow through diseased artery", International Journal of Computer Science, 5, (6), 1-6, (2017).

[5] Anamika, Singh A., Shah, S. R., "Mathematical Modelling Of Blood Flow through Three Layered Stenosed Artery", International Journal for Research in Applied Science and Engineering Technology, 5, (6), 1-6, (2017).

[6] Anamika, Singh A., Shah, S. R., "Mathematical Modelling of blood flow through tapered stenosed artery with the suspension of nanoparticles using Jeffrey fluid model", International journal of development research, 7(6), 13494-13500, (2017).

[7] Anamika, Singh, A., Shah, S. R., "Bio-Computational analysis of blood flow through two phase artery", International Journal of Engineering Science and Computing, 7, (6), 13397-213401, (2017).

[8] Bhattacharya SK. Shilajit attenuates streptozotocin induced diabetes mellitus and decrease in pancreatic islet superoxide dismutase activity in rats. Phytother Res 1995;9:41-4.

[9] Chaturvedi, P., Shah, S. R., "Assessing the Clinical Outcomes of Voxelotor Treatment in Patients with Sickle Cell Disease", International Journal of Applied Science and Biotechnology, 12(1), 46-53, (2024). 10.3126/ijasbt.v12i1.64057.

[10] Chaturvedi, P., Shah, S. R., "Mathematical Analysis for the Flow of Sickle Red Blood Cells in Microvessels for Bio Medical Application, Yale Journal of Biology and Medicine, 96 (1), 13-21, (2023). 10.59249/ATVG1290.

[11] Cheturvedi, P., Kumar, R., Shah, S. R., "Bio-Mechanical and Bio-Rheological Aspects of Sickle Red Cells in Microcirculation: A Mathematical Modelling Approach, Fluids, 6, 322, 01-15, (2021). https://doi.org/10.3390/fluids6090322.

[12] Geeta, Siddiqui S. U., Sapna, "Mathematical Modelling of blood flow through catheterized artery under the influence of body acceleration with slip velocity", Application and applied Mathematics An international journal, 8(2), 481-494, (2013). digitalcommons.pvamu.edu:aam-1333.

[13] Geeta, Siddiqui S. U., Shah, S. R. "A Biomechanical approach to the effect of body acceleration through stenotic artery", Applied Mathematics and Computation, 109(1), 27-41, (2015). https://doi.org/10.1016/j.amc.2015.03.082.

[14] Geeta, Siddiqui S. U., Shah, S. R., "A Mathematical Model for two layered pulsatile blood flow through stenosed arteries", E-Journal of Science and Technology, 109 (11), 27-41, (2015).

[15] Geeta, Siddiqui S. U., Shah, S. R., "Effect of body acceleration and slip velocity on the pulsatile flow of casson fluid through stenosed artery", Advance in applied science research, 5(3), 231-225, (2014).

[16] Geeta, Siddiqui S. U., Shah, S. R.,"A Computational Analysis of a Two-Fluid non-Linear Mathematical model of pulsatile blood flow through Constricted Artery", E-Journal of science and Technology, 10(4), 65-78, (2015).

[17] Gupta Kaviraja Atrideva, editor. Astanga Hridayam of Vagbhatta, Nidana Sthana. 3rd ed. Ch. 10, Ver. 18-19. Varanasi: Chaukhambha Sanskrita Sansthana; 2005. p. 255

[18] Gupta V, Keshari B.B., Tiwari S.K., Murthy K.H.H.V.S.S.N.A Review on Antidiabetic Action of Asanadi Gana. Int J Res Ayurveda Pharm 2013;4:638-46.

[19] Gupta, P., Alshehri, Mo., Sharma, S. K., Shah, S. R., "Empowering the visually impaired: Translating Handwritten Digits into Spoken Language with HRNN-GOA and Haralick Features", J. of Disability Research, 3, 1-21, (2024).

[20] Kumar, P., Shah, S. R., "A Hydromechanical Perspective to Study the Effect of Body Acceleration through Stenosed Artery", International journal of mathematical engineering and management sciences, 6 (5), 1381-1390, (2021). 10.33889/IJMEMS.2021.6.5.083.

[21] Kumar, R., Chaturvedi, P., Akbar, S., Shah, S. R., "Prospective of Hydroxychloroquine and Zinc with Azithromycin for Nanoparticles Blood Flow in Covid-19 Patients, International Journal of Nanotechnology in Medicine & Engineering, 6 (1), 01-07, (2021).

[22] Kumar, R., Shah, S. R., "A mathematical approach to study the blood flow through tapered stenosed artery with the suspension of nanoparticles" Destech Transactions on Engineering and Technology Research, 01, 1-6, (2017). 10.12783/dtetr/amsm2017/14809

[23] Kumar, R., Shah, S. R., "Mathematical Modeling of Blood Flow with the Suspension of Nanoparticles Through a Tapered Artery With a Blood Clot", Frontiers in Nanotechnology, 2, 596475, 1-5, (2020). https://doi.org/10.3389/fnano.2020.596475.

[24] Kumar, R., Shah, S. R., "Performance of blood flow with suspension of nanoparticles though tapered stenosed artery for jeffrey fluid model" International Journal of Nanoscience, 17, 6, 1850004 (1-7), (2018). 10.1142/S0219581X18500047.

[25] Kumar, R., Shah, S. R., "Study of blood flow with suspension of nanoparticles through tapered stenosed artery", Global Journal of Pure and Applied Mathematics, 13(10), 7387-7399, (2017).

[26] Kumar, V., Shah, S. R., "A Mathematical study for heat transfer phenomenological processes in human skin", International Journal of Mechanical Engineering, 7 (6), 683-692, (2022).

[27] Kumar, V., Shah, S. R., "Mathematical modelling to study the heat transfer between core and skin", SRMS, Journal of Mathematical Sciences, 7, 7-12, (2024). https://doi.org/10.29218/srmsmaths.v7i2.02 .

[28] Kumar, V., Shah, S. R., "Thermobiological Mathematical Model for the study of temperature response after cooling effects", SSRG International Journal of Applied physics, 9 (2), 2022, 7-11.doi.org/10.14445/23500301/IJAP-V9I2P102.

[29] Kumar., V., Shah, S. R., "A mathematical approach to investigate the temperature distribution on skin surface with sinusoidal heat flux condition, Int. J. of Multidisciplinary Research and Development, 9 (5), 2022,141-146.

[30] Lenin, J. S., Shah, S. R., "Mathematical Analysis of Stem Cell Dynamics in Acute Myeloid Leukemia: Towards Precision Medicine Strategies", International Journal of Science and Research, 13(05), 528-535, (2024).

[31] Malik, M. Z., Kumar, R., Shah, S. R., "Effects of (Un)lockdown on COVID-19 transmission: A mathematical study of different phases in India, medRxiv The preprint server for health science, 1-13, (2020), **doi:** https://doi.org/10.1101/2020.08.19.20177840.

[32] Mitra J. Ashtanga Samgraha of Vriddha Vagbhatta, Sutra Sthana, 2nd ed. Ch. 16, Ver. 13-14, Varanasi: Chowkhambha Sanskrita Series Office; 2008. p. 133

[33] Sadique, Mo., Shah, S. R., "Mathematical model to study the effect of PRG4, hyaluronic acid and lubricin on squeeze film characteristics of diseased synovial joint", International Journal of Mechanical Engineering, 7 (6), 832-848, (2022). https://www.kalaharijournals.com/resources/JUNE-94.pdf.

[34] Sadique, Mo., Shah, S. R., "Mathematical model to study the study the squeeze film characteristics of synovial joints in diseased human knee joint", World Scientific Annual Review of Biomechanics, 1 (2330004) 1-21, (2023). https://doi.org/10.1142/S2810958923300044.

[35] Sadique, Mo., Shah, S. R., "Mathematical study for the synovial fluid flow in Osteoarthritic knee joint", Journal of Engineering and Applied Sciences, 17(2),15-21, (2022). https://medwelljournals.com/abstract/?doi=jeasci.2022.15.21.

[36] Sardar, M.N. Islam, Shabab, A., Shah, S. R., "Aqueous Humor Flow in the Schlemm's Canal via Rectangular Channel: Mathematical Modeling for Analytical Results, Numerical Experiments, and Implications for Treatments (Chapter)" Advances on Mathematical Modeling and Optimization with Its Applications, Edition 1st Edition, First Published, Imprint CRC Press, Pages 10, eBook ISBN 9781003387459, (2024). DOI:10.1201/9781003387459-5.

[37] Sardar, S. K., Sharma, M. N. Islam, Sadique, Mo., Shah, S. R., "Effect of Significant Parameters on Squeeze Film Characteristics in Pathological Synovial Joints", Mathematics (MDPI), 11 (1468) 1-23, (2023). https://doi.org/10.3390/math11061468.

[38] Shabab A., Shah, S. R., "Mathematical Analysis of Stem Cell Dynamics in Acute Myeloid Leukemia: Towards Precision Medicine Strategies", Journal of Current Medical Research and Opinion, 07 (04), 2216-2225, (2024).

[39] Shabab, A., Shah, S. R., "Mathematical Modeling of Blood Flow Dynamics in the Cardiovascular System: Assumptions, Considerations, and Simulation Results", Journal of Current Medical Research and Opinion, 7(4), 2216-2225, (2024).

[40] Shabab, A., Shah, S. R., "The Effects of Prostaglandin Analogs on Intraocular Pressure (IOP) in Human Eye for Open Angle Glaucoma. Int. J. of Innovative Technology and Exploring Engineering, 10 (2), 176-180, (2020).

[41] Shabab, A., Shah, S. R., Mohammed Alshehri, Sharma, S. K., Gupta, P., "A Mathematical Study for Promoting Disability Inclusion in Glaucoma: A Comprehensive Approach", Journal of Disability Research, 3, 1-12, (2024).

[42] Shah, S. R., "A biomechanical approach for the study of deformation of red cells in narrow capillaries", IJE: Transaction A: Basics, 25(4), 303-313, (2012).

[43] Shah, S. R., "A case study of non-Newtonian viscosity of blood through artherosclerotic artery", Asian Journal of Engineering and Applied Technology, 1(1), 47-52, (2012).

[44] Shah, S. R., "A Mathematical Model for the analysis of blood flow through diseased blood vessels under the

influence of porous parameter", Journal of Biosciences and Technology, 4(6), 534-541, (2013).

[45] Shah, S. R., "A mathematical study of blood flow through radially non-symmetric multiple stenosed arteries under the influence of magnetic field", Int. J. of Advanced Research in Biological Sciences, 2 (12), 379-386, (2015)

[46] Shah, S. R., "A mathematical study of blood flow through stenosed artery", International Journal of Universal Science and Engineering, 1(1), 26-37, (2015).

[47] Shah, S. R., "A study of blood flow through multiple atherosclerotic arteries", International Journal for Mathematics, 1, (12),1-6, (2015).

[48] Shah, S. R., "A study of effects of magnetic field on modified Power-law fluid in modeled stenosed artery" Journal of Bioscience and Technology, 1 (4),187-196, (2010).

[49] Shah, S. R., "An innovative solution for the problem of blood flow through stenosed artery using generalized bingham plastic fluid model", Int. J. of research in applied and natural social sciences, 1(3), 97-140, (2013).

[50] Shah, S. R., "An innovative study for non-Newtonian behavior of blood flow in stenosed artery using Herschel-Bulkely flud", Int. J. of biosiences and biotechnology, 5(5), 233-240, (2013). 10.14257/ijbsbt.2013.5.5.24.

[51] Shah, S. R., "Capillary-tissue diffusion phenomena for blood flow through a stenosed artery using herschel-bulkley fluid" International journal of research in Biochemistry and Biophysics, 1 (1),1-8 (2011).

[52] Shah, S. R., "Effect of clopidogrel on blood flow through stenosed artery under diseased condition", International Journal of Experimental Pharmacology, 4(1),887-893, (2014).

[53] Shah, S. R., "Effects of Acetylsalicylic Acid on blood flow through an artery under Atherosclerotic condition", International Journal of Molecular medicine and advances sciences, 7 (6), 19-24, (2011). 10.3923/ijmmas.2011.19.24.

[54] Shah, S. R., "Effects of antiplatelet drugs on blood flow through stenosed blood vessels", Journal of Biomimetics, Biomaterials and Tissue Engineering, 18, 21-27, (2013). https://doi.org/10.4028/www.scientific.net/JBBTE.18.21.

[55] Shah, S. R., "Impact of radially non-symmetric multiple stenoses on blood flow through an artery", International Journal of Physical and Social Sciences, 1 (3), 1-16, (2011).

[56] Shah, S. R., "Mathematical analysis of blood flow through atherosclerotic arterial segment having non-symmetric mild stenosis". International Journal of Research in Pure and Applied Physics, 1,1-5, (2011).

[57] Shah, S. R., "Mathematical Study of Blood Flow through Atherosclerotic Artery in the Presence of Porous Effect", International Journal of Modern Sciences and Engineering Technology, 2, (12), 12-20, (2015).

[58] Shah, S. R., "Non-Newtonian flow of blood through an atherosclerotic artery", Research journal of applied sciences. 6 (1), 76-80, (2011). 10.3923/rjasci.2011.76.80.

[59] Shah, S. R., "Performance modeling and analysis of magnetic field on nutritional transport capillary tissue system using modified Herschel-Bulkely fluid", Int. J. of Advanced research in physical sciences, 1(1), 33-41, (2014).

[60] Shah, S. R., "Performance Study on Capillary-Tissue Diffusion Phenomena for Blood Flow through Stenosed Blood Vessels", American journal of pharmatech research, 2(2), 695-705, (2012).

[61] Shah, S. R., "Response of *blood flow through* an atherosclerotic *artery* in the presence of *magnetic field* using Bingham plastic fluid" International Journal of Pharmaceutical and Biomedical Research, 2(3), 96-106, (2011).

[62] Shah, S. R., "Role of Non-Newtonian behavior in blood flow through normal and stenosed artery", Research journal of Biological sciences, 6(9), 453-458, (2011).

[63] Shah, S. R., "Significance of Aspirin on Blood Flow to Prevent Blood Clotting through Inclined Multi-Stenosed Artery", Letters In Health and Biological Sciences, 2(2), 97-100, (2017). DOI:10.15436/2475-6245.17.018.

[64] Shah, S. R., "Study of dispersion of drug in blood flow with the impact of chemical reaction through stenosed artery", International journal of Biosciences, 21 (3), 21-29, (2022). http://dx.doi.org/10.12692/ijb/21.3.199-208.

[65] Shah, S. R., "Study of modified Casson's fluid model in modeled normal and stenotic capillary-tissue diffusion phenomena" International journal of computational engineering & management, 11, 51-57, (2011).

[66] Shah, S. R.,"A biomechanical approach for the study of Two-phase blood flow through stenosed artery", International Journal of research studies in biosciences, 1(2),24-32, (2013).

[67] Shah, S.R., "Clinical influence of hydroxychloroquine with azithromycin on blood flow through blood vessels for the prevention and Treatment of covid-19", Int. J. of Bio., pharmacy and allied science, 10(7), 2195-2204, (2021).

[68] Shastri Kaviraj Ambikadutta, editor. Sushruta Samhita of Susruta, Chikitsa Sthana, 13th ed. Che. 13, Ver. 8-9. Varanasi: Chaukhamba Sanskrit Sansthana; 2002. p. 65

[69] Siddiqui S. U., Sapna, Km., "Herschel-Bulkely fluid model for stenosis shape aspects of blood flow through an artery", Ultra Science, International journal of physical sciences, 18 (3), 407-416, (2006).

[70] Siddiqui S. U., Shah, S. R., "A Physiologic Model for the problem of blood flow through Diseases blood vessels", International journal of advances in Applied Sciences, 5(2), 58-64, (2016). DOI:10.11591/ijaas.v5.i2.pp58-64.

[71] Siddiqui, S. U., Shah, S. R., "A Comparative Study for the Non-Newtonian Behaviour of Blood Flow through Atherosclerotic Arterial Segment", Int. J. of Pharmaceutical Sci. Review and Research, 9 (2), 120-125, (2011).

[72] Siddiqui, S. U., Shah, S. R., "Two-phase model for the study of blood flow through stenosed artery", International Journal of Pharmacy and Biological Sciences, 1(3), 246-254, (2011).

[73] Singh, A., Shah, S. R., Siddiqui S. U., "Effects of inclined multi-stenoses arteries on blood flow characteristics using bingham plastic fluid", International Journal for Mathematics, 1, (12), 7-14, (2015).

[74] Singh, A., Shah, S. R., Siddiqui S. U., "Mathematical Modeling and Numerical Simulation of Blood Flow through Tapered Artery", International Journal of Innovative Science, Engineering & Technology, 3, (2), 710-717, (2016). https://ijiset.com/vol3/v3s2/IJISET_V3_I2_97.pdf.

[75] Singh, A., Shah, S. R., Siddiqui S. U., "Mathematical Modelling and Analysis of Blood Flow through Diseased Blood Vessels", International Journal of Engineering and Management Research, 5, (6), 366-372, (2015). https://doi.org/10.3389/fnano.2020.596475.

[76] Singh, A., Shah, S. R., Siddiqui S. U., "Performance of blood flow through two phase stenosed artery using Herschel-Bulkley model", Int. J. of Applied And Pure Science and Agriculture, 2, (2), 228-240, (2016).

[77] Singh, A., Siddiqui S. U., Shah, S. R., "A Mathematical Model to study the similarities of blood fluid models through inclined multi-stenosed artery", International Journal of Engineering Research and Modern Eduacation, 2, (1), 108-115, (2017). https://core.ac.uk/download/pdf/144783771.pdf.

[78] Singh, A., Siddiqui S. U., Shah, S. R., "Mathematical Modeling of peristaltic blood flow through a vertical blood vessel using prandtl fluid model", Int. J. of Mathematics and Computer Research, 4, (9), 710-717, (2016).

[79] Singh, S., "A two-layered model for the analysis of arterial rheology" International Journal of Computer Science and Information Technology, 4, 37-42. (2011).

[80] Singh, S., "Analysis of non-newtonian fluid flow in a stenosed artery", International journal of physical sciences, 4(11), 663-671, (2009). https://academicjournals.org/article/article1380630965_Sapna.pdf

[81] Singh, S., "Clinical significance of aspirin on blood flow through stenotic blood vessels" Journal of Biomimetics, Biomaterials and Tissue Engineering, 10 (17) 24-35, (2011). https://doi.org/10.4028/www.scientific.net/JBBTE.10.17.

[82] Singh, S., "Effects of shape of stenosis on arterial rheology under the influence of applied magnetic field" Int. J. of Biomedical Engineering and Technology, 6 (3), 286-294, (2011). DOI:10.1504/IJBET.2011.041466.

[83] Singh, S., "Influence of magnetic field on blood flow through stenosed artery using casson's fluid model", International Journal of BioEngineering, CardioPulmonary Sciences and Technology, 1,1-7, (2010).

[84] Singh, S., "Numerical modeling of two-layered micropolar fluid through a normal and stenosed artery", International journal Engineering, 24 (2), 177-187, (2011). DOI: 10.5829/idosi.ije.2012.25.04a.02.

[85] Singh, S., "Numerical modelling for the modified Power-law fluid in stenotic capillary-tissue diffusion phenomena", Archives of Applied Science Resaerch, *An Int. peer reviewed J. of Appl. Sci.,* 2 (1), 104-112, (2010).

[86] Singh, S., "The effect of Saline Water on viscosity of blood through stenosed blood vessels using Casson's fluid model", Journal of Biomimetics, Biomaterials and Tissue Engineering, 9, 37-45, (2011). https://doi.org/10.4028/www.scientific.net/JBBTE.9.37.

[87] Singh, S., and Shah, R. R., "A numerical model for the effect of stenosis shape on blood flow through an artery using power-law fluid", Advance in applied science research, *An Int. peer reviewed J. of Sci.,* 1, 66-73, (2010).

[88] Thomas, S., Kumar, R., Shah, S. R., "Understanding the impact of feedback regulations on blood cell production and leukemia dynamics using model analysis and simulation of clinically relevant scenarios", Applied Mathematical Modelling, (2024). https://doi.org/10.1016/j.apm.2024.01.048.

[89] Trivedi NA, Mazumdar B, Bhatt JD, Hemavathi KG. Effect of shilajit on blood glucose and lipid profile in alloxan-induced diabetic rats. Indian J Pharmacol 2004;36:373-6.

[90] Upadhyaya Yadunandana, editor. Ashtanga Hridaya of Vagbhatta, Sutra Sthana. 2nd ed. 2. Che. 15, Ver. 19-20. Varanasi: Chowkhambha Prakashana; 2009. p. 105