



# Descending aorta subject-specific one-dimensional model validated against *in vivo* data

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## ABSTRACT

The aorta plays a major role in the cardiovascular system and its function and structure are primarily affected by aging, eating habits, life style and other cardiovascular risk factors, inducing increased stiffness which is associated with cardiovascular and cerebral morbi-mortality. Our objective was to develop and validate a robust subject-specific one-dimensional wave propagation numerical model of the descending aorta. This model with a cross-sectional area, velocity and pressure formulation is built using geometric and hemodynamic data measured on a specific person and is validated against *in vivo* data acquired on the same subject at three distinct anatomical locations along the thoracic aorta. We studied seven healthy volunteers, who underwent carotid applanation tonometry and aortic cardiovascular magnetic resonance (CMR). Responses of our model in terms of changes in central pressure waveform with arterial alterations were consistent with previously described physiological knowledge. Quantitative validation averaged over the three descending aortic locations and the seven subjects provided low rms errors (given in percentage of the maximal clinical value) between simulated and CMR data, i.e. area:  $10 \pm 6\%$ , velocity:  $11 \pm 3\%$ , flow rate:  $9 \pm 3\%$ . Finally, we also found low rms ( $5 \pm 2\%$ ) when comparing simulated pressure in the proximal aortic location against tonometric carotid pressure curves. In conclusion, this simple model performs similar to more complex models of the entire systemic arterial tree at a fraction of the cost, and could be of major usefulness in the non-invasive and local estimation of proximal biomechanical and hemodynamic indices.

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## 1. Introduction

Both structural and functional alterations of large arteries, especially the aorta, occur with aging as well as with aggravating pathologic, genetic and environmental factors (Lakatta and Levy, 2003), resulting in arterial stiffening which has been associated with cardiovascular and cerebral morbi-mortality (Mitchell et al., 2010). One-dimensional (1D) computational fluid dynamics models, simulating parts or the entire systemic circulation, are widely used for studying arterial pressure and flow waves (Stergiopoulos

et al., 1992; Olufsen et al., 2000; Segers and Verdonck, 2000; Sherwin et al., 2003; Steele et al., 2003; Wang and Parker, 2004; Bessens et al., 2007; Matthys et al., 2007; Alastruey et al., 2008; Bessens et al., 2008; Raymond et al., 2009, 2011, 2012). Indeed, they can provide insights into wave propagation and reflection, allowing for a better characterization of the arterial system and its interactions with target organs. Despite their approximations and sensitivity to changes in arterial caliber and distensibility, as well as to peripheral wave reflections, 1D models are computationally attractive, compared to the more accurate three-dimensional models. Valid questions are whether 1D models may be easily adapted to a specific subject, i.e. which features and parameters must be precisely tuned? and how to quantitatively validate model predictions? To date, when available, validations of 1D models including the aorta were performed against either *in vitro* (Segers and Verdonck, 2000; Matthys et al., 2007; Huberts et al., 2012) or *in vivo* (Stergiopoulos et al., 1992; Olufsen et al., 2000; Steele et al., 2003; Raymond et al., 2009, 2011) data. Among these studies,

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# Template Journal Of Biomechanics

**Karol Miller,Poul Nielsen**



## **Template Journal Of Biomechanics:**

**Biomechanics of the Upper Limbs** Andris Freivalds, 2011-02-16 There is already a wealth of literature covering cumulative trauma disorders and medical management as well as the biomechanics of manual material handling and lower back problems. However, despite a spike in the number of work-related musculoskeletal disorders (WRMSDs) in the upper limbs due to a sharp increase in the amount of computer-related jobs, few if any books have focused exclusively on WRMSDs until now. *Biomechanics of the Upper Limbs: Mechanics, Modeling, and Musculoskeletal Injuries*, Second Edition, offers vital information and tools to improve analysis of external forces and their effects on the human body. This can help ergonomists better understand job stressors and the role they play in the development of disorders, enabling them to modify the work environment and educate practitioners to better control harmful situations. Using the author's medical and engineering expertise to distill essential subject matter and useful technical data, this comprehensive text explores biomechanics of the upper limbs and the motor control system. The structure and physiology of the human musculoskeletal and neuromuscular systems, recent research findings and solutions to various ergonomic problems, models of various components of the neuromuscular systems as well as larger systems in the upper limbs, risk factors for disorders and tools used to identify their causes. Designed as a textbook for a typical semester-long graduate-level engineering or kinesiology course, this book includes a link to an ancillary website that offers materials such as PowerPoint slides, sample exams, and an instructor's manual with complete solutions. It also serves as a practical up-to-date engineering-oriented resource for researchers, industrial ergonomists, industrial hygienists, and medical professionals who require supplementary material. [Fundamentals of Biomechanics](#)

Duane Knudson, 2013-04-17 *Fundamentals of Biomechanics* introduces the exciting world of how human movement is created and how it can be improved. Teachers, coaches, and physical therapists all use biomechanics to help people improve movement and decrease the risk of injury. The book presents a comprehensive review of the major concepts of biomechanics and summarizes them in nine principles of biomechanics. *Fundamentals of Biomechanics* concludes by showing how these principles can be used by movement professionals to improve human movement. Specific case studies are presented in physical education, coaching, strength and conditioning, and sports medicine. **Biomechanics and Gait Analysis**

Nicholas Stergiou, 2020-03-25 *Biomechanics and Gait Analysis* presents a comprehensive book on biomechanics that focuses on gait analysis. It is written primarily for biomedical engineering students, professionals, and biomechanists with a strong emphasis on medical devices and assistive technology but is also of interest to clinicians and physiologists. It allows novice readers to acquire the basics of gait analysis while also helping expert readers update their knowledge. The book covers the most up-to-date acquisition and computational methods and advances in the field. Key topics include muscle mechanics and modeling, motor control and coordination, and measurements and assessments. This is the go-to resource for an understanding of fundamental concepts and how to collect, analyze, and interpret data for research, industry, clinical, and

sport Details the fundamental issues leading to the biomechanical analyses of gait and posture Covers the theoretical basis and practical aspects associated with gait analysis Presents methods and tools used in the field including electromyography signal processing and spectral analysis amongst others *Biomechanics in Orthopaedic Diseases and Surgery* Jingwei Zhang, Cheng-Kung Cheng, Chia-Ying Lin, 2025-01-30 The mechanical environment of the musculoskeletal system plays a fundamental role in orthopaedic diseases Understanding the magnitude pattern and duration of biomechanical factors and how they impact surgical treatment is an ongoing topic of interest in biomechanics However the way forces and stresses acting on the skeletal system affect disease progression and treatment outcomes is not yet fully elucidated As a result investigating the biomechanical responses in the incidence and surgical treatment of orthopaedic diseases such as osteoarthritis can significantly enhance existing surgical treatment strategies and foster the development of new pharmaceutical interventions Our goal is to consolidate groundbreaking studies in this field to advance the understanding of the biomechanical principles underlying disease progression and create a foundation for novel therapeutic strategies

Human Orthopaedic Biomechanics Bernardo Innocenti, Fabio Galbusera, 2022-02-24 Human Orthopaedic Biomechanics Fundamentals Devices and Applications covers a wide range of biomechanical topics and fields ranging from theoretical issues mechanobiology design of implants joint biomechanics regulatory issues and practical applications The book teaches the fundamentals of physiological loading and constraint conditions at various parts of the musculoskeletal system It is an ideal resource for teaching and education in courses on orthopedic biomechanics and for engineering students engaged in these courses In addition all bioengineers who have an interest in orthopedic biomechanics will find this title useful as a reference particularly early career researchers and industry professionals Finally any orthopedic surgeons looking to deepen their knowledge of biomechanical aspects will benefit from the accessible writing style in this title Covers theoretical aspects mechanics stress analysis constitutive laws for the various musculoskeletal tissues and mechanobiology Presents components of different regulatory aspects failure analysis post marketing and clinical trials Includes state of the art methods used in orthopedic biomechanics and in designing orthopedic implants experimental methods finite element and rigid body models gait and fluoroscopic analysis radiological measurements Pregnant Occupant Biomechanics Stefan Duma, 2011-04-05 This ground breaking book provides substantial new analysis and summary data about pregnant occupant biomechanics and will serve as a critical asset to anyone in the field of automobile safety The overall goal of this book is to provide the reader with a complete resource for issues relating to the pregnant occupant This multi authored book is thoroughly vetted and includes chapter contributions from highly qualified practitioners in the field A total of 19 technical papers are featured and are broken into six chapters Each chapter begins with a brief summary and analysis of the research for that topic and is followed by a selection of references The remainder of the chapter includes a selection of the very best full length technical papers on the topic which are intended to provide depth and compliment the new material **Routledge Handbook of Motor**

**Control and Motor Learning** Albert Gollhofer, Wolfgang Taube, Jens Bo Nielsen, 2013-01-17 The Routledge Handbook of Motor Control and Motor Learning is the first book to offer a comprehensive survey of neurophysiological behavioural and biomechanical aspects of motor function Adopting an integrative approach it examines the full range of key topics in contemporary human movement studies explaining motor behaviour in depth from the molecular level to behavioural consequences The book contains contributions from many of the world's leading experts in motor control and motor learning and is composed of five thematic parts Theories and models Basic aspects of motor control and learning Motor control and learning in locomotion and posture Motor control and learning in voluntary actions Challenges in motor control and learning Mastering and improving motor control may be important in sports but it becomes even more relevant in rehabilitation and clinical settings where the prime aim is to regain motor function Therefore the book addresses not only basic and theoretical aspects of motor control and learning but also applied areas like robotics modelling and complex human movements This book is both a definitive subject guide and an important contribution to the contemporary research agenda It is therefore important reading for students scholars and researchers working in sports and exercise science kinesiology physical therapy medicine and neuroscience

**Computational Biomechanics for Medicine** Karol Miller, Poul Nielsen, 2010-03-10

Mathematical modelling and computer simulation have proved tremendously successful in engineering One of the greatest challenges for mechanists is to extend the success of computational mechanics to fields outside traditional engineering in particular to biology biomedical sciences and medicine The proposed workshop will provide an opportunity for computational biomechanics specialists to present and exchange opinions on the opportunities of applying their techniques to computer integrated medicine For example continuum mechanics models provide a rational basis for analysing biomedical images by constraining the solution to biologically reasonable motions and processes Biomechanical modelling can also provide clinically important information about the physical status of the underlying biology integrating information across molecular tissue organ and organism scales The main goal of this workshop is to showcase the clinical and scientific utility of computational biomechanics in computer integrated medicine

Spine and Joint Articulation for Manual Therapists Giles

Gyer, Jimmy Michael, Ben Calvert-Painter, 2016-09-01 The book focuses on the practical application of articulation and mobilisation techniques with clear explanations and visual support of the techniques Techniques are described for all body regions Most other books for therapists include only one chapter on these important techniques This book covers a variety of best practise techniques for all areas of the body Examples are given to show how to adapt the techniques with the patient in different positions It also addresses the use of these techniques on children the elderly and pregnant women The mechanisms of each technique are explained with reference to the related anatomy and physiology Information is also given to help the therapist use the techniques safely for both themselves and their patients by adapting their own stance and posture to get maximum effect with minimum effort

**Perspectives in Dynamical Systems II – Numerical and**

**Analytical Approaches** Jan Awrejcewicz, 2024-06-18 This proceedings volume gathers selected peer reviewed papers presented at the Dynamical Systems Theory and Applications International Conference DSTA 2021 held virtually on December 6-9 2021 organized by the Department of Automation Biomechanics and Mechatronics at Lodz University of Technology Poland This volume focuses on numerical and analytical approaches while Volume I concentrates on studies on applications Being a truly international conference this 16th iteration of DSTA received submissions from authors representing 52 countries The program covered both theoretical and experimental approaches to widely understood dynamical systems including topics devoted to bifurcations and chaos control in dynamical systems asymptotic methods in nonlinear dynamics stability of dynamical systems lumped mass and continuous systems vibrations original numerical methods of vibration analysis non smooth systems dynamics in life sciences and bioengineering as well as engineering systems and differential equations DSTA conferences aim to provide a common platform for exchanging new ideas and results of recent research in scientific and technological advances in modern dynamical systems Works contained in this volume can appeal to researchers in the field whether in mathematics or applied sciences and practitioners in myriad industries

*Reading Prehistoric Human Tracks* Andreas Pastoors, Tilman Lenssen-Erz, 2021-02-26 This Open Access book explains that after long periods of prehistoric research in which the importance of the archaeological as well as the natural context of rock art has been constantly underestimated research has now begun to take this context into focus for documentation analysis interpretation and understanding Human footprints are prominent among the long time under researched features of the context in caves with rock art In order to compensate for this neglect an innovative research program has been established several years ago that focuses on the merging of indigenous knowledge and western archaeological science for the benefit of both sides The book gathers first the methodological diversity in the analysis of human tracks Here major representatives of anthropological statistical and traditional approaches feature the multi layered methods available for the analysis of human tracks Second it compiles case studies from around the globe of prehistoric human tracks For the first time the most important sites which have been found worldwide are published in a single publication The third focus of this book is on firsthand experiences of researchers with indigenous tracking experts from around the globe expounding on how archaeological science can benefit from the ancestral knowledge This book will be of interest to professional archaeologists graduate students ecologists cultural anthropologists and laypeople especially those focussing on hunting gathering and pastoralist communities and who appreciate indigenous knowledge

**Digital Human Modeling and Medicine** Gunther Paul, Mohamed H. Doweidar, 2022-12-04 Digital Human Modeling and Medicine The Digital Twin explores the body of knowledge and state of the art in Digital Human Modeling DHM and its applications in medicine DHM is the science of representing humans with their physical properties characteristics and behaviors in computerized virtual models These models can be used standalone or integrated with other computerized object design

systems to both design or study designs of medical devices or medical device products and their relationship with humans They serve as fast and cost efficient computer based tools for the assessment of human functional systems and human system interaction This book provides an industry first introductory and practitioner focused overview of human simulation tools with detailed chapters describing body functional elements and organs organ interactions and fields of application Thus DHM tools and a specific scientific practical problem functional study of the human body are linked in a coherent framework Eventually the book shows how DHM interfaces with common physical devices in medical practice answering to a gap in literature and a common practitioner question Case studies provide the applied knowledge for practitioners to make informed decisions A non specialist level up to date overview and introduction to all medically relevant DHM systems to inform trialing procurement decisions and initial application Includes user level examples and case studies of DHM applications in various medical fields Clearly structured and focused compendium that is easy to access read and understand

Introduction to Sports Biomechanics Roger Bartlett, 2014-01-15 Introduction to Sports Biomechanics Analysing Human Movement Patterns is a genuinely accessible and comprehensive guide to all of the biomechanics topics covered in an undergraduate sports and exercise science degree Now in a fully revised and updated third edition the book explores both the qualitative and quantitative analysis of human movement covering the following key topics Movement patterns the essence and purpose of sports biomechanics Qualitative analysis of sports movements Sports movement patterns and the geometry of motion Quantitative motion analysis in sports biomechanics What causes sports movements Forces and moments of force The anatomy of human movement Every chapter contains cross references to key terms and definitions learning objectives and summaries study tasks to confirm and extend understanding and suggestions for further reading In addition to the printed textbook readers of this new edition will also have access to an Interactive eTextbook version a new kind of e book that can be used on both mobile and desktop devices offering students an unparalleled level of interactivity Featuring video data files pop up definitions hyperlinks self test quizzes and interactive labelling and sorting tasks this new electronic edition brings the subject of sports biomechanics to life like no other textbook With downloadable resources also provided for instructors including PowerPoint slides and answer guidelines this remains an essential course text for students of sport and exercise human movement sciences ergonomics biomechanics physical education and sports performance and coaching

Frontiers in Nano-therapeutics Nishat Tasnim, Baiju G. Nair, Katla Sai Krishna, Sudhakar Kalagara, Mahesh Narayan, Juan C. Noveron, Binata Joddar, 2017-06-22 This brief highlights recent research advances in the area of nano therapeutics Nanotechnology holds immense potential for application in a wide range of biological and engineering applications such as molecular sensors for disease diagnosis therapeutic agents for the treatment of diseases a vehicle for delivering therapeutics and imaging agents for theranostic applications both in vitro and in vivo The brief is grouped into the following sections namely A Discrete Nanosystems B Anisotropic Nanoparticles C Nano films coated layered and D Nano composites *Finite*

*Element Mesh Generation* Daniel S.H. Lo, 2015-01-15 Highlights the Progression of Meshing Technologies and Their Applications Finite Element Mesh Generation provides a concise and comprehensive guide to the application of finite element mesh generation over 2D domains curved surfaces and 3D space Organised according to the geometry and dimension of the problem domains it develops from the basic meshing algorithms to the most advanced schemes to deal with problems with specific requirements such as boundary conformity adaptive and anisotropic elements shape qualities and mesh optimization It sets out the fundamentals of popular techniques including Delaunay triangulation Advancing front ADF approach Quadtree Octree techniques Refinement and optimization based strategies From the geometrical and the topological aspects and their associated operations and inter relationships each approach is vividly described and illustrated with examples Beyond the algorithms the book also explores the practice of using metric tensor and surface curvatures for generating anisotropic meshes on parametric space It presents results from research including 3D anisotropic meshing mesh generation over unbounded domains meshing by means of intersection re meshing by Delaunay ADF approach mesh refinement and optimization generation of hexahedral meshes and large scale and parallel meshing along with innovative unpublished meshing methods The author provides illustrations of major meshing algorithms pseudo codes and programming codes in C or FORTRAN Geared toward research centers universities and engineering companies Finite Element Mesh Generation describes mesh generation methods and fundamental techniques and also serves as a valuable reference for laymen and experts alike

**Research Methods in Biomechanics, 2E** Gordon Robertson, Graham Caldwell, Joseph Hamill, Gary Kamen, Saunders Whittlesey , 2013-09-25 Detailing up to date research technologies and approaches Research Methods in Biomechanics Second Edition assists both beginning and experienced researchers in developing methods for analyzing and quantifying human movement

*Biomechanics of the Spine* Fabio Galbusera, Hans-Joachim Wilke, 2018-04-23 Biomechanics of the Spine encompasses the basics of spine biomechanics spinal tissues spinal disorders and treatment methods Organized into four parts the first chapters explore the functional anatomy of the spine with special emphasis on aspects which are biomechanically relevant and quite often neglected in clinical literature The second part describes the mechanics of the individual spinal tissues along with commonly used testing set ups and the constitutive models used to represent them in mathematical studies The third part covers in detail the current methods which are used in spine research experimental testing numerical simulation and in vivo studies imaging and motion analysis The last part covers the biomechanical aspects of spinal pathologies and their surgical treatment This valuable reference is ideal for bioengineers who are involved in spine biomechanics and spinal surgeons who are looking to broaden their biomechanical knowledge base The contributors to this book are from the leading institutions in the world that are researching spine biomechanics Includes broad coverage of spine disorders and surgery with a biomechanical focus Summarizes state of the art and cutting edge research in the field of spine biomechanics Discusses a variety of methods including In vivo and In vitro testing and finite element and musculoskeletal



modeling      **Biomechanics** Christopher D Armstrong,2018-11-02 The last ten years have seen explosive growth in the technology available to the collision analyst changing the way reconstruction is practiced in fundamental ways The greatest technological advances for the crash reconstruction community have come in the realms of photogrammetry and digital media analysis The widespread use of scanning technology has facilitated the implementation of powerful new tools to digitize forensic data create 3D models and visualize and analyze crash vehicles and environments The introduction of unmanned aerial systems and standardization of crash data recorders to the crash reconstruction community have enhanced the ability of a crash analyst to visualize and model the components of a crash reconstruction Because of the technological changes occurring in the industry many SAE papers have been written to address the validation and use of new tools for collision reconstruction Collision Reconstruction Methodologies Volumes 1 12 bring together seminal SAE technical papers surrounding advancements in the crash reconstruction field Topics featured in the series include Night Vision Study and Photogrammetry Vehicle Event Data Recorders Motorcycle Heavy Vehicle Bicycle and Pedestrian Accident Reconstruction The goal is to provide the latest technologies and methodologies being introduced into collision reconstruction appealing to crash analysts consultants and safety engineers alike      *Advances in Brain Mechanics* Silvia Budday,Philip Bayly,Gerhard A. Holzapfel,2022-02-04      **Two-dimensional Drafting Template and Three-dimensional Computer Model Representing the Average Adult Male in Automotive Seated Postures** Neil James Bush,1992

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