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INTERDISCIPLINARY COLLABORATION THE PRESENT AND THE FUTURE - THE ROLE OF COMPUTER SCIENCE IN PHYSIOTHERAPY

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Abstract: *IT methods and tools are increasingly used in physiotherapy diagnosis and therapy, as well as in the care and monitoring of patients in telerehabilitation and home rehabilitation, and physiotherapy itself is becoming increasingly interdisciplinary. The aim of the article is to review to what extent the opportunities related to the interdisciplinary development of physiotherapy have been used and how much potential there is for further, stimulated development.*

Słowa kluczowe: *Physiotherapy; exercise evaluation; mobile health; pose estimation; rehabilitation; remote monitoring.*

Współpraca interdyscyplinarna teraźniejszością i przyszłością - rola informatyki w fizjoterapii

Streszczenie: *Metody i narzędzia informatyczne znajdują coraz szersze zastosowanie w diagnostyce i terapii fizjoterapeutycznej oraz opiece i monitorowaniu pacjentów w ramach telerehabilitacji i rehabilitacji domowej, a sama fizjoterapia staje się coraz bardziej interdyscyplinarna. Celem artykułu jest przegląd, na ile możliwości związane z interdyscyplinarnym rozwojem fizjoterapii zostały wykorzystane, a ile w nich tkwi jeszcze potencjału na dalszy, stymulowany rozwój.*

Słowa kluczowe: *Fizjoterapia; ocena ćwiczeń; zdrowie mobilne; ocena pozycji; rehabilitacja; zdalny monitoring.*

1. Wprowadzenie

IT methods and tools are increasingly used in physiotherapy diagnosis and therapy, as well as in the care and monitoring of patients in telerehabilitation and home rehabilitation and physiotherapy itself is becoming increasingly interdisciplinary. A review of scientific publications with the keywords "interdisciplinary", "physiotherapy", "physical therapy" and related fields showed 2,424 publications published in the years 1964-2024, including 487 reviews. The dynamics of the growth of the number of the above-mentioned publications are large: 1122 (46.29%) publications were published in the last 5 years, and as many as 1740 (71.78%) in the last 10 years (Figure 2).

Figure 1. Number of scientific publications with the keywords "interdisciplinary", "physiotherapy", "physical therapy" and related ones (1964-2024).

A review of scientific publications with the keywords "computer science", "infotmation technology", "medical informatics", "physiotherapy", "physical therapy" and related fields showed only 86 publications published in the years 2004-2024, including 12 reviews. The dynamics of

the growth of the number of the above-mentioned publications are large: 59 (68.61%) publications were published in the last 5 years, and as many as 80 (93.02%) in the last 10 years (Figure 1).

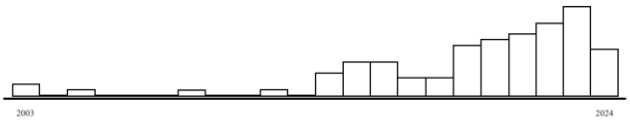

Figure 2. Number of scientific publications with the keywords "computer science", "infotmation technology", "medical informatics", "physiotherapy", "physical therapy" and related ones (2003-2024).

Many possibilities created within the above-mentioned framework. interdisciplinary research does not leave us without threats - their balance in the form of a SWOT matrix (Strengths, Weaknesses, Opportunities, and Threats) is presented in Table 1.

Table 1. SWOT matrix.

	Positive	Negative
Internal	STRENGTHS A wider range of impacts Diverse research methodologies More accurate and faster diagnostics Greater development opportunities Synergy effect Larger groups of researchers Long term data analysis	WEAKNESSES Lack of domination of clinical disciplines Lack of interdisciplinary staff The need for social acceptance
External	OPPORTUNITIES Automation Telerehabilitation Telecare	THREATS High implementation costs Cheap, unproven solutions

The aim of the article is to review to what extent the opportunities related to the interdisciplinary development of physiotherapy have been used and how much potential there is for further, stimulated development.

2. Review results

Physiotherapy sessions are often limited by the availability and cost of physiotherapists or the need for patients to cycle to the session location. Part of the solution to this problem may lie in the development of wearables and camera-based systems to detect changes in the position of human body parts and support rehabilitation. Innovative approaches can provide smartphone-based position and movement estimation for assessing movement quality and providing feedback on physiotherapy progress, allowing patients to self-perform exercises in shoulder rehabilitation based on tracking the position of 33 key points on the patient's body. This position is compared with data from reference videos developed by physiotherapists to verify correct exercise performance. An optoelectronic motion capture system (QTM) was used to validate the above software [1]. Increasing the use of home rehabilitation is particularly important in this group of patients who are recovering at home after illnesses or injuries requiring cyclical, targeted physiotherapy. A review of current technological trends used in home shoulder rehabilitation systems allowed for the observation of a wide range of available solutions: wearable devices, robots, exoskeletons, as well as programming methods and tools based on machine learning (ML), virtual reality (VR), augmented reality (AR, which complements the real world with computationally generated data).) and scenarios and games based on them [2]. Physiotherapy, including at home, plays an important role in improving balance and mobility, especially in patients with traumatic brain injury (TBI). It uses VR to generate multimodal feedback for patients immersed in it. The effectiveness of this form of therapy may be improved by combining VR with other parallel methods, but the optimal VR protocol requires further interdisciplinary research [3]. The quality and availability of data sets is crucial to enable the creation of telerehabilitation systems with repeatable effectiveness. Relying on reliable, historical data sets also creates the basis for faster development of future work. Signals are diverse, data sets are heterogeneous, and there are no universally recognized standards. An examination of publicly available datasets used for automatic affect and emotion recognition (AAER) using artificial intelligence (AI) and highlighting cardiovascular (CV) signals showed that the most frequently studied signal was electrocardiography (ECG, 83.33% of the datasets), and the most frequently used intervention technique was video stimulation (52.38% of experiments). It is worth noting that the quality of the analyzed data was mostly assessed as low and requires improvement in research and analysis methodology [4]. Healthcare change strategies in the area of musculoskeletal physiotherapy are being observed at all levels:

- macro (politics),
- meso (provision of services),

- micro (clinical practice).

Patients and their families/caregivers are the main stakeholders driving the above. changes, their education is also improving. There is a strong focus on digital intelligent mobile solutions for physiotherapy at the patient's home using telemedicine (including remote patient monitoring), blockchain technology, AI and big data sets (and in the field of rare diseases: small data sets). Planning and expansion of systems and capacity building are progressing to support better access to rehabilitation and musculoskeletal care. It is necessary to facilitate interdisciplinary cooperation, research, popularization of their results, implementation and evaluation of solutions for the care of the musculoskeletal system [5].

A review of computational approaches to assessing patient outcomes in rehabilitation programs using motion capture systems showed them grouped into three main categories:

- discreet traffic assessment,
- rule-based approaches,
- template-based approaches.

The main area of research is currently the use of machine learning (ML) methods for movement assessment in (tele)rehabilitation. The main research problems concern:

- data representation,
- feature engineering,
- traffic segmentation,
- scoring function.

The key points are:

- sensors for recording rehabilitation movements,
- model data sets,
- computational methods and tools for assessing patient treatment outcomes in rehabilitation programs [6]. As can be seen from the above analysis here is more computer science than rehabilitation/physiotherapy. It seems that the proposed interdisciplinary approach will now and in the near future play a key role in complementing and expanding the traditional assessment of the effectiveness of the rehabilitation process. This will serve not only to relieve and support clinicians (physiotherapists, but also doctors), but also to support patients during home telerehabilitation [6].

Robot-assisted physiotherapy and AI/ML offers a breakthrough approach to improving the motor skills and quality of life of patients undergoing physiotherapy, particularly home and remote physiotherapy. Patients experience significant positive effects from such therapy, especially when combined with other physiotherapy modalities, results are significantly improved in motor skills, in addition, improvement is more personalised and effective, highlighting the importance of tailoring interventions to the specific needs of each patient [7-10].

The global aging population faces serious health challenges including increasing susceptibility to decline in cognitive and functional capabilities (including activities of daily living) and, consequently, deficits and disabilities due to natural aging/neurodegeneration processes. The WHO vision for healthy aging applies here. Using robots and exoskeletons in physiotherapy in a group of elderly people, an improvement in the quality of gait, joint mobility, muscle strength and balance, as well as a reduction in the impact of a sedentary lifestyle, pain perception, muscle effort and metabolic costs during movement have already been observed. Immediate improvement in functional abilities can be observed in just one session, but restoring or maintaining the functional abilities of the patient's body usually takes a longer time - robots are only a supporting solution, repair processes (if possible) must take time. Research to date shows consistent and significant improvements in critical parameters across a broad spectrum of conditions following intervention with rehabilitation robots and exoskeletons in older adults. As part of the further development of technologies and research supporting physiotherapy, they will allow us to better shape and use their potential in promoting healthy aging and improving the well-being of older people [11-14].

3. Discussion

The development of cheap, reliable sensors and ML for motion capture and analysis facilitate the development of systems for automatic assessment of the patient's functional status and the progress of the rehabilitation process.

3.1. Limitations of current studies

The current state of knowledge shows that computer science can significantly improve the scientific basis and practice of physiotherapy. However, there are several limitations that researchers and clinicians should consider:

- Availability and affordability of IT solutions for physiotherapy: not all patients may have access to the technology required for computer-assisted physiotherapy interventions (wearable devices, virtual reality systems, high-speed Internet for telerehabilitation - in Poland, white spots in the coverage of fifth generation (5G) mobile networks) will be removed by 2027), and the cost of these technologies may be prohibitive for some people or health care facilities, limiting their widespread use.

- Technical complexity: implementing IT solutions in physiotherapy practice often requires specialized technical knowledge and resources, including software development skills, data analysis capabilities and IT infrastructure. Therefore, in conditions with limited technical support, problems may occur, e.g. with the integration of solutions within a common other devices and software of the rehabilitation process.
- Evidence-based practice (EBP) paradigm: many computer-assisted physical therapy interventions are relatively new and require robust clinical evidence to demonstrate their effectiveness and safety compared to existing traditional approaches. From the above reasons, further research is needed before implementation to validate these technologies through well-designed clinical trials and longitudinal studies, addressing issues related to effectiveness, long-term outcomes and potential adverse effects.
- Patient acceptance, engagement, and motivation: some patients may be hesitant to use computer-assisted physical therapy interventions due to concerns about privacy, data security, or discomfort with the technology. Addressing this issue requires careful consideration of user interface design, education, and support to remove potential barriers, increase usability, improve public awareness, and convince patients of the benefits.
- Integrating IT solutions into existing physical therapy workflows and clinical practice guidelines can be challenging due to resistance or skepticism from colleagues, regulatory barriers, or logistical issues [15-20].

By eliminating the above-mentioned limitations or by mitigating their impact, it is possible to use the full potential of IT in physiotherapy, ensuring the provision of safe, effective and patient-centered care.

3.2. Directions for further research

Research into IT applications in physiotherapy is growing, offering innovative ways to improve patient care, streamline rehabilitation programmes and improve outcomes. Key further research primarily includes:

- Testing the effectiveness of telerehabilitation platforms in the remote delivery of physiotherapy servicesL from assessing patient satisfaction through adherence to treatment plans to comparing clinical outcomes with traditional outpatient or home-based physiotherapy;
- Wearable technology: integration of sensors and wearable devices to monitor patient movement, track therapy progress and provide real-time feedback, whether for gait analysis, postural correction or adherence to exercise conditions and timings.
- Virtual reality (VR) and augmented reality (AR) for pain management and increasing patient engagement and correctness of patient exercise - immersive environments tailored to specific patient needs and assessing their impact on treatment outcomes.
- Exploring the potential of machine learning algorithms and artificial intelligence in analysing patient data, predicting treatment response and personalising rehabilitation programmes could include the development of AI-based decision support systems for physiotherapists and the automation of routine tasks to improve efficiency;
- Research into the use of data analytics techniques to learn from large data sets generated in physiotherapy practice by analysing patient outcomes, identifying trends and optimising treatment protocols.
- Additionally, exploring the development of clinical decision support systems that will use the above insights to help physiotherapists make informed decisions.
- Investigating the effectiveness of gamification-based rehabilitation exercises in increasing patient motivation, engagement and adherence to treatment plans, including the design of interactive games and apps that make therapy sessions more enjoyable and rewarding for patients..
- Investigating the integration of robotics into physiotherapy practice for ancillary purposes, such as robotic exoskeletons for gait rehabilitation or robotic devices for upper limb therapy - the aforementioned studies may focus on evaluating the efficacy and safety of these technologies in different clinical settings;
- Evaluating the usability and effectiveness of mobile health (mHealth) apps for delivering physiotherapy interventions, monitoring progress and promoting self-management strategies. This includes investigating the impact of app-based interventions on patient outcomes and healthcare utilisation [21-25].

By further exploring these areas, researchers can further develop the role of informatics in physiotherapy and unlock new opportunities to improve patient care and rehabilitation outcomes. The development of research on the role of AI/ML in physiotherapy deserves special attention.

Further research into the role of AI and ML in physiotherapy may focus on several key areas to develop this common area of research:

- Predictive analysis of treatment outcomes - conducting prospective studies to develop predictive models using AI and ML algorithms to predict patient outcomes based on various factors such as demographics, clinical history and treatment protocols. This can help physiotherapists tailor interventions to individual patients and optimise treatment plans for better outcomes.
- Exploring the use of AI and ML techniques to analyse patient data and generate personalised rehabilitation programmes tailored to specific impairments, functional goals and preferences: how adaptive algorithms can dynamically adjust treatment parameters based on patient progress and feedback, leading to more effective and efficient rehabilitation strategies.
- Develop and validate artificial intelligence-based tools for objective and quantitative assessment of patient function, movement patterns and biomechanics. This includes the use of computer vision, motion analysis and sensor technology to automatically analyse gait, posture, joint range of motion and muscle strength, providing valuable information for making treatment decisions and monitoring progress over time.
- Design and evaluation of AI-based clinical decision support systems that help physiotherapists diagnose musculoskeletal conditions, select appropriate interventions and monitor patient progress, and use ML algorithms to analyse medical imaging data, clinical notes and other patient information to provide evidence-based recommendations and alerts.
- Exploring the integration of AI and ML algorithms in robotic rehabilitation devices and assistive technologies used in physiotherapy: from the development of intelligent control algorithms that adjust device behaviour in real time based on patient interaction and physiological feedback, to increasing the effectiveness and safety of robot-assisted rehabilitation interventions.
- Investigating the effectiveness of AI-based remote monitoring systems and telerehabilitation platforms for delivering physiotherapy services outside of traditional clinical settings, including assessing the feasibility, acceptability and clinical outcomes of virtual rehabilitation programmes, as well as the role of AI in optimising treatment and patient engagement in remote settings.
- Addressing the challenges of data integration, interoperability and standardisation to enable seamless information exchange between AI-based physiotherapy systems and electronic medical record platforms: starting with the development of standard data formats, ontologies and interoperability frameworks to facilitate the aggregation and analysis of heterogeneous data sources for research and clinical practice.
- Exploring the ethical, legal and social implications of integrating AI and ML technologies into physiotherapy practice, including k exploring issues related to patient privacy, consent, algorithm bias, transparency and accountability, and developing guidelines and governance frameworks to ensure responsible and equitable use of AI in Healthcare [26-30].

By developing research in these areas, stakeholders can harness the transformative potential of artificial intelligence and machine learning to improve the quality, accessibility and outcomes of physiotherapy services, ultimately improving the quality of life for patients with musculoskeletal and movement disorders.

Hence, computer-aided diagnostics and computational data analysis in physiotherapy are areas of research and clinical practice that can benefit the most from interdisciplinary research. They allow you to make your vision come true precise personalized physiotherapy focused on the patient and his goals (common goal setting). Therapy plans will be able to be fully adapted to the needs and priorities of each patient, without compromising their effectiveness (first the quality of movement, then its quantity).

To sum up IT provides physiotherapy with advanced data analysis tools to accurately assess patient progress and treatment effectiveness. Automation through computer algorithms can streamline administrative tasks in physiotherapy clinics, improving efficiency and reducing human error. Virtual reality applications developed through IT enable immersive rehabilitation experiences, increasing patient engagement and motivation. Wearable technology integrated with informatics can monitor patient movements in real time, providing valuable feedback to therapists and facilitating remote monitoring. Machine learning algorithms can analyse vast amounts of medical data to identify patterns and predict patient outcomes, helping physiotherapists make informed treatment decisions. Telehealth platforms developed using informatics enable physiotherapists to reach patients in remote areas or those unable to attend in-person sessions, improving accessibility to care. Computer-aided design (CAD) software helps to design customised assistive devices and orthotics tailored to individual patient needs, optimising rehabilitation outcomes. However, the reliance on technology in physiotherapy introduces challenges, such as concerns about data privacy and the need for ongoing training to keep

up with technological advances. Integrating IT into physiotherapy requires an initial investment in infrastructure [31-33].

Cyber security threats pose a serious risk to the integrity and confidentiality of patient data stored and transmitted via physiotherapy computer systems, potentially leading to breaches and invasions of privacy. Over-reliance on technology can undermine the personalised, person-centred approach to care in physiotherapy, reducing the therapeutic alliance between patients and practitioners and impacting on patient outcomes. The complexity and technical nature of IT applications in physiotherapy may exacerbate existing health disparities, as patients without access to or familiarity with technology may face barriers to receiving optimal care. Ethical concerns arise around the use of artificial intelligence and automated decision-making algorithms in physiotherapy, including issues of bias, liability and the potential for algorithms to replace clinical judgement. Compliance challenges, such as navigating data privacy laws and ensuring the safe and effective use of AI-enabled medical devices, add to the complexity and potential legal risks in physiotherapy practice [34-36].

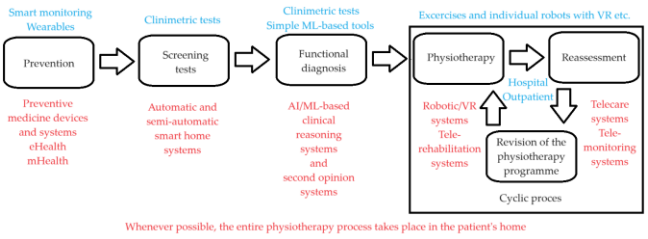

Figure 3. Schematic overview of the physiotherapy process, including interdisciplinary elements that are already present (blue) and future elements that can be introduced to enrich the physiotherapy process (red).

4. Conclusions

The high incidence of diseases of the musculoskeletal system, with co-occurring multi-morbidities, makes the need to provide personalized integrated care and self-treatment (including implementation of rehabilitation programs) at the patient's home more and more urgent. Interdisciplinary cooperation is crucial to fully understand the technological factors that may affect the effectiveness of physiotherapy, especially in home rehabilitation. The rehabilitation program within the cycle is subject to continuous evaluation and optimization, also as patients' functional results improve. Moreover, technologies (including IT) are evolving rapidly, so it is necessary to monitor the current state of knowledge and clinical practice, observe and assess the possibilities of improving the effectiveness of physiotherapy using emerging new technologies, as well as develop and explain key features of hardware and software used in rehabilitation systems, so as not to limit their availability, but to maximize the effect.

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