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- Biomechanics
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Preface

The primary objectives of this conference are to provide a dynamic forum for scientists to present their most recent research findings in the fields of biomechanics and biomedical engineering, as well as to foster the establishment of new professional contacts within these disciplines.

We extend a cordial invitation to all scientists, engineers, physicians, and entrepreneurs engaged in the broad areas of biomechanics and biomedical engineering. Participants are encouraged to share their expertise, exchange knowledge, gain valuable experience, and build meaningful new relationships during the conference.

JULIUS GRIŠKEVIČIUS
Scientific Chairman of the International Conference BIOMDLORE 2025

DECIPHERING ATRIAL REPOLARIZATION MORPHOLOGY: A SPLINE INTERPOLATION FRAMEWORK FOR ATRIAL ARRHYTHMIA DIAGNOSIS

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ABSTRACT

BACKGROUND: The characterization of atrial repolarization (Ta wave) remains largely elusive due to its inherently low amplitude and concealment beneath the dominant QRS complex.

OBJECTIVE: This study aims to witness Ta wave within QRS complex using spline interpolation framework.

METHODS: 10-second ECGs of 50 Sinus Tachycardia (SiT) and 20 Atrial Tachycardia (AT) were recorded using standard 12-lead. Lead-II signals were pre-processed for noise removal and fiducial points detection. Later, three spline models were used to synthesize hidden Ta wave using the datapoints from PR and ST segment. Further, validation analysis was performed to select the optimal spline model with the Ta wave of Atrio-Ventricular Block (AVB) ECG.

RESULTS: It was noted that the clamped cubic & b spline interpolation model gave the best SSIM score of 0.7 and lowest power spectrum % difference of 1.33 of interpolated Ta wave within QRS complex. Further, Ta wave voltage and temporal features including Ta dispersion, area, peak location, Ta area/duration, duration/amplitude, and Ta2/Ta1 were crafted. Statistically significant P, Ta & P-Ta features were fed to 7 Machine Learning (ML) models. The best ML models were used to design a stacked ensemble architecture with combined P-Ta to enhance the classification accuracy to 99% and F1 score 0.99.

CONCLUSIONS: The proposed method demonstrated that along with the existing P wave features, Ta wave features have potential in better classification of atrial arrhythmia, while interpolation model offers ease of implementation and adaptability to diverse clinical applications.

KEYWORDS: arrhythmia, atrial repolarization wave, atrial tachycardia, Atrio-Ventricular Block, electrocardiogram, spline interpolation.

REFERENCES:

Das, K., Basu, S., & Sarkar, S. (2024). Ectopic atrial rhythm with atrial repolarisation wave mimicking as inferior wall ST elevation myocardial infarction. *IHJ Cardiovascular Reports*, *8*, 4–6. https://doi.org/10.1016/j.ihjcvr.2024.02.002

He, J., Liu, S., Feng X., Li, C., Huo, H., Yang, C., Deng, X., & Wang, A. (2024). Comprehensive analysis of heart rate variability features for accurate prediction of paroxysmal atrial fibrillation. *Biomed Signal Process Control*, *87*, Article 105489. https://doi.org/10.1016/j.bspc.2023.105489

Mishra, A., Bhusnur, S., Mishra, S. K., & Singh, P. (2024). Comparative analysis of parametric B-spline and Hermite cubic spline based methods for accurate ECG signal modelling. *Journal of Electrocardiology*, *86*, Article 153783. https://doi.org/10.1016/j.jelectrocard.2024.153783

Sivaraman, J., Uma, G., Venkatesan, S., Umapathy, M., & Elumalai Dhandapani, V. (2015). Normal limits of ECG measurements related to atrial activity using a modified limb lead system. The *Anatolian Journal of Cardiology*, *15*, 2–6. https://doi.org/10.5152/akd.2014.5155

THE APPLICATION OF A GAMIFICATION MODEL IN TEACHING AN INTRODUCTION TO BIOENGINEERING

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ABSTRACT

BACKGROUND: Adding game mechanics such as points, levels, badges, and reward systems can increase motivation, engagement, and knowledge retention, particularly in engineering education where it supports both hard and soft skills (Subhash & Cudney, 2018).

OBJECTIVE: To determine whether a structured, gamified course design improves student engagement, perceived learning, and usability in an entry-level biomedical engineering course.

METHODS: The course integrated game elements and personalized pacing within the HealthTEK project framework. Students progressed through curated tasks, discussed challenges in teams, and received immediate feedback. The instructor monitored progress in real time and adjusted difficulty and objectives accordingly. Perceptions were assessed via a structured survey and open-ended comments.

RESULTS: All 26 students completed the survey (100%). Respondents overwhelmingly agreed that learning objectives were clear and achieved and that the content was well structured and comprehensible. Most reported an appropriate balance between theory and practice and noted that points/levels and visible progress increased motivation, consistency of participation, and sense of achievement. System usability (interface, navigation, responsiveness) received high ratings. Minor suggestions included clearer phrasing of a few tasks, better contextualization of some examples, and improved mobile optimization. Open-ended comments emphasized that the gamified format exceeded expectations by making complex topics more accessible and the learning experience more enjoyable and interactive.

CONCLUSIONS: The gamified redesign was effective in enhancing engagement, motivation, and perceived understanding of complex biomedical concepts. With small refinements (clearer task wording, selective rebalancing of theory and practice, and stronger links to professional applications), the approach appears to be a robust, scalable pedagogy for early biomedical engineering curricula.

KEYWORDS: gamification, biomedical engineering, engagement, usability, engineering education.

ACKNOWLEDGEMENTS: We acknowledge the financial support of the HealthTEK project, co-funded by Erasmus+ of the European Union.

REFERENCES:

Subhash, S., & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review of literature. *Computers in Human Behavior, 87*, 192–206. https://doi.org/10.1016/j.chb.2018.05.028

GAME CONCEPTS FOR A BIOMEDICAL ENGINEERING COURSE: A BIOMECHANICS USE CASE

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ABSTRACT

BACKGROUND: Biomechanics plays a key role in orthopedic engineering, enabling the analysis of human movement, detection of abnormalities, and development of effective prosthetics, orthoses, and surgical solutions. To improve the teaching of these complex concepts, gamification has been introduced as an innovative method that fosters engagement, motivation, and knowledge retention (Bronzino & Peterson, 2020).

OBJECTIVE: To integrate game-based activities into a biomechanics course for biomedical engineering students in order to increase engagement, enhance conceptual understanding, and support interdisciplinary learning.

METHODS: The gamified module targeted second-year students and included four components: foot biomechanics, assessment techniques, diagnostic equipment, and orthopedic interventions. Game elements comprised quizzes, bingo, simulations, case studies, escape-room challenges, and role-play. Activities were aligned with course objectives, combining theoretical content with applied problem solving.

RESULTS: Preliminary feedback indicated strong student engagement and motivation. Participants emphasized clarity of objectives, enjoyment of interactive tasks, and improved understanding of biomechanical principles. Games such as quizzes, simulations, and escape rooms were particularly effective in reinforcing learning.

CONCLUSIONS: Gamification is an effective strategy for teaching biomechanics in biomedical engineering. It supports knowledge acquisition, critical thinking, and collaboration while making complex content accessible and engaging. Future work will evaluate long-term outcomes and adapt the model to other biomedical courses.

KEYWORDS: gamification, biomedical engineering, biomechanics, orthopaedics.

ACKNOWLEDGEMENTS: We acknowledge the financial support of the HealthTEK project, co-funded by Erasmus+ of the European Union.

REFERENCES:

Bronzino, J. D., & Peterson, D. R. (Eds.). (2020). *Biomechanics: principles and applications*. CRC Press.

ENHANCING TECHNOLOGY TRANSFER IN HEALTHCARE: EFFECTIVE COLLABORATION BETWEEN RESEARCH INSTITUTIONS AND INDUSTRY

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ABSTRACT

BACKGROUND: The healthcare sector marked by rapid innovation cycles and stringent regulation presents unique challenges and opportunities for technology transfer. Effective collaboration among academia, research institutions, and industry is crucial for accelerating the development and implementation of innovations that improve patient outcomes and health-system performance (Mazzucato, 2021).

OBJECTIVE: To analyze current collaboration practices and identify barriers and facilitators of effective technology transfer between research and industry in healthcare.

METHODS: The study sample comprised participants from a broad range of organizations, including research institutions and technology companies. The survey included nine open-ended questions designed to elicit qualitative insights into experiences, needs, and challenges. Key topics covered required support for technology implementation, features that make innovations attractive to business, regulatory hurdles, and strategies to engage researchers in commercialization.

RESULTS: Of 114 invitees, 30 completed the survey (26.3%). Frequently cited enablers included access to diversified financial resources, regulatory advisory services, and research infrastructure. Respondents emphasized the need for financial support across the entire technology life cycle from research to commercialization through grants, tax incentives, and co-funding mechanisms, particularly for startups and small- and medium-sized enterprises (SMEs). Regulatory support (e.g., expert consulting on market access and interpretation of complex standards) was also seen as crucial. Access to advanced research infrastructure such as laboratories and centers of excellence was identified as a significant factor enabling effective academia–industry collaboration. Among the main barriers, respondents highlighted regulatory complexity, including cross-regional inconsistencies and the high cost of compliance.

CONCLUSIONS: To strengthen technology transfer in healthcare, priority actions include: broadening access to funding along the full innovation pathway; expanding specialized regulatory advisory services; and improving availability of shared research infrastructure that supports academia–industry partnerships.

KEYWORDS: technology transfer, healthcare, industry–academia collaboration, survey, regulation.

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REFERENCES:

Mazzucato, M. (2021). *Mission economy: A moonshot guide to changing capitalism*. HarperCollins.

MEDICAL TECHNOLOGIES, PATIENT COMFORT, AND ENGAGEMENT - PRACTICAL AND COMMUNICATION ASPECTS

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ABSTRACT

BACKGROUND: A crucial part of the effective implementation of technology transfer in healthcare is identifying and securing the support of key stakeholders and ensuring their engagement at every stage of the process. Primary stakeholders include academic institutions, businesses, regulatory bodies, hospitals, and patients (Fernandes, 2023; Sham et al., 2024).

OBJECTIVE: To assess the level of trust that patients and the public place in innovative medical technologies and to understand their perceived benefits, barriers, and expectations regarding the use of these technologies in healthcare.

METHODS: An online survey was conducted between October 25 and December 23, 2024, to explore perceived benefits, barriers, and expectations from the user perspective. A custom questionnaire comprising 14 mostly closed-ended items covered trust, safety, comfort, and acceptance of technologies in healthcare. The sample included individuals with prior patient experience recruited via LinkedIn and email.

RESULTS: Among 32 respondents, most reported direct experience with modern medical technologies such as electronic health records (EHRs), telemedicine, wearable monitoring devices, artificial intelligence (AI) tools, and surgical robotics. Overall feedback was positive, with respondents noting improvements in diagnostic accuracy, patient safety, treatment efficiency, and comfort. At the same time, challenges were identified, particularly limited communication from clinical staff, short consultation times, and the use of complex technical terminology, which reduced patients' understanding and confidence. Key recommendations included enhancing clinician–patient communication, providing additional staff training on technology use, improving integration of digital systems, guaranteeing equitable access regardless of location, and strengthening data security to protect patient privacy.

CONCLUSIONS: Successful implementation of advanced technologies requires more than technical deployment. Equitable access, clear and consistent communication with patients, and sufficient training and preparedness of healthcare staff are essential to maximizing the impact of innovation.

KEYWORDS: medical technologies, patients care, hospitals, healthcare.

ACKNOWLEDGEMENTS: This scientific work was co-financed by the state budget under the Minister of Education and Science program "Science for Society II" (project No. NdS-II/SP/0181/2023/01). Funding amount: PLN 800,000; total project value: PLN 800,000.

REFERENCES:

Fernandes, M. A. (2023). *Study of effective frameworks to support medical technology innovation in the hospital setting* [Doctoral dissertation, University of Porto].

Sham, S., Shiwlani, S., Kumar, S. K., Bai, P., Bendari, A. (2024). Empowering patients through digital health literacy and access to electronic medical records (EMRs) in the developing world. *Cureus*, *16*(4), Article e57527. https://doi.org/10.7759/cureus.57527

A CASCADE OF DYSFUNCTION: HOW OBESITY ALTERS MUSCLE-TENDON HEALTH

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ABSTRACT

BACKGROUND: Overweight remains a major global issue, straining healthcare systems through obesity-related comorbidities, including musculoskeletal disorders – a major cause of reduced quality of life.

OBJECTIVE: The central aim of the studies presented here is to provide a comprehensive understanding of how obesity affects muscle-tendon health, from molecular and structural alterations to loss of function.

METHODS: Using a translational approach, we investigated diet-induced obesity in C57BL/6 mice, assessing muscle-tendon mechanics, structural alterations, and key signaling pathways driving adaptation. Metabolic and functional evaluations provided insight into broader physiological consequences. In human studies, we examined how obesity affects respiratory function and daily movements, such as calf raises, through changes in muscle-tendon structure and mechanics.

RESULTS: Obesity alters the muscle-tendon unit, increasing non-elastic stiffness and viscosity, partly due to excess connective tissue infiltration (collagen, fat) and ECM remodeling. These changes contribute to increased tissue frailty, weakness, reduced movement efficiency, and greater fatigability.

CONCLUSIONS: Using a translational approach, we identified a "cascade of dysfunction" in the complex physiological response to obesity, where structural and mechanical alterations in muscles and tendons contribute to functional decline. Obesity exerts its effects both directly, by modulating tissue composition and mechanics, and indirectly, by imposing excess mechanical loading, leading to chronic tissue damage and altered movement patterns, often unmatched by muscle strength. These changes increase the cost of movement and predispose individuals to weakness and fatigability.

KEYWORDS: obesity, mechanobiology, skeletal muscle, tendon.

REFERENCES:

Cesanelli, L., Cesanelli, F., Degens, H., & Satkunskiene, D. (2024). Obesity-related reduced spirometry and altered breathing pattern are associated with mechanical disadvantage of the diaphragm. *Respiratory Physiology & Neurobiology*, *325*, Article 104267. https://doi.org/10.1016/j.resp.2024.104267

Cesanelli, L., Degens, H., Toper, C. R., Kamandulis, S., & Satkunskiene, D. (2025). Lower calf raise efficiency in obesity is partially related to higher triceps surae MTU passive stiffness, hysteresis, and reduced relative strength. *Journal of Applied Physiology*, *138*(4), 1066–1078. https://doi.org/10.1152/japplphysiol.00702.2024

Cesanelli, L., Minderis, P., Balnyte, I., Ratkevicius, A., Degens, H., & Satkunskiene, D. (2025). Obesity-driven musculotendinous remodeling impairs tissue resilience to mechanical damage. *Cell and Tissue Research*, *400*(3), 287–302. https://doi.org/10.1007/s00441-025-03967-1

Wu, L., & Coletta, D. K. (2025). Obesity and type 2 diabetes mellitus: insights from skeletal muscle extracellular matrix remodeling. American Journal of Physiology-Cell Physiology, *328*(6), C1752–C1763. https://doi.org/10.1152/ajpcell.00154.2024

2D BIOMECHANICAL ANALYSIS OF FUNDAMENTAL KICKBOXING TECHNIQUES USING OPENPOSE ON A SINGLE-CAMERA SETUP

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ABSTRACT

BACKGROUND: The kinematic analysis of fundamental kicking techniques plays a crucial role in combat sports, including kickboxing. Accurate evaluation of these movements is essential not only for enhancing competitive performance but also for injury prevention. Previous research has highlighted both the physiological demands of elite kickboxers (Rydzik et al., 2021) and the biomechanical indicators relevant to striking efficiency (Corcoran et al., 2024). In modern sport, the integration of advanced technology is indispensable, providing objective feedback that benefits both scientific understanding and practical training applications.

OBJECTIVE: The present study aims to develop a method capable of assessing four fundamental kicks (front, roundhouse, side, and hook) from a single camera angle, providing objective performance metrics to support coaches and athletes in training and technique analysis. Furthermore, the study seeks to identify and analyze performance differences between novice and advanced practitioners.

METHODS: Ten novice and ten advanced kickboxers executed four fundamental – front, side, roundhouse, and hook – kick techniques with both legs. The kicking motions were captured with a single-camera setup and subsequently analyzed using the OpenPose (Cao et al., 2021) human pose estimation software. Specific parameters were selected, and the total execution time was calculated for each of the four kicking techniques to characterize hip mobility and kick height.

RESULTS: Advanced kickboxers showed better results and shorter execution time during the four kick movements, however, only the execution time of the non-dominant front kick ($p = 0.0015$) and of the side kick for both legs ($p = 0.0208$; $p = 0.0172$) presented statistically significant results.

CONCLUSIONS: The developed methodology is capable of associating numerical results for four fundamental kick movements and delivering execution times in 2D. Although the inclusion of more participants, primarily elite athletes, would yield more detailed results and differences between the groups.

KEYWORDS: competitive sport, kickboxing, kicking performance, motion analysis, OpenPose.

REFERENCES:

Cao, Z., Hidalgo, G., Simon, T., Wei, S.-E., & Sheikh, Y. (2021). OpenPose: Realtime multi-person 2D pose estimation using part affinity fields. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *43*(1), 172–186. https://doi.org/10.1109/TPAMI.2019.2929257

Corcoran, D., Climstein, M., Whitting, J., & Del Vecchio, L. 2024. Impact force and velocities for kicking strikes in combat sports: A literature review. *Sports*, *12*(3), Article 74. https://doi.org/10.3390/sports12030074

Rydzik, Ł., Maciejczyk, M., Czarny, W., Kędra, A., & Ambroży, T. (2021). Physiological responses and bout analysis in elite kickboxers during international K1 competitions. *Frontiers in Physiology*, *12*, Article 691028. https://doi.org/10.3389/fphys.2021.691028

APPLICATION OF TWO-DIMENSIONAL ENTROPY MEASURES FOR DETECTING SIGNS OF PHARYNGEAL LYMPHOID HYPERPLASIA IN EQUINE ENDOSCOPIC IMAGES

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ABSTRACT

BACKGROUND: In equine pharyngeal mucosa, the lymphoid tissue forms aggregated nodular lymphoid follicles. Their proliferation and growth is assessed using resting endoscopy and graded on a scale from 0 to 4 of pharyngeal lymphoid hyperplasia (PLH). Grade 0 indicates healthy mucosa, while grades 1 to 4 are often associated with active respiratory tract infections.

OBJECTIVE: In equine pharyngeal mucosa, the lymphoid tissue forms aggregated nodular lymphoid follicles. Their proliferation and growth is assessed using resting endoscopy and graded on a scale from 0 to 4 of pharyngeal lymphoid hyperplasia (PLH). Grade 0 indicates healthy mucosa, while grades 1 to 4 are often associated with active respiratory tract infections.

METHODS: This study applies texture analysis of endoscopic images to detect signs of PLH using multi-scale entropy measures implemented in Python. Endoscopic images of the pharynx were collected from 70 horses clinically assessed as having PLH grades 0 to 4. The images were segmented, converted to grayscale, and filtered using Normalize, Mean, Median, and Laplacian filters in Python. Texture features were then calculated using the following two-dimensional entropy measures across five scales: sample entropy (SampEn2D), fuzzy entropy (FuzzEn2D), permutation entropy (PermEn2D), dispersion entropy (DispEn2D), distribution entropy (DistEn2D), and Espinosa entropy (EspEn2D).

RESULTS: After Normalize filtering, SampEn2D differed between grades 1 and 2; FuzzEn2D and DispEn2D differed between grades 1 and 3; while DistEn2D and EspEn2D differed grades 0 and 4.

CONCLUSIONS: The combination of entropy measures and filtering techniques enables the detection of PLH signs in equine endoscopic images, supporting veterinary diagnostics.

KEYWORDS: diagnostic imaging, endoscopy, pharyngitis, lymphoid follicles, horse.

REFERENCES:

Baker, C. W., & Boles, C. L. (1978). Pharyngeal lymphoid hyperplasia in the horse. *Journal Equine Medical Surgery*, *2*(4), 202–207.

Borowska, M. (2023). *Wprowadzenie do zastosowania entropii w analizie sygnałów i obrazów biomedycznych oraz jej aplikacje w medycynie i weterynarii.* Politechnika Białostocka. https://doi.org/10.24427/978-83-67185-81-3

THE APPLICATION OF AN ENSEMBLE OF CONVOLUTIONAL NEURAL NETWORKS FOR HUMAN RECOGNITION BASED ON THE GROUND REACTION FORCES

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ABSTRACT

BACKGROUND: Biometric recognition can be achieved by analyzing ground reaction forces (GRFs) generated during an individual's gait. Traditional approaches to gait recognition are based on the manual extraction of features from GRF signals and the use of classical machine learning algorithms. Recently, increasing popularity has been achieved by deep learning methods, including convolutional neural networks (CNNs) that, during learning, can automatically identify features from data expressed as a time series, eliminating the necessity of manual selection of traits that contribute to the greatest extent to the differentiation between classes. It is worth noting that deep networks do not always produce the best human recognition results (Horst et al., 2023). Literature concerning machine learning has repeatedly shown that ensemble learning allows the achievement of better classification results than the utilization of a single classifier.

OBJECTIVE: The aim of the present work is the design of a biometric system that will recognize a person on the basis of GRFs and an ensemble of classifiers, with its base classifiers being CNNs.

METHODS: During examinations each CNN possessed the same general architecture. A certain difference between the utilized CNNs was constituted in the number of channels (e.g. time series) representing components of GRFs fed into the CNNs' input. The weighted vote with weight based on rank order technique for combining base classifier decisions was utilized. The study utilized a dataset for a total of 5,980 gait cycles from 322 individuals (Derlatka & Parfieniuk, 2023).

RESULTS: The optimal outcomes were achieved through the utilization of all GRF components in the learning of CNN. This approach yielded a recognition rate of 96.57% and the combination of seventeen base classifiers in ensemble classifiers resulted in a 99.57% correct recognition.

CONCLUSIONS: The attained results for the recognition of people are very good and confirm the considerable possibilities for the application of gait as a biometric. The analysis of the outcomes confirmed that the quality of the ensemble of classifiers improves along with increase in the number of base classifiers, as well as with greater accuracy of recognition of individual base classifiers.

KEYWORDS: human gait recognition, biometrics, ground reaction forces, convolutional neural networks, ensemble classifiers.

REFERENCES:

Derlatka, M., & Parfieniuk, M. (2023). Real-world measurements of ground reaction forces of normal gait of young adults wearing various footwear. *Scientific Data*, *10*, Article 60. https://doi.org/10.1038/s41597-023-01964-z

Horst, F., Slijepcevic, D., Simak, M., Horsak, B., Schöllhorn, W. I., & Zeppelzauer, M. (2023). Modeling biological individuality using machine learning: A study on human gait. *Computational and Structural Biotechnology Journal*, *21*, 3414–3423. https://doi.org/10.1016/j.csbj.2023.06.009

PATELLAR TENDON PROPERTIES AND NEUROMUSCULAR PERFORMANCE ACROSS DIFFERENT POWER SPORTS

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ABSTRACT

BACKGROUND: Tendons play a crucial role in force transmission, and their adaptation to training depends on load magnitude and characteristics. Explosive sports differ in movement patterns, yet share common practices aimed at maximizing force and speed. Whether these differences result in distinct tendon adaptations remains unclear.

OBJECTIVE: To compare patellar tendon morphology, mechanical properties, and performance outcomes among elite athletes from different explosive sports.

METHODS: Forty-one elite male athletes (sprinters, long/high jumpers, gymnasts, karate) were assessed during the pre-competition phase. Patellar tendon dimensions and stiffness were measured by ultrasonography, while isometric and concentric knee torques were assessed with an isokinetic dynamometer and EMG. Countermovement jump performance was analyzed on a force plate. Data were evaluated with ANOVA, Tukey post hoc tests, and Pearson's correlations ($\alpha \leq 0.05$).

RESULTS: Tendon morphology and stiffness were largely similar across sports. Gymnasts exhibited the lowest torque and jump performance, while sprinters and long jumpers achieved the highest values. Patellar tendon stress differed significantly between groups and correlated strongly with maximal knee extension torque and peak jump power.

CONCLUSIONS: Sport-specific demands did not markedly alter patellar tendon structure or stiffness. Instead, tendon stress reflected overall force output, emphasizing the importance of balanced training loads to optimize performance and reduce injury risk.

KEYWORDS: long-term adaptation, sport-specific training, cross-sectional area, stiffness, stress, strength, power, rate of force development.

REFERENCES:

Bohm, S., Mersmann, F., & Arampatzis, A. (2015). Human tendon adaptation in response to mechanical loading: A systematic review. *Sports Medicine – Open*, *1*, Article 7. https://doi.org/10.1186/s40798-015-0009-9

Kongsgaard M., Reitelseder, S., Pedersen, T. G., Holm, L., Aagard, P., Kjaer, M., & Magnusson, S. P. (2007). Region-specific patellar tendon hypertrophy in humans following resistance training. *Acta Physiologica*, *191*, 111–121. https://doi.org/10.1111/j.1748-1716.2007.01714.x

Magnusson, S. P., Narici, M. V., Maganaris, C. N., & Kjaer, M. (2008). Human tendon behaviour and adaptation in vivo. *The Journal of Physiology*, *586*, 71–81. https://doi.org/10.1113/jphysiol.2007.139105

Seynnes, O. R., Erskine, R. M., Maganaris, C. N., Longo, S., Simoneau, E. M. , Grosset J. F. , & Narici, M. V. (2009). Training-induced changes in patellar tendon structure and mechanics. *Journal of Applied Physiology*, *107*, 523–530. https://doi.org/10.1152/japplphysiol.00213.2009

Wiesinger, H.-P., Rieder, F., Kösters, A., Müller, E., & Seynnes, O. R. (2016). Sport-specific tendon stiffness profiles in athletes. *PLoS ONE*, *11*(6), Article e0158441. https://doi.org/10.1371/journal.pone.0158441

INTELLIGENT WEARABLE SELF-POWERED SENSING TECHNOLOGY ENABLED BY MOLECULAR ENGINEERING

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ABSTRACT

BACKGROUND: The rapid proliferation of wearable technologies has reshaped the landscape of personalized healthcare, environmental monitoring, and human–machine interaction. Conventional wearable sensors, however, are often constrained by external power requirements and insufficient adaptability to complex real-world conditions. To address these limitations, the concept of self-powered wearable sensors has emerged, offering sustainable energy harvesting and autonomous operation. Nevertheless, achieving high performance, long-term stability, and multifunctionality in such devices remains a formidable challenge. Recent advances in the convergence of molecular engineering and machine learning thus paves the way for the development of intelligent self-powered wearable sensors, capable of delivering reliable performance while addressing critical societal needs, such as environmental safety monitoring and biomedical diagnostics.

OBJECTIVE: The objective is to establish a universal design paradigm for next-generation intelligent self-powered wearable sensors by synergistically integrating molecular engineering strategies with machine learning algorithms. Specifically, this study aims to: (1) enhance device performance and stability through rational functional group design; (2) develop robust self-powered platforms capable of sustainable operation without external power supplies, thereby improving practicality in real-world environments; (3) incorporate machine learning-driven data analytics to enhance the adaptability and accuracy of the sensors in complex data environments.

METHODS: For the fabrication of self-powered photodetectors, indium tin oxide (ITO)-coated glass substrates were sequentially ultrasonicated in detergent, deionized water, acetone, and 2-propanol, followed by ultraviolet-ozone treatment for 60 min. The TiO_x precursor solution was filtered through a 0.45 μm nylon membrane and spin-coated onto the substrates at 3000 rpm for 60 s, followed by thermal annealing at 200 °C for 60 min to yield a 20 nm thick film. A solution of 3,9-bis(2-methylene-(3-(1,1-dicyanomethylene)-indanone))-5,5,11,11-tetrakis(4-hexylphenyl)-dithieno[2,3-d:2′,3′-d′]-s-indaceno[1,2-b:5,6-b′]dithiophene (ITIC, 20 mg/mL in chlorobenzene) was filtered through a 0.45 μm polytetrafluoroethylene (PTFE) membrane and spin-coated at 2000 rpm for 60 s onto the TiO_x layer, followed by annealing at 80 °C for 10 min (thickness ≈ 40 nm). The $CH_3NH_3Sn_{0.25}Pb_{0.75}I_3$ perovskite precursor solution containing a metal–organic framework additive (UiO-66-NH_2, 20 mg/mL) was filtered through a 0.45 μm PTFE membrane and deposited via a two-step spin-coating process (1000 rpm for 10 s, followed by 5000 rpm for 40 s) in a nitrogen-filled glovebox. During the first 20 s of the second step, 400 μL of ortho-xylene was gently dropped onto the spinning substrate. The resulting films were annealed at 100 °C for 10 min, forming a ≈350 nm thick perovskite layer. Subsequently, a solution of poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine] (PTAA, 10 mg/mL in chloroform) containing 1 wt% molybdenum tris[1-(trifluoroethanoyl)-2-(trifluoromethyl)ethene-1,2-dithiolene] (Mo(tfd-$COCF_3$)$_3$) as a dopant and 5 wt% 1,2-bis[4-

(azidomethyl)phenyl]-1,2-diphenylethene (TPE-MN3) as a cross-linker was spin-coated atop the perovskite film. Crosslinking was carried out under UV irradiation (wavelength = 254 nm, intensity = 5 mW/cm²) for 4 min in an inert atmosphere. Finally, a 150 nm thick Ag electrode was deposited by thermal evaporation under high vacuum ($< 1 \times 10^{-6}$ Torr). As for the fabrication of triboelectric nanogenerators, hydrogels were prepared by dissolving acrylic acid (AA) and 3-dimethyl(methacryloyloxyethyl)ammonium propane sulfonate (DMAPS) monomers at a mass ratio of 4:1 in an ionic liquid. The ionic liquid content in the gel precursor solution was approximately 69.1 wt%. Ammonium persulfate (APS, 0.55 wt% relative to the total monomer weight) was added as a photoinitiator. After purging nitrogen and degassing under vacuum, the solution was poured into a quartz mold composed of a PDMS spacer sandwiched between two transparent glass plates. The hydrogel was then photo-crosslinked under UV light (wavelength = 365 nm) for 30 min to yield the final layer. The surface morphology, roughness, and surface potential of the samples were characterized using a tapping-mode atomic force microscope (Dimension Icon, Bruker), equipped with a Kelvin probe force microscopy module. The open-circuit voltage, short-circuit current, and charge density of the devices were measured using a digital oscilloscope (Rigol DS1102E), a low-noise current preamplifier (SR570, Stanford Research Systems), and an electrometer (Keithley 6517A), respectively.

CONCLUSIONS: This work demonstrates that combining molecular engineering with machine learning provides a powerful framework for advancing intelligent self-powered wearable sensors. By tuning interfacial properties through functional group design and enabling adaptive data analysis via machine learning, we achieved enhanced device performance, long-term stability, and multifunctionality. These findings highlight the broad potential of this strategy for next-generation sensing systems in both environmental and biomedical domains.

KEYWORDS: molecular engineering, machine learning, intelligent self-powered sensors, wearable electronics.

REFERENCES:

Chang, C.-Y., Cheng, Y.-H., & Ho, C.-Y. (2022a). Surface engineering of a triboelectric nanogenerator for room temperature high-performance self-powered formaldehyde sensors. *Journal of Material Chemistry A*, *10*, Article 22373. https://doi.org/10.1039/D2TA04433A

Chang, C.-Y., Wu, K.-S., & Chang, C.-Y. (2022b). N-type conjucated polymer as multi-functional interfacial layer for high-performance and ultra-stable self-powered photodetectors based on perovskite nanowires. *Advanced Functional Materials*, *32*(8), Article 2108356. https://doi.org/10.1002/adfm.202108356

Chang, C.-Y., Yang, J.-R., Liu, Y.-S., & Panda, A. (2024). Facile surface functionalization of triboelectric layers via electrostatically self-assembled zwitterionic molekules for achieving efficient and stable antibacterial flexible triboelectric nanogenerators. *Materials Horizons*, *11*(3), 646–660. https://doi.org/10.1039/D3MH01529G

Chang, C.-Y., Chin, Y.-L., Chang, C.-Y., & Holovský, J. (2025). Facile interface engineering enabled efficient and stable self-powered perovskite photodetectors for Versalite photosensing applications *Advanced Functional Materials*, *35*(20), Article 2422732. https://doi.org/10.1002/adfm.202422732

ADAPTIVE EMG SIGNAL PROCESSING AND NORMALIZATION STRATEGY FOR EMG-DRIVEN MUSCULOSKELETAL MODELS

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ABSTRACT

BACKGROUND: Accurate interpretation of electromyography (EMG) signals is essential for reliable control of musculoskeletal (MS) models in biomechanics and rehabilitation applications. Conventional preprocessing methods may not account for subject-specific signal characteristics and task-related muscle function.

OBJECTIVE: This study aimed to develop and validate an adaptive and personalised EMG preprocessing pipeline to enhance the physiological accuracy of EMG-driven musculoskeletal models during elbow flexion-extension tasks.

METHODS: EMG signals from six upper limb muscles were recorded using a Delsys system while participants performed elbow flexion-extension movements. The signals were preprocessed using individualized spectral filtering and a dual-stage normalization approach. First, dynamic maximum voluntary contraction (MVC) based min–max normalization was applied to standardize signal amplitudes. Second, functional weighting was used to scale each muscle's activation based on its biomechanical contribution to the movement. The processed signals were used as input to an OpenSim elbow model, and resulting joint kinematics were compared to reference motion data captured by an Xsens system.

RESULTS: The EMG-driven OpenSim model showed strong agreement with the Xsens data, with correlation coefficients exceeding 0.98 and root mean square error (RMSE) values below 8°. While a minor systematic offset was observed, joint angle trajectories remained consistent and physiologically plausible across trials.

CONCLUSIONS: The proposed subject-specific EMG preprocessing pipeline enhances the accuracy and interpretability of biomechanical models. Future research should explore adaptive signal alignment techniques and AI-based processing methods to improve model robustness in dynamic and wearable scenarios.

KEYWORDS: musculoskeletal simulation, EMG, signal normalization, OpenSim, muscle weighting, adaptive filtering.

REFERENCES:

Ao, D., Vega, M. M., Shourijeh, M. S., Patten, C., & Fregly, B. J. (2022). EMG-driven musculoskeletal model calibration with estimation of unmeasured muscle excitations via synergy extrapolation. *Frontiers in Bioengineering and Biotechnology*, *10*, Article 962959. https://doi.org/10.3389/fbioe.2022.962959

Cisnal, A., Gordaliza, P., Pérez Turiel, J., & Fraile, J. C. (2023). Interaction with a hand rehabilitation exoskeleton in EMG-driven bilateral therapy: Influence of visual biofeedback on the users' performance. *Sensors*, *23*(4), Article 2048. https://doi.org/10.3390/s23042048

Samarakoon, S. M. U. S., Herath, H. M. K. K. M. B., Yasakethu S. L. P., Fernando, D., Madusanka, N., Yi, N., & Lee, B.-I. (2025). Long short-term memory-enabled electromyography-controlled adaptive wearable robotic exoskeleton for upper arm rehabilitation. *Biomimetics*, *10*(2), Article 106. https://doi.org/10.3390/biomimetics10020106

Tahmid, S., Font-Llagunes, J. M., & Yang J. (2024). Upper extremity muscle activation pattern prediction through synergy extrapolation and electromyography-driven modeling. *Journal of Biomechanical Engineering*, *146*, Article 011005. https://doi.org/10.1115/1.4063899

Trigili, E., Grazi, L., Crea, S., Accogli, A., Carpaneto, J., Micera, S., Vitiello, N., & Panarese, A. (2019). Detection of movement onset using EMG signals for upper-limb exoskeletons in reaching tasks. *Journal of NeuroEngineering and Rehabilitation*, *16*, Article 45. https://doi.org/10.1186/s12984-019-0512-1

EFFECTS OF HIGH-VOLUME MECHANICAL LOADING ON THE CONTRACTILITY, STRUCTURE, AND MECHANICAL PROPERTIES OF THE TRICEPS SURAE MUSCLE-TENDON UNIT

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ABSTRACT

BACKGROUND: The triceps surae muscle–tendon unit (MTU) is crucial for force transmission and energy storage. Muscles adapt rapidly through neural and contractile changes, whereas tendon adaptations such as stiffness and structural remodeling occur more slowly (Arampatzis et al., 2007; Bohm et al., 2015). Intense or repeated loading can reduce Achilles tendon echo intensity and alter stiffness, with muscle function often recovering faster than tendon properties (Kubo et al., 2012; Wiesinger et al., 2015).

OBJECTIVE: To examine the effects of high-volume mechanical loading on contractility, structure, and mechanical properties of the triceps surae MTU in young, physically active males and females.

METHODS: Twenty-two participants (12 males, 10 females; age: 24.3 ± 4.2 years; BMI: 23.5 ± 2.5) completed a fatigue protocol of bilateral calf raises at 70 bpm, performed in 60-s sets with 120-s rest until exhaustion. Assessments were conducted at baseline, immediately post-exercise, and 24 h later. Muscle contractility was measured via peak torque (PT) and EMG; structure by ultrasound echo intensity (EI); and mechanical properties by passive stiffness and hysteresis efficiency.

RESULTS: Within 24 hours, Achilles tendon (AT) EI significantly decreased across all regions in both males and females ($p < 0.001$), whereas gastrocnemius EI remained unchanged. A significant reduction in AT CSA was observed immediately post-fatigue only in the middle portion of the females' AT ($p = 0.015$). Electromyographic analysis revealed a post-exercise decrease in gastrocnemius lateralis activation and an increase in soleus activation ($p < 0.01$). PT significantly declined in both sexes following the protocol ($p < 0.001$), with recovery observed after 24 hours. In males, the fatigue protocol led to significant increases in MTU stiffness, stored energy, and lost energy ($p < 0.001$), accompanied by a significant decrease in hysteresis efficiency ($p < 0.05$). After 24 hours, only lost energy remained significantly elevated ($p < 0.05$).

CONCLUSIONS: High-volume loading induces marked fatigue and early tendon changes, with muscle function recovering faster than tendon properties. These findings highlight a discrepancy in recovery timelines, underscoring the need for extended assessment to capture long-term adaptations.

KEYWORDS: Achilles tendon, echo intensity, ultrasound, muscle-tendon unit, mechanical properties.

REFERENCES:

Arampatzis, A., Karaminidis, K., & Albracht, K. (2007). Adaptational responses of the human Achilles tendon by modulation of the applied cyclic strain magnitude. *Journal of Experimental Biology*, *210*(15), 2743–2753. https://doi.org/10.1242/jeb.003814

Bohm, S., Mersmann, F., & Arampatzis, A. (2015). Human tendon adaptation in response to mechanical loading: A systematic review and meta-analysis of exercise intervention studies on healthy adults. *Sports Medicine – Open*, *1*, Article 7. https://doi.org/10.1186/s40798-015-0009-9

Kubo, K., Ikebukuro, T., Maki, A., Yata, H., & Tsunoda, N. (2012). Time course of changes in the human Achilles tendon properties and metabolism during training and detraining in vivo. *European Journal of Applied Physiology*, *112*, 2679–2691. https://doi.org/10.1007/s00421-011-2248-x

Wiesinger, H. P., Kösters, A., Müller, E., Seynnes, O. R. (2015). Effects of increased loading on in vivo tendon properties: A systematic review. *Medicine & Science in Sports & Exercise*, *47*(9), 1885–1895. https://doi.org/10.1249/MSS.0000000000000603

DESIGN AND DEVELOPMENT OF A WIRELESS GLOVE FOR GAMIFIED UPPER LIMB REHABILITATION IN PARKINSON'S DISEASE

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ABSTRACT

BACKGROUND: Upper extremity rehabilitation is critical for individuals with neurological disorders such as Parkinson's disease, where motor impairments significantly affect daily functionality (Frazzitta et al., 2015; Laver et al., 2017). Existing rehabilitation gloves often lack adaptability, comfort, wireless functionality, or integrated strength training elements.

OBJECTIVE: This study presents the design, development, and preliminary evaluation of a novel wireless rehabilitation glove aimed at enhancing motor recovery through gamified therapy tailored for Parkinson's disease.

METHODS: The glove integrates a lightweight forearm frame, palm component, and textile glove with embedded connectors. It was designed using anthropometric data and manufactured with PLA and flexible TPU via 3D printing to ensure comfort, modularity, and low cost. Resistance bands and hooks enable strength training, while wireless communication (ESP8266 microcontroller, Wi-Fi) streams motion data from IMU sensors to a computer interface. The system connects with the RehaBEElitation serious game (Cardoso Mendes et al., 2023), allowing users to control an avatar through hand and wrist movements, fostering motivation and engagement.

RESULTS: The 227.6 g prototype (60.3 g on the hand) reduced distal loading, with simulations confirming durability. Tests with healthy volunteers showed accurate wrist motion detection, ~90% pinch gesture reliability, stable 50 Hz transmission, and 70–100 ms real-time response.

CONCLUSIONS: The developed smart glove integrates motion capture, resistance training, and gamified therapy in a wireless, lightweight system. Its adaptable, user-centered design addresses key limitations of existing devices and shows strong potential for home-based rehabilitation in Parkinson's disease.

KEYWORDS: hand rehabilitation, wireless system, gamified therapy, smart glove, Parkinson's disease.

REFERENCES:

Cardoso Mendes, L., Abreu Rosa de Sá, A., Alves Marques, I., Morère Y., & de Oliveira Andrade, A. (2023). RehaBEElitation: The architecture and organization of a serious game to evaluate motor signs in Parkinson's disease. *PeerJ Computer Science*, *9*, Article e1267. https://doi.org/10.7717/peerj-cs.1267

Frazzitta, G., Maestri, R., Bertotti, G., Riboldazzi, G., Boveri, N., Perini, M., Uccellini, D., Turla, M., Comi, C., Pezzoli, G., & Ghilardi, M. F. (2015). Intensive rehabilitation treatment in early Parkinson's

disease: A randomized pilot study with a 2-year follow-up. *Neurorehabilitation and Neural Repair*, *29*(2), 123–131. https://doi.org/10.1177/1545968314542981

Laver, K. E., Lange, B., George, S., Deutsch, J. E., Saposnik, G., & Crotty, M. (2017). Virtual reality for stroke rehabilitation. *Cochrane Database of Systematic Reviews*, *11*, Article CD008349. https://doi.org/10.1002/14651858.CD008349.pub4.

INTEGRATING BIOMECHANICAL METRICS INTO CLINICAL PROSTHETIC DECISION MAKING

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ABSTRACT

BACKGROUND: Transfemoral amputation profoundly alters gait, often resulting in asymmetry, compensatory movement patterns, and increased musculoskeletal loading (Benton et al., 2024). Despite continuous progress in prosthetic knee technology, including the transition from mechanical to microprocessor-controlled systems, functional outcomes remain highly variable. A major challenge is that clinical decisions regarding prosthesis selection and adjustment are often guided by observation and patient feedback rather than objective biomechanical evidence (Persine et al., 2024). Without quantitative assessment, subtle gait deviations may go unnoticed until they contribute to long-term complications. Advanced biomechanical analysis provides an opportunity to capture precise kinematic and kinetic data, offering measurable metrics that can enhance clinical decision-making, improve prosthesis fitting, and support individualized rehabilitation strategies.

OBJECTIVE: To identify and evaluate biomechanical metrics that support clinical decision-making and enhance the individualization of prosthesis fitting in transfemoral amputees.

METHODS: In the study of biomechanical gait characteristics, a subject with a left above-knee amputation (male, 32 years old, height 192 cm, weight 94 kg) volunteered to participate. The participant was evaluated using two different prosthetic knee systems: a mechanical knee and a microprocessor-controlled knee. For each condition, gait trials were repeated six times with 1–2-minute breaks between walks. Kinematic data were collected using a Qualisys motion analysis system with 12 Oqus 7 cameras operating at 120 Hz. Ground reaction forces were recorded using two AMTI force plates. Additional treadmill-based gait analysis was performed with the Rehawalk HP Cosmos system in combination with the Zebris FDM-T, which integrates a pressure sensor matrix operating at 120 Hz.

RESULTS: Analysis revealed pronounced gait asymmetry with the mechanical knee, characterized by excessive pelvic obliquity of up to 12° on the prosthetic side. This was accompanied by shorter step length, reduced stance time, and asymmetric loading, indicating functional instability. In contrast, the microprocessor-controlled knee reduced pelvic obliquity to 5°, with more balanced step length and improved stance phase duration. Load distribution between limbs became more symmetrical, and hip joint motion more closely matched normative patterns.

CONCLUSIONS: This study demonstrated measurable gait differences, including kinematic and kinetic data. Motion analysis effectively identifies asymmetries and compensatory strategies that may not be visible through clinical observation alone.

Integrating these data into clinical workflows can support evidence-based decisions, optimize prosthesis alignment, and enhance individualized rehabilitation outcomes.

KEYWORDS: transfemoral amputation, leg prostheses, gait biomechanics, motion analysis.

REFERENCES:

Benton, A. M., Toderita, D., Egginton, N. L., Liu, S., Amiri, P., Sherman, K., Bennet, A. N., & Bull, A. M. J. (2024). Muscle recruitment during gait in individuals with unilateral transfemoral amputations wearing modern prostheses. *Bioengineering & Biotechnology*, *12*, Article 1429574. https://doi.org/10.3389/fbioe.2024.1429574

Persine, S., Leteneur, S., Gillet, C., Bassement, J., Charlaté, F., & Simoneau-Buessinger, E. (2024). Kinetic adaptations of the intact limb in transfemoral amputees using a microprocessor prosthetic knee. *Gait & Posture*, *108*, 170–176. https://doi.org/10.1016/j.gaitpost.2023.11.022

CNN-BASED ENSEMBLE ARCHITECTURES WITH EXPLAINABLE AI FOR CUTANEOUS MELANOMA IDENTIFICATION

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ABSTRACT

BACKGROUND: In recent years, the application of deep learning, particularly Convolutional Neural Networks (CNNs), have revolutionized medical image analysis by significantly enhancing diagnostic accuracy and efficiency (Powroznik et al., 2024; Skublewska-Paszkowska et al., 2024). CNNs have demonstrated superior performance in detecting and classifying melanoma from dermoscopic images (Ahmad et al., 2025). Modern techniques such as ensemble learning allow one to combine single models by leveraging their strengths of feature extraction, and as a result, obtaining more reliable architecture.

OBJECTIVE: The aim of this study is to develop and evaluate the effectiveness of deep neural networks for the automatic diagnosis and classifying benign and malignant melanoma. Ensemble learning approaches are examined to leverage the strengths of individual models for superior diagnostic performance.

METHODS: Three pre-trained deep learning models, ResNet152, DenseNet201 and EfficientNet-B4, were involved in order to detect benign and malignant melanoma skin lesions. The study utilized combined ISIC datasets gathered between 2018 and 2020 that consist of dermoscopic images. The above-mentioned deep learning algorithms were verified using accuracy, precision, recall, and F1-score metrics. The performance of skin cancer detection was enhanced utilizing soft, hard voting, and XGBoost ensemble learning methods.

RESULTS: This study identified EfficientNet-B4 as the optimal pre-trained model for melanoma classification, providing the highest accuracy (90.4%) and stability on the test dataset. This architecture outperformed all other models in key metrics, achieving an F1 score of 90.6%, indicating an excellent balance between precision (90.8%) and sensitivity (90.4%). The Grad-CAM technique proved that this model concentrates on the lesion's irregular edges and darker regions that reflect to features characteristic of melanoma, which often presents with asymmetry, irregular borders, and variable pigmentation. The soft voting ensemble learning of all three models (ResNet152, Dense-Net201, and EfficientNet-B4) achieved the highest accuracy (91.3%), confirming the effectiveness of this method. The combination of ResNet152 and EfficientNet-B4 also obtained an accuracy of 91.3%, suggesting that these models classify exceptionally well together.

CONCLUSIONS: The findings of this study have the potential to significantly impact the field of dermatology by providing a reliable tool for early melanoma detection, ultimately improving patient survival rates.

KEYWORDS: melanoma, skin cancer identification, deep learning, CNN, ensemble learning.

REFERENCES:

Ahmad, M., Ahmed, I., Chehri, A., & Jeon, G. (2025). Fusion of metadata and dermoscopic images for melanoma detection: Deep learning and feature importance analysis. *Information Fusion*, *124*, Article 103304. https://doi.org/10.1016/j.inffus.2025.103304

Powroznik, P., Skublewska-Paszkowska, M., Nowomiejska, K., Aristidou, A., Panayides, A., & Rejdak, R. (2024). Deep convolutional generative adversarial networks in retinitis pigmentosa disease images augmentation and detection. *Advances in Science and Technology Research Journal*, *19*(2), 321–340. https://doi.org/10.12913/22998624/196179

Skublewska-Paszkowska, M., Powroznik, P., Rejdak, R., & Nowomiejska, K. (2024). Application of convolutional gated recurrent units U-net for distinguishing between retinitis pigmentosa and cone–rod dystrophy. *Acta Mechanica et Automatica*, *18*(3), 505–513. https://doi.org/10.2478/ama-2024-0054

AN EXPLAINABLE AI ENSEMBLE MODEL FOR ACQUIRED VITELLIFORM LESION IDENTIFICATION

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ABSTRACT

BACKGROUND: Retinal diseases gradually weaken eyesight and may even potentially lead to blindness. Recognizing changes in the retina-based OCT imaging allows for the detection of diseases at their early stages and thus for making an appropriate diagnosis. In this study, acquired vitelliform lesions (AVL), drusen, and healthy cases are identified utilizing various CNN-based architectures, such as the Convolutional Gated Recurrent Units U-Net, Deep CNN-GRU Network, Residual Attention CNN. The dataset consisting of OCT images was created using photographs gathered from two research centers and publicly available OCT database (Powroznik et al., 2025).

OBJECTIVE: The main aim of this study is to develop an accurate automatic tool to identify AVL and Drusen distortions, and to distinguish them from healthy cases. For this purpose, the CNN-based models are proposed. Moreover, three ensemble learning methods are applied to create the most effective architecture.

METHODS: Three single models obtained to be very effective in recognition the retinal diseases: Convolutional Gated Recurrent Units U-Net, Deep CNN-GRU Network, Residual Attention CNN. In order to further enhance the performance of AVL, drusen, and normal cases identification, bagging, boosting, and stacking of ensemble learning methods for all models were applied (Powroznik et al., 2024).

RESULTS: The single models reached the accuracy of 85.59%–92.12%, while the bagging, boosting, and stacking obtained the accuracy of 97.41%, 96.89%, 97.93%, respectively.

CONCLUSIONS: This study gives in-depth insight into AVL, drusen, and normal cases identification. Moreover, Grad-CAM method was applied to visualize the most relevant image areas based on which CNN models provide their decision-making.

KEYWORDS: retinal diseases, AVL, DRUSEN, GRU U-Net, Deep CNN-GRU Network, ensemble learning.

REFERENCES:

Powroznik, P., Skublewska-Paszkowska, M., Nowomiejska, K., Gajda-Deryło, B., Brinkmann, M., Concilio, M., Toro, M. D., & Rejdak, R. (2025). Residual self-attention vision transformer for detecting acquired vitelliform lesions and age-related macular drusen. *Scientific Reports*, *15*, Article 17107. https://doi.org/10.1038/s41598-025-02299-y

Powroznik, P., Skublewska-Paszkowska., M., Rejdak, R., & Nowomiejska, K. (2024). Automatic method of macular diseases detection using deep CNN-GRU network in OCT images. *Acta Mechanica et Automatica*, *18*(4), 697–706. https://doi.org/10.2478/ama-2024-0074

SELF-POWERED HYDROGEL TRIBOELECTRIC SENSORS FOR REAL-TIME GAIT MONITORING

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ABSTRACT

BACKGROUND: Various techniques are used to capture human body motion, such as IMUs and marker-based video camera systems, but each of these systems requires a power source. The triboelectric nanogenerator (TENG) has been described in the scientific literature (Fan et al., 2012), The sensor is based on the interaction of electrostatic induction and friction effects. According to their energy-generation principle, nanogenerators are classified into three categories: piezoelectric nanogenerators (PENG), pyroelectric nanogenerators (PyNG), and triboelectric nanogenerators (TENG) (Zhou et al., 2025). Hydrogel-based TENGs can be classified into four categories according to the polymer type: polyacrylamide (PAM), polyvinyl alcohol (PVA), cellulose, and other hydrogels (Wei & Sun, 2025). TENGs can readily generate voltages from several hundred volts to even tens of kilovolts, with currents in the microampere range (Tang et al., 2025).

OBJECTIVE: The aim of the study is to test and apply the Hydro-TENG sensor for real-time gait analysis.

METHODS: During the experiment, two Hydro-TENG sensors were used, attached to the subject's heel and toes. A 10 kΩ resistor was connected to the Hydro-TENG sensors, and the assembly was interfaced with the Shimmer3 (Proto3 Deluxe) via a TRRS cable. The Shimmer3 (Proto3 Deluxe) has two analog inputs, allowing two Hydro-TENG sensors to be connected for human gait analysis.

RESULTS: Based on the detected angular velocity peaks, the Hydro-TENG sensor generates the highest voltage during heel contact and during the lifting of the toes.

CONCLUSIONS: The chosen mounting locations allow detecting the main gait events, thereby identifying gait in real time.

KEYWORDS: triboelectric nanogenerator (TENG), IMU, GAIT, Hydrogel.

REFERENCES:

Fan, F.-R., Tian, Z.-Q., & Wang, Z. L. (2012). Flexible triboelectric generator. *Nano Energy*, *1*(2), 328–334. https://doi.org/10.1016/j.nanoen.2012.01.004

Tang, Y., Liu, X., Xiong, Y., Xu, B., & Zhou, Y. (2025). Emerging frontiers in triboelectric nanogenerator for biohealth apparatus. *Nano Energy*, *138*, Article 110844. https://doi.org/10.1016/j.nanoen.2025.110844

Wei, R., & Sun, S. (2025). A MXene-based double-network conductive hydrogel triboelectric nanogenerator for intelligent sports monitoring. *Energy Reports*, *13*, 3773–3781. https://doi.org/10.1016/j.egyr.2025.03.028

Zhou, T., Wei, J., Zhang, X., Wu, L., Guo, S., An, Q., Feng, Z., & Guo, K. (2025). Design and construction of high-performance triboelectric nanogenerators and their biomedical applications. *Applied Materials Today*, *42*, Article 102570. https://doi.org/10.1016/j.apmt.2024.102570

APPLICATION OF DEEP LEARNING TO TOMOGRAPHIC PROJECTION SEGMENTATION FOR METAL ARTIFACT REDUCTION IN CBCT

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ABSTRACT

BACKGROUND: Accurate segmentation of structures such as metallic implants is a key step in medical image processing. This paper presents a method for automatic segmentation of implants in CT projections using a U-Net convolutional network (Liang et al., 2019, Zhu et al., 2021).

OBJECTIVE: The aim of the study was to develop and test a model that would allow the precise extraction of areas containing metal implants, which are a source of significant interference in tomograms.

METHODS: The U-Net model was trained on a dataset comprising projections with metallic implants and corresponding manually annotated binary masks. Segmentation performance was assessed using Precision, Recall, Jaccard Index, and Accuracy. To ensure statistical robustness, results were analyzed on 50 randomly selected test images (Ronneberger et al., 2015).

RESULTS: The average metric scores were: Precision 0.9831, Recall 0.9752, Jaccard 0.9589, and Accuracy 0.9983. The Shapiro–Wilk test indicated non-normal data distribution ($p < 0.001$ for all metrics), justifying the use of non-parametric statistics. A one-sample Wilcoxon test confirmed that all metrics significantly exceeded the reference threshold of 0.9 ($p < 0.0001$).

CONCLUSIONS: The results indicate that the trained U-Net model is highly effective in the task of segmenting implants in projections. The quality of the generated masks enables their further use in the processes of interpolating sinograms and improving the quality of reconstruction images, which was confirmed in the study (Bousias Alexakis & Armenakis, 2020; Ronneberger et al., 2015).

KEYWORDS: artificial neural network, CT, image reconstruction, metal artifact reduction, medical images.

REFERENCES:

Bousias Alexakis, E., & Armenakis, C. (2020). Evaluation of UNet and UNet++ architectures in high resolution image change detection applications. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *43*, 1507–1514. https://doi.org/10.5194/isprs-archives-XLIII-B3-2020-1507-2020

Liang, K., Zhang, L., Yang, Y., Chen, Z., & Xing, Y. (2019). Metal artifact reduction for practical dental computed tomography by improving interpolation-based reconstruction with deep learning. *Medical Physics*, *46*(12), e823–e834. https://doi.org/10.1002/mp.13644

Ronneberger, O., Fischer, P. & Brox, T. (2015). U-net: Convolutional networks for biomedical image segmentation. In N. Navab, J. Hornegger, W. Wells, & A. Frangi (Eds.), *Lecture notes in computer science: Vol. 9351. Medical image computing and computer-assisted intervention–MICCAI 2015* (pp. 234–241). Springer. https://doi.org/10.1007/978-3-319-24574-4_28

Zhu, L., Han, Y., Xi, X., Li, L., & Yan, B. (2021). Completion of metal-damaged traces based on deep learning in sinogram domain for metal artifacts reduction in CT images. *Sensors*, *21*(24), Article 8164. https://doi.org/10.3390/s21248164

NEAR-INFRARED REFLECTANCE PULSE OXIMETRY: PROOF OF CONCEPT STUDY

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ABSTRACT

BACKGROUND: Transmission mode pulse oximeters are widely used for non-invasive blood oxygen saturation (SaO2) measurements (Nitzan et al., 2014). They commonly exploit photoplethysmography (PPG) signals at red-NIR wavelength pairs (e.g. 660/940 nm) with different penetration depths in skin. In reflectance mode, differences in photon path lengths in skin at both wavelengths cause calibration and accuracy problems.

OBJECTIVE: To investigate whether arterial oxygen saturation (SaO2) can be reliably measured using a pair of selected near-infrared (NIR) wavelengths with similar penetration depths and photon path lengths in skin.

METHODS: We performed photoplethysmography (PPG) measurements at promising from this point 808 nm and 1064 nm wavelengths of lasers and LEDs. The backscattered PPG pulses were recorded using an originally developed measurement setup, focusing on the AC signal amplitudes and the AC-DC component amplitude ratios.

RESULTS: Detectability of reflectance PPG signals from fingers and other body sites by Si-photodiodes was demonstrated at both working wavelengths, so confirming their suitability for pulse oximetry. To achieve controllable reduction of SaO2, arterial cuffs and inhaling of a hypoxic gas mixture with reduced oxygen concentration were applied. As expected, the SaO2 level decreased with growing cuff pressure and with lower oxygen content in the inhaled gas.

CONCLUSIONS: Our results supported potential of using the 808/1064 nm or close to them NIR wavelength pairs (e.g. emitted by double-wavelengths semiconductor micro-lasers) for exploitation in future reflectance pulse oximeters. If compared with the "classical" 660nm/940nm wavelength pair, the differences of oxy- and deoxy-hemoglobin absorption in this NIR spectral range are several times lower, so special attention in further studies should be paid to proper NIR-PPG signal acquisition and processing.

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KEYWORDS: pulse oximetry, photoplethysmography, near-infrared, blood oxygenation.

REFERENCES:

Nitzan, M., Romem, A., & Koppel, R. (2014). Pulse oximetry: Fundamentals and technology update. *Medical Devices: Evidence and Research*, *7*, 231–239. https://doi.org/10.2147/MDER.S47319

EFFECT OF SILICONE MODIFIERS ON SELECTED PROPERTIES OF CERAMICS FABRICATED BY DIRECT INK WRITING

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ABSTRACT

BACKGROUND: Ceramic materials are valued in biomedical engineering for their hardness, chemical resistance, and biocompatibility, but their brittleness and low fracture toughness limit wider applications (Vaiani et al., 2023). Additive manufacturing, particularly direct ink writing (DIW), enables the production of complex ceramic structures with controlled geometry and porosity (Alparslan & Bayraktar, 2025). Despite advantages, challenges remain regarding ink rheology, sintering shrinkage, and mechanical stability. The use of silicone-based modifiers, such as polysiloxanes and preceramic polymers, offers a way to improve printability, enhance strength, and reduce cracking during processing (Francis, 2021).

OBJECTIVE: The aim of the study was to evaluate the influence of various silicone-based modifiers on the phase stability and compressive strength of corundum ceramics produced by the DIW method.

METHODS: The study used a corundum ceramic paste made of fine-grained aluminum oxide (Al_2O_3) with a glycerol-water binder, modified with Silres BS OH 100 and HMS 504 additives in concentrations of 1.5 and 3% by weight. The samples were prepared using the DIW method, dried in two stages, and sintered at 1000 °C for 1 hour. Their structural and mechanical properties were evaluated using X-ray diffraction and compressive strength tests.

RESULTS: XRD analysis confirmed that all samples, both modified and unmodified, exhibited corundum (α-Al_2O_3) diffraction peaks, indicating that the silicone modifiers had no effect on phase stability. The unmodified ceramics had a compressive strength of approximately 21 MPa. The addition of Silres BS OH 100 only slightly improved the strength, reaching 24.7 ± 2.7 MPa at 3%. In contrast, HMS 504 significantly increased the strength to 39.4 ± 3.2 MPa at 3%. These results indicate that the type of modifier strongly influences the microstructural and mechanical properties of ceramics produced by the DIW method.

CONCLUSIONS: The study showed that the effectiveness of silicone modifiers in corundum ceramics produced by the DIW method depends on their type and concentration, while XRD analysis confirmed no effect on phase stability. Silres BS OH 100 had a limited effect, while HMS 504 significantly improved mechanical properties, especially at a concentration of 3%.

KEYWORDS: ceramic, direct ink writing, DIW method, 3D printing, silicone modifiers.

REFERENCES:

Alparslan, C., & Bayraktar, Ş. (2025). Advances in digital light processing (DLP) bioprinting: A review of biomaterials and its applications, innovations, challenges, and future perspectives, *Polymers*, *17*(9), Article 1287. https://doi.org/10.3390/polym17091287

Francis, A. (2021). Biological evaluation of preceramic organosilicon polymers for various healthcare and biomedical engineering applications: A review. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, *109*(5), 744–764. https://doi.org/10.1002/jbm.b.34740

Vaiani, L., Boccaccio, A., Uva, A. E., Palumbo, G., Piccininni, A., Guglielmi, P., Cantore, S., Santacroce, L., Charitos, I. A., & Ballini, A. (2023). Ceramic materials for biomedical applications: An overview on properties and fabrication processes. *Journal of Functional Biomaterials*, *14*(3), Article 146. https://doi.org/10.3390/jfb14030146

A PLUSH ROBOT WITH CAPACITIVE SENSING FOR TACTILE INTERACTION RECOGNITION AND RESPONSIVE BEHAVIOUR

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ABSTRACT

BACKGROUND: In recent years, interest in robotic toys for social, psychological, and pedagogical applications has increased. Interactive devices can stimulate learning in both neurotypical children (Salma et al., 2025) and those with developmental disorders, such as autism (Marzano et al., 2021). Our team has developed a plush robotic toy in the form of a stuffed animal, integrating flexible capacitive textile sensors into its fur to preserve softness and comfort. While microchips for capacitive readout are widely available, it remains uncertain whether capacitance waveforms can be reliably used to classify tactile interactions such as touches, squeezes, or impacts.

OBJECTIVE: The objective of the study was the validation of the plush robot's capacitive sensing through the development of an AI-supported algorithm for tactile interaction recognition.

METHODS: The toy was developed as a plush cat with capacitive sensors integrated into eight anatomical zones: nose, ears, head, neck, back, belly, paws, and tail. Sensor capacitance was measured using the IQS7222C-001-QNR integrated circuit, controlled by an ESP32-WROVER-E processor that also provides Classic Bluetooth™ connectivity. Interaction trials were conducted with both adult and child volunteers, who performed representative tactile behaviors classified as socially acceptable (e.g., stroking, holding) and non-acceptable or aggressive (e.g., hitting, squeezing). In total, 1,275 waveforms were recorded; 80% were used for training a one-dimensional convolutional neural network (CNN), and 20% were reserved for testing.

RESULTS: The developed AI-based algorithm achieved a classification accuracy of 82%, distinguishing between strokes, scratches, taps, kicks, holding, and squeezing.

CONCLUSIONS: The research demonstrated that capacitive sensors, combined with an AI algorithm, can provide sufficient touch detection accuracy to enable implementation within a toy behavioral response algorithm. Nevertheless, further data collection is required, particularly of additional types of tactile interactions not included in the initial study, to improve performance.

KEYWORDS: haptic feedback, capacitive sensors, textile sensors, interactive toys, smart toys.

REFERENCES:

Marzano, G., Zorzi, S., & Tambato, V. (2021). Improving social communication skills in Autism spectrum disorders using programmable toy robots. *Proceedings of the International Scientific Conference*, *3*, 173–184. https://doi.org/10.17770/sie2021vol3.6149

Salma, Z., Hijón-Neira, R., Pizarro, C., & Abdul Moqeet, A. (2025). Effectiveness of robot-mediated learning in fostering children's social and cognitive development. *Applied Sciences*, *15*(7), Article 3567. https://doi.org/10.3390/app15073567

LABEL PROPAGATION FOR IDENTIFYING NOISY LABELS IN CERVICAL CYTOLOGY

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ABSTRACT

BACKGROUND: As computer-aided diagnosis of medical images advances and machine learning models become more sophisticated, the issue of inconsistent initial manual annotations – known as noisy labels – becomes a critical, non-negligible factor. These noisy labels significantly compromise the accuracy and performance of machine learning models.

OBJECTIVE: Devising and evaluating a high-accuracy method for identifying and eliminating noisy labels from cervical cytology image datasets, which is inherently difficult due to the challenge of discretely categorizing a continuous pathological progression, further compounded by inconsistency among multiple annotators

METHODS: We devised an unsupervised learning methodology that involves building a similarity graph from the image data, where each node represents an image, and then focusing on the mismatch between node similarity and the assigned labels. The core technique is leveraging label propagation to detect this mismatch. Because label propagation is intrinsically a semi-supervised learning method, the primary challenge lies in two areas: adapting it for unsupervised use and determining the optimal strategy for selecting the initial nodes to start the propagation process.

RESULTS: Our method achieved the highest accuracy on synthetic noise ratios up to 19%, surpassing the baseline established by the repeated cross-validations method across two types of cervical cytology image data: our own prepared dataset and the benchmark Herlev dataset.

CONCLUSIONS: We demonstrated the effectiveness of our label propagation-based method for identifying noisy labels in cervical cytology. This was shown by comparing its performance against the current state-of-the-art method across a range of practical noise ratios, and by analyzing how the selection of the initial nodes influences the accuracy of the label propagation execution.

KEYWORDS: similarity graph, label propagation, noisy label, graph clique.

REFERENCES:

Chen, J., Ramanathan, V., Xu, T., & Martel, A. L. (2024). Detecting noisy labels with repeated cross-validations. In M. G. Linguraru, Q. Dou, A. Feragen, S. Giannarou, B. Glocker, K. Lekadir, & J. A. Schnabel (Eds.), *Lecture notes in computer science: Vol. 15010. Medical image computing and computer assisted intervention – MICCAI 2024* (pp. 197–207). Springer. https://doi.org/10.1007/978-3-031-72117-5_19

Iida, Y., Mrazovac, B, Ishigure, Y., Sato, I., & Niimi, A. (2025, July 12–13). Unreliable annotation detection with similarity graph in cervical cytology. In *Proceedings of the IEEE International Conference on Intelligent Methods, Systems, and Applications* (pp. 395–400). Giza, Egypt. IEEE. https://doi.org/10.1109/IMSA65733.2025.11166957

Nambu, Y., Mariya, T., Shinkai, S., Umemoto, M., Asanuma, H., Sato, I., Hirohashi, Y., Torigoe, T., Fujino, Y., & Saito T. A. (2022). screening assistance system for cervical cytology of squamous cell atypia based on a two-step combined CNN algorithm with label smoothing. *Cancer Medicine*, *11*(2), 520–529. https://doi.org/10.1002/cam4.4460

Northcutt, C., Jiang, L., & Chuang, I. (2021). Confident learning: Estimating uncertainty in dataset labels. *Journal of Artificial Intelligence Research*, *70*, 1373–1411. https://doi.org/10.1613/jair.1.12125

MCADS: SIMULTANEOUS DETECTION AND ANALYSIS OF 18 CHEST RADIOGRAPHIC ABNORMALITIES USING MULTI-LABEL DEEP LEARNING

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ABSTRACT

BACKGROUND: Chest radiography remains a fundamental diagnostic tool for evaluating thoracic disease, yet its interpretation demands considerable time and specialized expertise. Worldwide shortages of trained radiologists and lengthy report turnaround times can delay treatment decisions and increase the risk of diagnostic errors.

OBJECTIVE: This work introduces MCADS (Multi-label Chest Abnormality Detection System), a deep-learning driven platform designed to automatically identify and interpret 18 distinct radiographic abnormalities in a single chest X-ray within seconds.

METHODS: MCADS integrates pre-trained convolutional neural network – DenseNet121 from TorchXRayVision – to balance breadth of pathology coverage with rapid inference. Images are uploaded and processed asynchronously on a central server to avoid interrupting clinical workflows. To enhance transparency and clinician confidence, the system employs Gradient-weighted Class Activation Mapping (Grad-CAM) to overlay heatmaps that pinpoint regions most influential to each predicted abnormality.

RESULTS: When evaluated on large, publicly available datasets (NIH ChestX-ray14, Stanford CheXpert, and MIMIC-CXR), MCADS achieved high area-under-the-curve performance metrics across all 18 target conditions. The platform consistently produced accurate, multi-condition analyses in under ten seconds per image.

CONCLUSIONS: MCADS demonstrates the potential to markedly accelerate chest X-ray interpretation by delivering fast, reliable, and explainable multi-abnormality screening. Its deployment could substantially reduce radiologist workload, mitigate diagnostic delays, and ultimately improve patient care within data-driven healthcare environments.

KEYWORDS: Chest radiography, deep learning, multi-label classification, TorchXRayVision, grad-CAM, diagnostic imaging, Convolutional Neural Networks (CNN), medical image analysis, automated diagnosis.

REFERENCES:

Cohen, J. P., Viviano, J. D., Bertin, P., Morrison, P., Torabian, P., Guarrera, M., Lungren, M. P., Chaudhari, A., Brooks, R., Hashir, M., & Bertrand, H. (2021). *TorchXRayVision: A library of chest X-ray datasets and models.* Arxiv. https://doi.org/10.48550/arXiv.2111.00595

MINIMUM BIOMECHANICAL REQUIREMENTS FOR PHYSIOTHERAPY EXERCISES AND ACTIVITIES OF DAILY LIVING

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ABSTRACT

BACKGROUND: The knee joint is one of the most common areas to suffer injuries or be affected by surgery. Physiotherapy rehabilitation could be a way to improve outcomes. Still there is a lack of evidence regarding the adequate rehabilitation practice following surgery/injury (Konnyu et al., 2023; Jenkins et al., 2022; Risberg et al., 2004). To recommend appropriate exercises, the demands on the knee joint during these exercises and during activities of daily living (ADLs) must be known.

OBJECTIVE: Assess knee kinematics, joint loading and muscle activity of knee flexors and extensors during selected physiotherapy exercises and ADLs.

METHODS: 30 healthy subjects (age: 22.8 ± 2.1 y, height: 172 ± 8 cm, weight: 67.9 ± 10.5 kg) were recruited. Motion data was recorded at 60 Hz using a marker-less motion capture system (CapturyLive v255, TheCaptury, Germany). Ground reaction forces were recorded at 600 Hz. An instrumented chair and staircase were built, to record forces during sit-to-stand movements and stair walking. Recorded kinematic and kinetic data were used as input for musculoskeletal simulations (AMS, v7.4.4, AnyBody Technology, Denmark).

RESULTS: Results showed that lunges, squats, gait, and stair walking involved high biomechanical demands, while tasks such as balance shifts and single leg stands required considerably less. Interestingly, ADLs like gait and stair walking demonstrated higher requirements than many physiotherapy exercises.

CONCLUSIONS: Patients typically receive physiotherapy following knee joint surgery/injury. Knowledge about the demands associated with physiotherapy exercises and ADLs are a step towards biomechanically informed exercise selection and the development of personalized rehabilitation programs.

KEYWORDS: personalized rehabilitation, musculoskeletal simulation, knee kinematics, knee kinetics.

REFERENCES:

Jenkins, S. M., Guzman, A., Gardner, B. B., Bryant, S. A., Rayos del Sol, S., McGahan, P., & Chen, J. (2022). Rehabilitation after anterior cruciate ligament injury: Review of current literature and recommendations. *Current Reviews in Musculoskeletal Medicine*, *15*, 270–179. https://doi.org/10.1007/s12178-022-09752-9

Konnyu, K. J., Thoma, L. M., Cao, W., Aaron, R. K., Panagiotou, O. A., Bhuma, M. R., Adam, G. P., Balk, E. M., & Pinto, D. (2023). Rehabilitation for total knee arthroplasty: A systematic review. *American*

Journal of Physical Medicine & Rehabilitation, *102*(1), 19–33. https://doi.org/10.1097/PHM.0000000000002008

Risberg, M. A., Lewek, M., & Snyder-Mackler, L. (2004). A systematic review of evidence for anterior cruciate ligament rehabilitation: How much and what type? *Physical Therapy in Sport*, *5*(3), 125–145. https://doi.org/10.1016/j.ptsp.2004.02.003

IMPLEMENTING EUROHEART-BASED DIGITAL SOLUTIONS IN MYOCARDIAL INFARCTION REGISTRY CLUSTERS IN LITHUANIA: A PILOT STUDY

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ABSTRACT

BACKGROUND: Cardiovascular diseases (CVD) are the leading cause of mortality in Lithuania. Improving CVD prevention, diagnosis, treatment, and monitoring requires the real-time collection of high-quality datasets.

OBJECTIVE: Vilnius University Hospital Santaros Klinikos and its partners' pilot project aimed to adopt a hospital information system (HIS) to facilitate data transfer to the EuroHeart system developed by the European Society of Cardiology (*EuroHeart Registry IT Platform*, Wallentin et al., 2019).

METHODS: The participating institutions updated their HIS for consistent data collection on CVD monitoring indicators. Three clinics were linked to a unified integration database via an ETL Agent Service. An Integration Data exchange platform synchronized local databases with a central ontology through secure VPN channels, incorporating data from external registers like the National Deaths Register and Health Insurance Register. Real-time reporting dashboards with 24 indicators, data quality analysis tools, and standardized data export services were created.

RESULTS: A platform was developed to standardize heterogeneous healthcare datasets, enabling real-time analytics and periodic integration with EuroHeart. A specific ontology was established to support interoperable data exchange, allowing Lithuanian healthcare institutions to engage in European research networks. A set of quality metrics-maintained data integrity, and specialized tools were designed for real-time analysis.

CONCLUSIONS: This system has the potential to effectively analyze and monitor CVD data from healthcare institutions nationwide. It streamlines data collection, enhances analytical capabilities, and ultimately improves health outcomes.

KEYWORDS: cardiovascular diseases (CVD), myocardial infarction, electronic health records (EHR), Euroheart registry, eHealth systems integration, and secondary health data.

REFERENCES:

EuroHeart Registry IT Platform. (n.d.). Retrieved June 20, 2025, from https://www.escardio.org/Research/euroheart/EuroHeart-Registry-IT-Platform

Wallentin, L., Gale, C. P., Maggioni, A., Bardinet, I., & Casadei, B. (2019). EuroHeart: European Unified Registries on heart care evaluation and randomized trials. *European Heart Journal*, *40*(33), 2745–2749. https://doi.org/10.1093/eurheartj/ehz599

STRESS RESPONSE OF DEGENERATIVE KNEE CARTILAGE UNDER MILD CYCLIC LOADING: INSIGHTS FROM EXPERIMENTAL DATA AND FINITE ELEMENT MODELING

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ABSTRACT

BACKGROUND: Osteoarthritis is a degenerative disease associated with cartilage wear, pain, and loss of joint function. While excessive mechanical loading accelerates degeneration, mild cyclic loading may help maintain cartilage homeostasis. However, the biomechanical response of degenerated cartilage under low-intensity cyclic loads remains insufficiently described.

OBJECTIVE: To analyze the stress state of degenerative knee joint cartilages subjected to mild cyclic loads by combining experimental measurements with finite element modeling.

METHODS: A three-dimensional finite element model of the knee joint was reconstructed from CT images and included femur, tibia, cartilages, and meniscus. Cortical and trabecular bone tissues were modeled as elastic continuum, while meniscus and cartilage were described using nonlinear experimental stress–strain data. Human cartilage explants from a stage III osteoarthritis patient were tested with a SAUTER FH 5 dynamometer, revealing nonlinear behavior and elastic hysteresis. The obtained force–displacement curves were incorporated into the numerical model. Various displacement loads were applied to simulate mild physiological loading.

RESULTS: Experimental analysis showed that degenerated cartilage retained elastic hysteresis behavior under stresses up to 0.13 MPa, with clear energy dissipation during loading–unloading cycles. Simulations demonstrated that preserved cartilage integrity ensured uniform stress distribution, while structural defects, such as longitudinal tears, produced localized stress concentrations. Additional modeling further emphasized the role of soft tissue integrity in balancing load transfer and highlighted distinct differences in stress redistribution patterns between intact and compromised tissues. These tendencies suggest that even mild cyclic loading may produce divergent mechanical responses depending on the structural condition of the cartilage.

CONCLUSIONS: Mild cyclic loading does not induce harmful stress concentrators in degenerative cartilage with preserved integrity, confirming its therapeutic potential in rehabilitation. However, when soft tissue integrity is lost, stress amplification occurs in subchondral bone, elevating the risk of microdamage. These findings underline the importance of tailoring physiotherapy and mechanical load regimes to the structural condition of the cartilage in osteoarthritis patients.

KEYWORDS: cartilage, finite element method, knee joint, meniscus, numerical modeling.

REFERENCES:

Ageberg, E., & Roos, E. M. (2015). Neuromuscular exercise as treatment of degenerative knee disease. *43*(1), 14–22. https://doi.org/10.1249/JES.0000000000000030

Alekna, V., Ardatov, O., Selivonec, J., & Chabarova, O. (2023). In Silico modeling the impact of cartilage stiffness on bone tissue stress. *Applied Sciences*, *13*(7), Article 4457. https://doi.org/10.3390/app13074457

Ardatov, O., Aleksiuk, V., Maknickas, A., Stonkus, R., Uzieliene, I., Vaiciuleviciute, R., Pachaleva, J., Kvedaras, G., & Bernotiene, E. (2023). Modeling the impact of meniscal tears on von mises stress of knee cartilage tissue. *Bioengineering*, *10*(3), Article 314. https://doi.org/10.3390/bioengineering10030314

Bomer, N., Cornelis, F. M. F., Ramos, Y. F. M., den Hollander, W., Storms, L., van der Breggen, R., Lakenberg, N., Slagboom, P. E., Meulenbelt, I., & Lories, R. J. L. (2016). The effect of forced exercise on knee joints in Dio2$^{-/-}$ mice: Type II iodothyronine deiodinase-deficient mice are less prone to develop OA-like cartilage damage upon excessive mechanical stress. *Annuals of the Rheumatic Diseases*, *75*(3), 571–577. https://doi.org/10.1136/annrheumdis-2014-206608

Caravaggi, P., Assirelli, E., Ensini, A., Ortolani, M., Mariani, E., Leardini, A., Neri, S., & Belvedere, C. (2021). Biomechanical-based protocol for in vitro study of cartilage response to cyclic loading: A proof-of-concept in knee osteoarthritis. *Frontiers in Bioengineering and Biotechnology*, *9*, Article 634327. https://doi.org/10.3389/fbioe.2021.634327

Chavda, S., Rabbani, S. A., & Wadhwa, T. (2022). Role and effectiveness of intra-articular injection of Hyaluronic Acid in the treatment of knee osteoarthritis: A systematic review. Cureus, *14*(4), Article e24503. https://doi.org/10.7759/cureus.24503

Deng, X., Xu, H., Hao, X., Liu, J., Shang, X., & Tao, X. (2023). Effect of moderate exercise on osteoarthritis. *Effort Open Reviews*, *8*(3), 148–161. https://doi.org/10.1530/EOR-22-0119

Gardashli, M., Baron, M., Huang, C., Kaplan, L. D., Meng, Z., Kouroupis D., & Best, T. M. (2024). Mechanical loading and orthobiologic therapies in the treatment of post-traumatic osteoarthritis (PTOA): A comprehensive review. *Frontiers in Bioengineering and Biotechnology*, *12*, Article 1401207. https://doi.org/10.3389/fbioe.2024.1401207

Kalsi, S., Singh, J., & Sharma, N. K. (2023). Mechanical properties variation of cortical bone with type of loading using FEM. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2023.01.324

Kettunen, J. A., & Kujala, U. M. (2004). Exercise therapy for people with rheumatoid arthritis and osteoarthritis. *Scandinavian Journal of Medicine & Science in Sports*, *14*(3), 138–142. https://doi.org/10.1111/j.1600-0838.2004.00396.x

Kong, H., Wang, X.-Q., & Zhang, X.-A. (2022). Exercise for Osteoarthritis: A literature review of pathology and mechanism. *Frontiers in Aging Neurocience*, *14*, Article 854026. https://doi.org/10.3389/fnagi.2022.854026

Lee, H.-S., & Salter, D. M. (2015). Biomechanics of cartilage and osteoarthritis. In Q. Chen (Ed.), *Osteoarthritis –progress in Basic Research and treatment*. IntechOpen. https://doi.org/10.5772/60011

Li, L., Yang, L., Yu, F., Shi, J., Zhu, L., Yang, X., Teng, H., Wang, X., & Jiang, Q. (2018). 3D printing individualized heel cup for improving the self-reported pain of plantar fasciitis. *Journal of Translational Medicine*, *16*, Article 167. https://doi.org/10.1186/s12967-018-1547-y

Maknickas, A., Alekna, V., Ardatov, O., Chabarova, O., Zabulionis, D., Tamulaitiene, M., & Kačianauskas, R. (2019). FEM-based compression fracture risk assessment in osteoporotic lumbar vertebra L1. *Applied Sciences*, *9*(15), Article 3013. https://doi.org/10.3390/app9153013

MeshLab. (n.d.). Retrieved 23 March, 2023, from https://www.meshlab.net/

Mora, J. C., Przkora, R., & Cruz-Almeida, Y. (2018). Knee osteoarthritis: Pathophysiology and current treatment modalities. *Journal of Pain Research*, *11*, 2189–2196. https://doi.org/10.2147/JPR.S154002

Norimatsu, K., Nakanishi, K., Ijuin, T., Otsuka, S., Takada, S., Tani, A., Matsuzaki, R., Matsuoka, T., & Sakakima, H. (2023). Effects of low-intensity exercise on spontaneously developed knee osteoarthritis in male senescence-accelerated mouse prone 8. *Arthritis Research and Theraphy*, *25*, Article 168. https://doi.org/10.1186/s13075-023-03162-z

Pabinger, C., Kobinia, G. S., & Dammerer, D. (2024). Injection therapy in knee osteoarthritis: cortisol, hyaluronic acid, PRP, or BMAC (mesenchymal stem cell therapy)? *Frontiers in Medicine*, *11*, Article 1463997. https://doi.org/10.3389/fmed.2024.1463997

Snyder, B. D., Piazza, S., Edwards, W.T., & Hayes, W. C. (1993). Role of trabecular morphology in the etiology of age-related vertebral fractures. *Calcified Tissue International*, *53*, S14–S22. https://doi.org/10.1007/BF01673396

SOLIDWORKS Web Help. (n.d.). Retrieved 23 March, 2023, from https://help.solidworks.com/

Uzieliene, I., Bironaite, D., Bagdonas, E., Pachaleva, J., Sobolev, A., Tsai, W.-B., Kvederas, G., & Bernotiene, E. (2023a). The effects of mechanical load on chondrogenic responses of bone marrow mesenchymal stem cells and chondrocytes encapsulated in Chondroitin Sulfate-Based Hydrogel. *International Journal of Molecular Sciences*, *24*(3), Article 2915. https://doi.org/10.3390/ijms24032915

Uzieliene, I., Bironaite, D., Pachaleva, J., Bagdonas, E., Sobolev, A., Tsai, W.-B., Kvedaras, G., & Bernotiene, E. (2023b). Chondroitin Sulfate-Tyramine-based hydrogels for cartilage tissue repair. *International Journal of Molecular Sciences*, *24*(4), Article 3451. https://doi.org/10.3390/ijms24043451

Wakimoto, Y., Miura, Y., Inoue, S., Nomura, M., & Moriyama, H. (2024). Effects of different combinations of mechanical loading intensity, duration, and frequency on the articular cartilage in mice. *Molecular Biology Reports*, *51*, Article 862. https://doi.org/10.1007/s11033-024-09762-5

Wang, W., Niu, Y., & Jia, Q. (2022). Physical therapy as a promising treatment for osteoarthritis: A narrative review. *Frontiers in Psychology*, *13*, Article 1011407. https://doi.org/10.3389/fphys.2022.1011407

3D Slicer Image Computing Platform. (n.d.). Retrieved 23 March, 2023, from https://www.slicer.org/

IMPACT OF SMOKING ON ACUTE STRUCTURAL AND FUNCTIONAL CHANGES IN THE TRICEPS SURAE MUSCLE-TENDON UNIT FOLLOWING EXERCISE-INDUCED FATIGUE

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ABSTRACT

BACKGROUND: Smoking has long been associated with a variety of negative health outcomes, including compromised cardiovascular function, reduced oxygen delivery, and impaired tissue healing (Degens et al., 2015). In the context of muscle recovery, smoking exacerbates the deleterious effects of exercise by impairing blood circulation and hindering the body's ability to synthesize proteins, such as collagen, necessary for muscle and tendon repair (Adatia et al., 2021). Specifically, nicotine-induced vasoconstriction reduces blood flow to the muscles, thereby limiting the delivery of essential nutrients and oxygen required for recovery processes (Bao et al., 2024; Anton et al., 2006). Moreover, the reduction in collagen turnover and protein synthesis in smokers may slow the regeneration of muscle fibers and the repair of tendons, resulting in prolonged muscle soreness and delayed recovery.

OBJECTIVE: This study's aim was to investigate the acute effects of smoking on structural and functional changes in the Triceps surae MTU following exercise-induced fatigue.

METHODS: Twelve participants (age 28 ± 5 years), including six smokers and six non-smokers, completed a fatigue protocol involving repetitive calf raises performed on the edge of a step at 50 beats per minute until full exhaustion. Pre- and post-exercise assessments included B-mode ultrasound for morphological evaluation and passive MTU stretching on an isokinetic dynamometer to assess mechanical properties.

RESULTS: Significant post-exercise increases were observed in smokers for gastrocnemius lateralis muscle thickness ($p = 0.004$), proximal Achilles tendon echo intensity ($p = 0.038$), and passive MTU stiffness ($p = 0.015$). Hysteresis increased significantly in both groups (smokers: $p < 0.001$; non-smokers: $p = 0.006$), while no significant changes were found in Achilles tendon cross-sectional area, anterior-posterior thickness, or joint range of motion in either group.

CONCLUSIONS: Exercise-induced fatigue elicits distinct structural and mechanical responses in smokers compared to non-smokers. Increased muscle swelling, tendon echogenicity, and stiffness in smokers suggest altered tissue behaviour and potentially impaired recovery mechanisms. These findings highlight the adverse acute effects of smoking on MTU adaptability.

KEYWORDS: smoking, musculoskeletal system, post-exercise recovery, ultrasonography, stiffness.

REFERENCES:

Adatia, A., Wahab, M., Shahid, I., Moinuddin, A., Killian, K. J., & Satia, I. (2021). Effects of cigarette smoke exposure on pulmonary physiology, muscle strength and exercise capacity in a retrospective cohort with 30,000 subjects, *PLoS ONE*, *16*(6), Article e0250957. https://doi.org/10.1371/journal.pone.0250957

Anton, M. M., Cortez-Cooper, M. Y., DeVan, A. E., Neidre, D. B., Cook, J. N., & Tanaka, H. (2006). Cigarette smoking, regular exercise, and peripheral blood flow. *Atherosclerosis*, *185*(1), 201–205. https://doi.org/10.1016/j.atherosclerosis.2005.05.034

Bao, K., Zheng, K., Zhou, X., Chen, B., He, Z., & Zhu, D. (2024). The effects of nicotine withdrawal on exercise-related physical ability and sports performance in nicotine addicts: A systematic review and meta-analysis. *Journal of the International Society of Sports Nutrition*, *21*(1), Article 2302383. https://doi.org/10.1080/15502783.2024.2302383

Degens, H., Gayan-Ramirez, G., & van Hees, H. W. (2015). Smoking-induced skeletal muscle dysfunction. From evidence to mechanisms. *American Journal of Respiratory and Critical Care Medicine*, *191*(6), 620–625. https://doi.org/10.1164/rccm.201410-1830PP

A CONCEPTUAL FRAMEWORK FOR PATIENT-SPECIFIC BIOMECHANICAL MODELLING IN TMJ ANKYLOSIS MANAGEMENT

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ABSTRACT

BACKGROUND: Temporomandibular joint (TMJ) ankylosis is a disorder caused by fusion between the mandibular condyle and temporal bone. Although relatively uncommon, TMJ ankylosis leads to restricted mouth opening, impaired mastication, facial asymmetry and long-term disability, particularly in children and young adults. Standard management involves arthroplasty or total jaw reconstruction, often combined with interpositional grafts or prosthetic replacements (Ma et al., 2015), followed by intensive physiotherapy. Despite these interventions, functional rehabilitation remains unpredictable, with many patients exhibiting restricted postoperative jaw mobility. The main challenge is that rehabilitation protocols lack objective tools to predict or measure functional outcomes, and surgical approach is mostly chosen based on surgeons' experience (De Roo et al., 2016). While finite element (FE) models have been applied in craniofacial biomechanical simulation (Sagl et al., 2019), most of them are based on healthy patient mandible. Since ankylosed mandibles have abnormal morphology and altered biomechanics, models derived from healthy anatomy cannot reliably guide surgical or rehabilitation procedures.

OBJECTIVE: To propose the development of a patient-specific biomechanical model of the ankylosed mandible, validated with motion capture data, to simulate jaw function. This approach is novel in its personalization to individual anatomy and direct linkage of simulation outputs to clinical decision-making for surgery and rehabilitation.

METHODS: The proposed approach integrates imaging, computational biomechanics, and motion analysis in four steps: (1) acquisition of CT/CBCT scans of ankylosed mandibles and 3D reconstruction; (2) development of finite element model with pathological morphology and material properties; (3) validation of simulated jaw motion against experimental data from motion capture; (4) application of the validated models to simulate surgical techniques and rehabilitation protocols, with outcomes expressed as predicted ranges of mandibular motion, condylar translation, contact stress distributions, and symmetry indices relevant to functional recovery.

RESULTS: This proposed framework is expected to generate validated patient-specific biomechanical models that reproduce jaw kinematics with root mean square error <2 mm against motion capture. Simulations will provide quantitative predictions of mandibular range of motion, condylar translation, and contact stress distributions, highlighting asymmetry and mechanical characteristics of ankylosis. These outputs will enable comparison of surgical scenarios and rehabilitation protocols, offering objective parameters – such as predicted mouth opening, excursion ranges, and load reduction at the joint – to support surgical decisions and treatment planning.

CONCLUSIONS: A biomechanical model of the ankylosed mandible, validated through motion capture systems, could significantly enhance treatment planning and rehabilitation strategies. By predicting range of motion, stress distribution, and symmetry, the framework can support surgical decision-making and rehabilitation planning, ultimately reducing the risk of re-ankylosis and improving functional recovery.

KEYWORDS: temporomandibular joint ankylosis, patient-specific model, motion capture, range of motion, rehabilitation.

REFERENCES:

De Roo, N., Van Doorne, L., Troch, A., Vermeersch, H., & Brusselaers, N. (2016). Quantifying the outcome of surgical treatment of temporomandibular joint ankylosis: A systematic review and meta-analysis. *Journal of Cranio-Maxillofacial Surgery*, *44*(1), 6–15. https://doi.org/10.1016/j.jcms.2015.08.019

Ma, J., Liang, L., Jiang, H., & Gu, B. (2015). Gap arthroplasty versus interpositional arthroplasty for temporomandibular joint ankylosis: A meta-analysis. *PLoS ONE*, *10*(5), Article e0127652. https://doi.org/10.1371/journal.pone.0127652

Sagl, B., Schmid-Schwap, M., Piehslinger, E., Kundi, M., & Stavness, I. (2019). A dynamic jaw model with a finite-element temporomandibular joint. *Frontiers in Physiology*, *10*, Article 1156. https://doi.org/10.3389/fphys.2019.01156

REAL-TIME VALIDATION OF A LAGRANGIAN INVERSE-DYNAMICS FRAMEWORK FOR ESTIMATING SHOULDER AND ELBOW JOINT TORQUES: A PILOT STUDY

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ABSTRACT

BACKGROUND: Accurate real-time estimation of joint torques is crucial for rehabilitation, ergonomics, and sports performance monitoring. Traditional inverse-dynamics methods require laboratory-based optical systems and force plates, which are costly and lack portability.

OBJECTIVE: This study aimed to validate a pilot real-time Lagrangian inverse-dynamics framework for estimating shoulder and elbow joint torques using only inertial measurement units (IMUs).

METHODS: Eight healthy volunteers (aged 25–30) performed upper-limb movements under three load conditions (0, 1, and 2 kg). Kinematic data were captured with the Xsens IMU system (60 Hz), transmitted to MATLAB, filtered using a 4th-order Butterworth filter (4 Hz), and processed via cubic spline interpolation. Angular velocities and accelerations were computed and used as inputs to a simplified three-degree-of-freedom musculoskeletal model. The calculated torques were validated against OpenSim simulations. Root Mean Square error (RMSE) and Mean Absolute Error (MAE) were computed for accuracy assessment.

RESULTS: Shoulder torque estimation showed an error of RMSE = 0.784 ± 0.157 Nm, while elbow torque error was RMSE = 0.620 ± 0.186 Nm. The highest discrepancies occurred at the shoulder due to its biomechanical complexity and sensitivity to soft tissue artefacts. End-to-end latency averaged 26 ± 3 ms (25 ± 2 ms filtering; 40 ± 3 ms interpolation), enabling real-time applicability.

CONCLUSIONS: The developed system demonstrated reliable real-time estimation of upper-limb joint torques using only wearable IMUs. The framework offers potential for clinical rehabilitation, ergonomic analysis, and sports performance monitoring. Future improvements should focus on personalized modeling, EMG integration, and real-time optimization.

KEYWORDS: real-time biomechanics, inverse dynamics, IMU-based motion capture, upper limb joint torques, Lagrangian mechanics.

REFERENCES:

Aliaj, K., Lawrence, R. L., Foreman, K. B., Chalmers, P. N., & Henninger, B. (2022). Kinematic coupling of the glenohumeral and scapulothoracic joints generates humeral axial rotation. *Journal of Biomechanics*, *136*, Article 111059. https://doi.org/10.1016/j.jbiomech.2022.111059

Beange, K. H. E., Chan, A. D. C., & Graham, R. B. (2023, June 14–16). Sources of error during inertial sensing of human movement: A critical review of the fundamentals. In *Proceedings of the 2023 IEEE International Symposium on Medical Measurements and Applications* (pp. 1–6). Jeju, Republic of Korea. IEEE. https://doi.org/10.1109/MeMeA57477.2023.10171885

Dorschky, E., Nitschke, M., Seifer, A.-N., van den Bogert, A. J., & Eskofier, M. (2019). Estimation of gait kinematics and kinetics from inertial sensor data using optimal control of musculoskeletal models. *Journal of Biomechanics*, *95*, Article 109278. https://doi.org/10.1016/j.jbiomech.2019.07.022

Franco-García, J. M., Rodal, M., Gutiérrez-Horrillo, R., Carlos-Vivas, J., Pérez-Gómez, J., Nobari, H., Ardigò, L. P., & Gianikellis, K. (2021). Shoulder kinematics and symmetry at different load intensities during bench press exercise. *Symmetry*, *13*(10), Article 1859. https://doi.org/10.3390/sym13101859

Hribernik, M., Umek, A., Tomažič, S., & Kos, A. (2022). Review of real-time biomechanical feedback systems in sport and rehabilitation. *Sensors*, *22*(8), Article 3006. https://doi.org/10.3390/s22083006

Leva, P. d. (1996). Adjustments to Zatsiorsky–Seluyanov's Segment inertia parameters. *Journal of Biomechanics*, *29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Majumder, S., & Deen, M. J. (2021). Wearable IMU-based system for real-time monitoring of lower-limb joints. *IEEE Sensors Journal*, *21*(6), 8267–8275. https://doi.org/10.1109/JSEN.2020.3044800

McGrath, R. L., Pires-Fernandes, M., Knarr, B., Higginson, J. S., & Sergi, F. (2017). Toward goal-oriented robotic gait training: The effect of gait speed and stride length on lower extremity joint torques. In *Proceedings of the 2017 International Conference on Rehabilitation Robotics (ICORR)* (pp. 270–275). London, UK. IEEE. https://doi.org/10.1109/ICORR.2017.8009258

Nasr, A., Inkol, K. A., Bell, S., & McPhee, J. (2021). InverseMuscleNET: Alternative machine learning solution to static optimization and inverse muscle modeling. *Frontiers in Computational Neuroscience 15*, Article 759489. https://doi.org/10.3389/fncom.2021.759489

Penichet-Tomás, A. (2024). Applied biomechanics in sports performance, injury prevention, and rehabilitation. *Applied Sciences*, *14*(24), Article 11623. https://doi.org/10.3390/app142411623

Vannatta, C. N., Heinert, B. L., & Kerzonek, T. W. (2020). Biomechanical risk factors for running-related injury differ by sample population: A systematic review and meta-analysis. *Clinical Biomechanics*, *75*, Article 104991. https://doi.org/10.1016/j.clinbiomech.2020.104991

Schepers, M., Giuberti, M., & Bellusci, G. (2018). *Xsens MVN: Consistent tracking of human motion using inertial sensing* (Technical report). Xsens Technologies B.V. https://doi.org/10.13140/rg.2.2.22099.07205

ANALYSIS OF MECHANICAL PROPERTIES OF NANOFIBER SCAFFOLDS: EFFECT OF DIFFERENT ELECTROSPINNING SOLVENTS

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ABSTRACT

BACKGROUND: This study investigates the influence of various solvents on the mechanical properties of bio-compatible and biodegradable polycaprolactone (PCL) nanofiber scaffolds produced by electrospinning. The goal is to determine how the type of solvent affects fiber morphology, mechanical strength, and potential applicability in tissue engineering.

METHODS: A total of 27 PCL nanofiber samples were fabricated using electrospinning with different solvent systems. Mechanical properties, including yield strength, elastic modulus, and elongation at break, were evaluated through uniaxial tensile testing. The load-displacement and stress–strain curves were plotted to compare the performance under solvent conditions. Morphological analysis was performed using scanning electron microscopy (SEM) to assess the structure and homogeneity. Viscosity and its effect on fibre formation were also considered.

RESULTS: The choice of solvent significantly affected the mechanical performance and morphology of the nanofibers. The chloroform-prepared PCL scaffold exhibited the highest mechanical strength, with an elastic modulus of 9.86 MPa and a yield strength of 1.11 ± 0.32 MPa. SEM analysis showed that solvents with lower viscosity produced more homogeneous and uniform fibres. No severe morphological degradation was observed under the tested conditions.

CONCLUSIONS: Solvent selection plays a crucial role in determining the structural and mechanical characteristics of electrospun PCL nanofibers. Chloroform-based PCL scaffolds demonstrated superior mechanical properties and uniform morphology, indicating their enhanced suitability for biomedical applications such as tissue engineering scaffolds.

KEYWORDS: scaffold, nanofiber, electrospinning, polycaprolactone, solvent, mechanical properties.

REFERENCES:

Baker, S. R., Banerjee, S., Bonin, K., & Guthold, M. (2016). Determining the mechanical properties of electrospun poly-ε-caprolactone (PCL) nanofibers using AFM and a novel fiber anchoring technique. *Materials Science and Engineering* C, *59*, 203–212. https://doi.org/10.1016/j.msec.2015.09.102

Conte, A. A., Sun, K., Hu, X., & Beachley, V. Z. (2020). Effects of fiber density and strain rate on the mechanical properties of electrospun polycaprolactone nanofiber mats. *Frontiers in Chemistry*, 8, Article 610. https://doi.org/10.3389/fchem.2020.00610

Huang, L., Bui, N.-N., Manickam, S. S., & McCutcheon, J. R. (2011). Controlling electrospun nanofiber morphology and mechanical properties using humidity. *Journal of Polymer Science, Part B: Polymer Physics*, *49*(24), 1734–1744. https://doi.org/10.1002/polb.22371

CALCULATION AND ANALYSIS OF MOVEMENT PARAMETERS USING DIFFERENT HUMAN BODY MODELS

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ABSTRACT

BACKGROUND: Human motion analysis provides valuable biomechanical data describing joint loads, muscle activity and body kinematics. Modern systems such as optical motion capture and inertial sensors enable high-accuracy movement assessment, which is particularly relevant for understanding lumbar spine biomechanics and preventing lower back pain.

OBJECTIVE: To develop and analyze musculoskeletal model of the lumbar spine using different motion capture tools, and to compare the biomechanical parameters obtained.

METHODS: Motion was recorded using two motion capture systems: the "Xsens" system with 17 inertial measurement units to capture full-body data and "BTS SMART-DX EVO" optical motion capture system, equipped with six infrared cameras and 41 reflective markers arranged according to Plug-in-Gait model. A healthy participant (height: 169 cm, weight: 67 kg) performed a flexion-extension movement on force plates to record ground reaction forces. The captured data was imported into the AnyBody (8.0 version) modeling system, where inverse dynamics was applied to compute lumbar intervertebral reaction forces. The results were post-processed and visualized in MATLAB 2024b for comparison between measurement modalities.

RESULTS: The analysis revealed the distribution of compression and anterior-posterior forces acting on the lumbar vertebrae (T12-L5). The highest compressive forces throughout the action time were in sacrum-L5 (up to 19N) and L5-L4 (up to 17N). Posterior-directed forces appeared during forward flexion and anterior forces during extension. A brief force spike near 10s marked movement stabilization.

CONCLUSIONS: The combination of inertial ("Xsens") and optical ("BTS SMART-DX EVO") motion capture systems with AnyBody modeling environment, enables reliable estimation of lumbar spine loads. The development workflow effectively identifies load changes during flexion and extension and can be applied for rehabilitation assessment, ergonomic evaluation and musculoskeletal model validation.

KEYWORDS: Xsens, Plug-In-Gait, motion analysis, inverse dynamics, AnyBody.

REFERENCES:

Bacon Z., Hicks Y., Al-Amri M., & Sheeran L. (2020). Low back pain classification using inertial measurement units: A preliminary analyis. *Procedia Computer Science*, *176*, 2822–2831. https://doi.org/10.1016/j.procs.2020.09.272

Senvaitis, K., & Daunoravičienė, K. (2023). Skeletal modeling in Rhino Grasshopper – a confirmed kinematic model. *Machines*, *11*(5), Article 556. https://doi.org/10.3390/machines11050556

Villalba-Meneses, F., Chaglla-Monge, K., Almeida-Galárraga, D., Cadena-Morejón, C., Moreno-Calvo, A., Marín, J., & Marín, J. J. (2024). Evaluation of deep oscillation therapy for the treatment of lumbar pain syndrome using motion capture systems: A systematic review. *Journal of Bodywork and Movement Therapies*, *38*, 180–190. https://doi.org/10.1016/j.jbmt.2024.01.010

HEART RATE VARIABILITY AS A PREDICTOR OF MIGRAINE: SLEEP-TIME DATA ANALYSIS OF PRE-MIGRAINE NIGHTS

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ABSTRACT

BACKGROUND: Migraine is a complex neurological disorder characterized by recurrent, often debilitating headaches. Current evidence suggests that autonomic nervous system (ANS) alterations play a significant role in migraine pathophysiology, affecting sensory, limbic, and homeostatic processing. Heart rate variability (HRV), a well-established, noninvasive marker of ANS function, is associated with migraine severity and treatment efficacy.

OBJECTIVE: In this study, we aimed to evaluate the use of wearable sensor technology in predicting migraine attacks by monitoring changes in the ANS during the prodrome phase.

METHODS: We recruited 23 migraine sufferers and analyzed HRV during nocturnal sleep using wearable biosensors and machine learning, extracting HRV features from BVP signals and applying feature engineering to predict migraine episodes.

RESULTS: The analysis of HRV provides an important approach to migraine attack prediction, revealing significant individual variability in physiological responses. Overall, these results lay the groundwork for developing more effective and personalized migraine prediction models, which could lead to earlier interventions and improved participant outcomes. Future research should consider controlled inclusion of post-migraine nights, potentially leveraging additional statistical or machine learning techniques to mitigate misclassification risks while capturing these transitional dynamics.

CONCLUSIONS: In conclusion, this study demonstrates the potential of wearable sensor technology in predicting migraine episodes by monitoring changes of the ANS during the prodrome phase. In this pilot study, our goal is an assistive, non-autonomous early-warning aid for already diagnosed users (human-in-the-loop), rather than a clinical diagnostic tool. The analysis of HRV during nocturnal sleep provides an important approach to migraine attack prediction, revealing significant individual variability in physiological responses. The balanced accuracy of prediction models varied across participants, highlighting the need for personalized prediction strategies.

The consistent selection of HRV features such as median of all NN (normal to normal) intervals, Percentage of absolute differences in successive NN intervals greater than 20 ms, and Inverse of the mean length of acceleration/deceleration segments by both embedded and ANOVA methods indicates stable, frequently informative descriptors in our setting. Their repeated appearance across different feature selection strategies highlights these metrics as key candidates for further investigation.

That said, the average performance levels observed (F1 ≈ 0.24–0.40) remain modest and are not sufficient for direct clinical deployment or use as a stand-alone early warning

system. These results should instead be viewed as a proof-of-concept: they demonstrate that physiological signals contain predictive information, but larger datasets, multimodal features, and longitudinal validation will be required before clinically useful accuracy can be achieved.

Overall, these results lay the groundwork for developing more effective and personalized migraine prediction models, aimed at practical, threshold-tuned early warning for diagnosed users. Further studies with larger and more diverse participant groups are recommended to validate these findings and refine the predictive models including analyses to explain variability and the addition of complementary signals (e.g., EDA, skin temperature).

KEYWORDS: feature extraction, heart rate variability, machine learning, migraine prediction, sleep analysis, wearable sensors.

REFERENCES:

Abromavičius, V., Serackis, A., Katkevičius, A., Kazlauskas, M., & Sledevič, T. (2023). Prediction of exam scores using a multi-sensor approach for wearable exam stress dataset with uniform preprocessing. *Technology and Health Care*, *31*(6), 2499–2511. https://doi.org/10.3233/THC-235015

Chuang, C.-H., Li, J.-Y., King, J.-T., Chen, W.-T., Chen, S.-P., Wang, Y.-F., Liu, H.-Y., Hsiao, F.-J., Pan, L.-L. H., Wang, S.-J., & Lai, K.-L. (2023). Abnormal heart rate variability and its application in predicting treatment efficacy in patients with chronic migraine: An exploratory study. *Cephalalgia*, *43*(10). https://doi.org/10.1177/03331024231206781

Fatisson, J., Oswald, V., & Lalonde, F. (2016). Influence diagram of physiological and environmental factors affecting heart rate variability: An extended literature overview. *Heart International*, *11*(1). https://doi.org/10.5301/heartint.5000232

Ferrari, M. D., Goadsby, P. J., Burstein, R., Kurth, T., Ayata, C., Charles, A., Ashina, M., van der Maggdenberg, A. M. J. M., & Dodick, D. W. (2022). Migraine. *Nature Review Disease Primers*, *8*, Article 2. https://doi.org/10.1038/s41572-021-00328-4

Goadsby, P. J., Holland, P. R., Martins-Oliveira, M., Hoffmann, J., Schankin, C., & Akerman, S. (2017). Pathophysiology of migraine: A disorder of sensory processing. *Physiological Review*, *97*(2), 553–622. https://doi.org/10.1152/physrev.00034.2015

Headache Classification Committee of the International Headache Society (IHS). (2018). The International Classification of Headache Disorders, 3rd edition. *Cephalalgia*, *38*(1), 1–211. https://doi.org/10.1177/0333102417738202

Kapustynska, V., Abromavičius, V., Serackis, A., Paulikas, Š., Ryliškienė, K., & Andruškevičius, S. (2024). Machine learning and wearable technology: Monitoring changes in biomedical signal patterns during pre-migraine nights. *Healthcare*, *12*(17), Article 1701. https://doi.org/10.3390/healthcare12171701

Kapustynska, V., Abromavičius, V., Serackis, A., Andruškevičius, S., Ryliškienė, K., & Paulikas, Š. (2025). Advancing a generalizable model for migraine prediction: Analysis of filtering techniques on physiological signals. *Technology and Health Care*, *35*(5), 2184–2193. https://doi.org/10.1177/09287329251332415

Karsan, N. (2024). Pathophysiology of migraine. *Continuum*, *30*(2), 325–343. https://doi.org/10.1212/CON.0000000000001412

Karthik, N., Sinha, S., Taly, A. B., Kulkarni, G. B., Ramachandraiah, C. T., & Rao, S. (2013). Alteration in polysomnographic profile in 'migraine without aura' compared to healthy controls. *Sleep Medicine*, *14*(2), 211–214. https://doi.org/10.1016/j.sleep.2012.10.019

Lipton, R. B. (2009). Tracing transformation: Chronic migraine classification, progression, and epidemiology. *Neurology*, *72*(5S1), S3–S7. https://doi.org/10.1212/WNL.0b013e3181974b19

Radha, M., Fonseca, P., Moreau, A., Ross, M., Cerny, A., Anderer, P., Long, X., & Aarts, R. M. (2019). Sleep stage classification from heart-rate variability using long short-term memory neural networks. *Scientific Reports*, *9*, Article 14149. https://doi.org/10.1038/s41598-019-49703-y

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health, 5*, Article 258. https://doi.org/10.3389/fpubh.2017.00258

Siirtola, P., Koskimäki, H., Mönttinen, H., & Röning, J. (2018). Using sleep time data from wearable sensors for early detection of migraine attacks. *Sensors*, *18*(5), Article 1374. https://doi.org/10.3390/s18051374

Tiseo, C., Vacca, A., Felbush, A., Filimonova, T., Gai, A., Glazyrina, T., Hubalek, A. I., Marchenko, Y., Overeem, L. H., Piroso, S., Tkachev, A., Martelletti, P., & Sacco, S. (2020). Migraine and sleep disorders: A systematic review. *The Journal of Headache and Pain, 21*, Article 126. https://doi.org/10.1186/s10194-020-01192-5

Zhang, L., Qiu, S., Zhao, C., Wang, P., & Yu, S. (2021). Heart rate variability analysis in episodic migraine: A cross-sectional study. *Frontiers in Neurology*, *12*, Article 647092. https://doi.org/10.3389/fneur.2021.647092

Zhao, Y. M., Liu, C. L., Li, Y. L., Jia, J., Wu, X. N., Li, S. N., Sun, L. T., & Nie, L. (2022). Characteristics of heart rate variability in patients with vestibular migraine. *Chinese Journal of Otorhinolaryngology Head and Neck Surgery*, *57*(5), 584–588 (in Chinesse).

STRUCTURAL DETERMINANTS OF EFFECTIVE ACADEMIC–INDUSTRY TECHNOLOGY TRANSFER IN BIOMEDICAL ENGINEERING

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ABSTRACT

BACKGROUND: While macro-level factors influencing collaboration are well-studied, the daily operational processes between academia and industry remain unclear, especially in biomedical engineering, where coordination is complex and critical (Clark et al., 2020; Javanmardi et al., 2024).

OBJECTIVE: This study fills this gap by analyzing decision-making, governance, and coordination practices from both perspectives to improve technology transfer and innovation outcomes.

METHODS: This study employed a mixed-methods approach, including a structured questionnaire distributed among academic and industrial stakeholders, complemented by detailed case studies illustrating practical examples of collaboration in biomedical technology transfer.

RESULTS: Findings reveal both converging and diverging motivations: academia values access to new technologies and societal impact, while industry prioritizes rapid market implementation and competitiveness. Key barriers include time constraints, conflicting publication and confidentiality demands, and challenges in intellectual property negotiations. Support mechanisms such as long-term funding, administrative support, and hybrid work models facilitate collaboration. Case studies demonstrate that successful partnerships hinge on clear regulatory frameworks and mutual understanding of objectives.

CONCLUSIONS: Future university-industry partnerships should prioritize clear communication, joint IP frameworks, and inclusive governance from the start. Involving clinical practitioners and end-users early improves product relevance, while proactive regulatory planning, supported by institutional guidance, helps avoid delays and compliance issues.

KEYWORDS: technology transfer, biomedical engineering, academic-industry collaboration, innovation, healthcare technologies.

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REFERENCES:

Clark, D., Dean, G., Bolton, S., & Beeson, B. (2020). Bench to bedside: The technology adoption pathway in healthcare. *Health and Technology, 10*, 537–545. https://doi.org/10.1007/s12553-019-00370-z

Javanmardi, E., Maresova, P., Xie, N., & Mierzwiak, R. (2024). Exploring business models for managing uncertainty in healthcare, medical devices, and biotechnology industries. *Heliyon, 10*(4), Article e25962. https://doi.org/10.1016/j.heliyon.2024.e25962

IMPACT OF SYNTHETIC DATA ON CLASSIFICATION USING MACHINE LEARNING ALGORITHMS

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ABSTRACT

BACKGROUND: The increasing demand for high-quality datasets in machine learning has driven the development of synthetic data generation methods. These techniques aim to overcome data scarcity, imbalance, and privacy concerns by producing artificial yet statistically valid data. Traditional approaches such as SMOTE have limitations in modeling complex, high-dimensional relationships, prompting the adoption of advanced generative methods including Generative Adversarial Networks (GANs) and transformer-based architectures (Gholampour, 2024; Sherman et al., 2016).

OBJECTIVE: The study aimed to evaluate and compare the effectiveness of SMOTE, GANs, and transformer-based models in generating synthetic numerical data to enhance machine learning classification performance.

METHODS: Several benchmark datasets were selected and preprocessed before applying the three synthetic data generation techniques. The resulting datasets were used to train standard classification algorithms, and model performance was assessed using metrics such as classification accuracy and data distribution balance. Comparative analyses were conducted to assess the quality, realism, and statistical coherence of the generated data.

RESULTS: Transformer-based models outperformed GANs and SMOTE in generating synthetic data that preserved statistical characteristics and long-range feature dependencies. GANs demonstrated superior ability in creating realistic samples and improving class balance compared to SMOTE, which struggled with complex data structures. However, transformer-based and GAN models were computationally demanding and sensitive to hyperparameter configurations.

CONCLUSIONS: Transformer models showed the highest effectiveness in generating statistically robust synthetic numerical data, while GANs provided valuable support for addressing class imbalance. Despite these advances, synthetic data cannot entirely replace real-world datasets due to authenticity limitations. Future research should focus on optimizing model architecture and developing automated hyperparameter tuning strategies to improve reliability and practical applicability.

KEYWORDS: synthetic data, transformer models, generative adversarial networks, classification.

REFERENCES:

Gholampour, S. (2024). Impact of nature of medical data on machine and deep learning for imbalanced datasets: clinical validity of SMOTE is questionable. *Machine Learning and Knowledge Extraction*, *6*(2), 827–841. https://doi.org/10.3390/make6020039

Sherman, R. E., Anderson, S. A., Dal Pan, G. J., Gray, G. W., Gross, T., Hunter, N. L., LaVange, L., Marinac-Dabic, D., Marks, P. W., Robb, M. A., & Shuren, J. (2016). Real-world evidence – what is it and what can it tell us. *New England Journal of Medicine*, *375*(23), 2293–2297. https://doi.org/10.1056/NEJMsb1609216

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