BMC Health Services Research

RESEARCH

Open Access

Advancing public health through technological rehabilitation: insights from a national clinician survey

Marianna Capecci[1], Marialuisa Gandolfi[2,3], Sofia Straudi[4], Rocco Salvatore Calabrò[5*], Nicolò Baldini[1], Lucia Pepa[6], Elisa Andrenelli[1], Nicola Smania[2,3], Maria Gabriella Ceravolo[1], Giovanni Morone[7,8], Donatella Bonaiuti[9] on behalf of HTA section of SIMFER (Italian Society of Physical and Rehabilitation Medicine)

Abstract

Introduction In the evolving healthcare landscape, technology has emerged as a key component in enhancing system efficiency and offering new avenues for patient rehabilitation. Despite its growing importance, detailed information on technology's specific use, types, and applications in clinical rehabilitation settings, particularly within the Italian framework, remains unclear. This study aimed to explore the use of technology and its needs by Physical Medicine and Rehabilitation medical doctors in Italy.

Methods We conducted a cross-sectional online survey aimed at 186 Italian clinicians affiliated with the Italian Society of Physical and Rehabilitation Medicine (SIMFER). The online questionnaire consists of 71 structured questions designed to collect demographic and geographical data of the respondents, as well as detailed insights into the prevalence and range of technologies they use, together with their specific applications in clinical settings."

Results A broad range of technologies, predominantly commercial medical devices, has been documented. These technologies are employed for various conditions, including common neurological diseases, musculoskeletal disorders, dementia, and rheumatologic issues. The application of these technologies indicates a broadening scope beyond enhancing sensorimotor functions, addressing both physical and social aspects of patient care.

Discussion In recent years, there's been a notable surge in using technology for rehabilitation across various disorders. The upcoming challenge is to update health policies to integrate these technologies better, aiming to extend their benefits to a wider range of disabling conditions, marking a progressive shift in public health and rehabilitation practices.

Keywords Survey, Technology, Disability, Rehabilitation, Professional training, Innovation, Robotics virtual reality, Exergaming, Non-invasive brain stimulation, Telerehabilitation, Sensors, Cognitive training, Balance training, Brain computer interfaces

*Correspondence:
Rocco Salvatore Calabrò
roccos.calabro@irccsme.it
Full list of author information is available at the end of the article

Introduction

The recent demographic changes, characterized by declining birth rates and increasing life expectancies due to advancements in health systems, have brought about significant health challenges associated with an aging population [1, 2]. This demographic change is contributing to a marked rise in the number of individuals experiencing functional declines for extended periods, leading to an uptick in non-communicable diseases and neurological disabilities stemming from both acute and chronic conditions [1]. Consequently, there's an escalating demand for rehabilitation resources aimed at supporting individuals with neurological and non-neurological disabilities [1].

Rehabilitation is a patient-centered and problem-solving process involving a multidisciplinary team of experts [3]. Its primary goal is to mitigate the morbidity and mortality associated with functional declines from various acute and chronic illnesses [3, 4]. In the context of the biopsychosocial model, rehabilitation is beneficial for anyone with either short-term or long-term disabilities arising from any cause and deliverable in any setting [3, 4].

Over time, rehabilitation has evolved into a progressively complex discipline, with numerous interventions and techniques being developed. This evolution is particularly notable in neurological rehabilitation, which has seen significant technological advancements driven by an improved understanding of neurobiological mechanisms underlying neurological disorders and recovery. Effective interventions for neurological disabilities often include intensive, repetitive, and task-oriented training to foster neuroplasticity and subsequent recovery. The cost-effectiveness of this type of rehabilitation interventions is still controversial: it seems to reduce hospitalization length and costs, but this is strictly related to the technology and the setting considered, such as semi-immersive virtual reality and home-based telerehabilitation [5–7].

Technological devices have become a cornerstone in rehabilitation, facilitating specific training features and enhancing factors like patient motivation and engagement, which are crucial for promoting neuroplasticity and recovery. The recent CICERONE Consensus Conference, a collaboration between the Italian Society of Physical Medicine and Rehabilitation (SIMFER) and the Italian Society of Neurological Rehabilitation (SIRN), has significantly advanced the field in Italy. It comprehensively classified these devices, evaluated their effectiveness, and explored their learning effects. The use of these devices in rehabilitation, particularly for improving mobility, gait, balance, and upper limb function, has been prevalent in both adults and children with neurological disabilities.

However, despite these advancements and the global use of rehabilitation technologies, there's a gap in understanding how these technologies are integrated into real-life clinical practices in Italy. Our study aims to address this gap by exploring two key aspects: the prevalence of technology in rehabilitation practices and facilities beyond research centers and labs, the types of technology most commonly used, the populations they serve, and their specific clinical or functional purposes in healthcare pathways.

Conducting this study is pivotal for gaining valuable insights into the practical application, accessibility, and utility of rehabilitation technologies in real-life settings. It will enable us to identify and address gaps and new directions in adopting and using these technologies. Understanding which technologies are used and their specific purposes is essential for justifying investments and shaping the direction of future research and development. This study will also assist in addressing upcoming challenges to update health policies to integrate these technologies better and designing targeted educational and training programs for rehabilitation professionals, equipping them with the skills needed to use these technologies effectively. Ultimately, by comprehensively understanding the current use of technology in rehabilitation, we can identify areas ready for innovation and enhancement. This will advance rehabilitation technology and promote patient-centered care, ensuring that the development and application of these technologies in public health truly meet the needs of those they are designed to help.

Materials and methods

Study design

A web-based, national cross-sectional survey, was developed by the Health Technology-Assisted Rehabilitation (HTA) Section of the Italian Society of Physical Medicine and Rehabilitation (SIMFER), established on November 16, 2020. This survey was aimed at a representative sample of Italian clinicians and experts in Physical and Rehabilitative Medicine, identified through the SIMFER membership list meeting the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines [8] and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [9]. This custom-designed survey was vetted and approved by the SIMFER advisory committee on March 26, 2021, and was conducted between April 17, 2021, and May 21, 2021.

Participants and setting

This survey was aimed at a representative sample of Italian clinicians and experts in Physical and Rehabilitative Medicine identified through the SIMFER membership list. Inclusion criteria were a) were enrolled in the Society at the time of the survey, b) owned a valid e-mail account, and c) consented to participate in social and scientific surveys as SIMFER members. The survey was emailed to all clinicians listed on the SIMFER website. A follow-up reminder was sent four weeks after the initial contact to encourage participation. Survey participation was voluntary and anonymous, ensuring confidentiality and data protection. They gave informed consent to participate in the study.

The study was conducted in accordance with the Declaration of Helsinki. The paper was approved by the Local Ethics Committee of the IRCCS Centro Neurolesi “Bonino-Pulejo”; code number: IRCCSME 12/23.

Questionnaire development and pre-testing

The authors crafted and refined an ad-hoc survey tailored to align with our study’s focus on technology, adapting elements from existing surveys in the field [10]. The development of the survey involved several iterative steps [11]. Initially, a comprehensive set of 68 questions was assembled, which underwent a rigorous evaluation for face and content validity [11]. This evaluation was conducted by a panel of eight experts (MC, MG, SS, RC, GM, NS, MGC, DB), each with specialized knowledge in rehabilitation, technology, and survey design. These clinicians and experts independently reviewed the initial list, collaborating subsequently to finalize it. The draft version of the survey was then tested on a convenience sample of 20 clinicians. Feedback from this preliminary submission provided insights into which questions needed more clarity, re-wording for better understanding, or other enhancements as suggested by the respondents. This feedback process was invaluable in refining the survey, with the panel of experts meticulously reviewing and finalizing the content accuracy, wording, sequence of questions, and overall structure. This ensured that each item was clear, unambiguous, and easily comprehensible [11]. Upon reaching a unanimous consensus, the questionnaire was locked in its final form, comprising 71 questions. This finalized version was then handed over to the system operator for widespread dissemination. The thorough process behind the survey’s design aimed to ensure that it effectively captured the nuanced perspectives of medical professionals in rehabilitation technology.

The survey was designed to be concise yet comprehensive, requiring approximately 7 to 10 min for completion. This duration aligns with the optimal completion time identified for maximizing response rates in online surveys [12]. There were no time limitations in filling out the survey.

The questionnaire was structured into three sections. The first section focused on the socio-demographic and professional profiles of the clinicians participating in the survey. It aimed to provide a background context for the responses received.

The second section delved into the specific technologies used by the respondents. Clinicians were presented with ten different systems lists and asked to identify which ones they utilized. To ensure clarity and minimize the risk of conceptual ambiguity or bias, the format of the questions in this section was primarily multiple-choice, with an option for respondents to provide free-text answers or notes for additional detail. This section was uniquely structured like a decision tree: for each technology listed if a clinician responded affirmatively to using it, they were then prompted to answer more in-depth questions about that technology. If the answer was negative, the questionnaire seamlessly guided them to the next technology, continuing until the end of the list. These in-depth questions explored the specific patient populations served and the functions targeted by each technology. Additionally, each subsection concluded with an open-ended question asking for the (brand) name of the device used.

The technologies listed are electromechanical devices, brain, nerve or muscle stimulation systems, virtual reality visors, motor and non-motor monitoring devices, and rehabilitation software delivered via tablet or PC belonging to the following categories.

- robotic devices for upper or lower limbs
- non-invasive brain stimulation,
- virtual reality (immersive or non-immersive),
- exergaming,
- technological systems for balance rehabilitation,
- functional electrical stimulation (FES),
- brain-computer interface (BCI),
- telerehabilitation platforms,
- sensors for monitoring motor functions of the upper and lower limbs,
- platforms for cognitive rehabilitation

Physical medicine systems such as Transfer Energy Capacitive and Resistive (TECAR) therapy, vibrations therapies, extracorporeal shock wave therapy, magnetotherapy or ultrasound were not included in the list of technologies sought by the survey.

The final section included queries to understand the length of time technology had been used at the center, its primary applications (whether for clinical or research purposes), the treatment protocols involved, and whether the technology was integrated into individual rehabilitation projects. It also sought to identify whether physicians had received specific training in these technologies or if there was still a gap in this area.

To ensure accessibility and ease of use, the questionnaire was designed to be completed on various devices, including laptops, tablets, and mobile phones. Additionally, it was anonymized to mitigate any risks associated with social desirability or self-presentation, ensuring that the responses were as honest and uninfluenced as possible. The English version of the survey can be found in Appendix 1. Table 1 reports a Detailed Description of the Survey Structure and Content.

We utilized the SurveyMonkey (SurveyMonkey, Palo Alto, California, www.surveymonkey.com) platform to conduct our online survey. The survey was active for eight weeks, starting April 18th, 2021. Before initiating the survey, we obtained the necessary permissions from the administrators of the SIMFER website. Following this, we contacted all clinicians through email blasts [11]. Each email included the survey link and a brief note explaining the study's purpose. The email also contained a statement clarifying that by clicking on the survey link and participating, respondents were giving their consent to be part of the study [11]. This approach ensured all participants were fully informed and willing to contribute to our research. A follow-up reminder was sent four weeks after the initial contact to encourage participation.

Participation in the survey was entirely voluntary, and we did not offer any incentives to the participants. They had the flexibility to either not respond to specific questions or to leave the entire questionnaire blank if they chose to [11].

To ensure accuracy and participant satisfaction with their responses, the survey had a back button that allowed participants to review and modify their answers before final submission. Regarding data security and participant privacy, the collected data were downloaded and stored on an encrypted computer, accessible solely to the project manager throughout all stages of the study. We took extra measures to reassure participants that their identities would remain confidential and not be disclosed to the investigators. To further this commitment to confidentiality and data protection, all personal identifiers, such as names and email addresses, were removed from the data [11].

1.275 Italian clinicians and rehabilitation experts registered with the were identified as potential participants, in detailed membership "…is open to natural persons (with Italian citizenship or with another citizenship if working in Italy), graduates in Medicine and Surgery, who have a specialisation qualification (or are enrolled at a residency school in Physical and Rehabilitation Medicine) in the discipline (physiatrics – Physical and Rehabilitation Medicine), or who can document titles, interest, commitment and activities in the discipline" [13]. Of these, 1.032 had valid email addresses. A response was received from 186 clinicians which constitutes an 18% response rate,

Table 1 Detailed description of the survey structure and content

Sections	Questions	Details
1. Socio-demographic and professional characteristics of interviewed physicians	Seven two or multiple-choice questions	Questions' topic: - region and country where clinicians work, - years of work experience, - type of institution (public/private/accredited private), - type of care (day hospital, inpatient intensive rehabilitation, extensive rehabilitation, etc.) and - use of electromechanical or robotic tools or any technology in rehabilitation setting
2. Rehabilitation Technology Usage: Trends, Applications, and Outcomes	Tree scheme questionnaire addressing for each used technology: - target population - training objectives - type of device	List of type of devices: - robotic devices for upper or lower limbs, - noninvasive brain stimulation, - virtual reality (immersive or non-immersive), - exergaming, - technological systems for balance rehabilitation, - Functional Electrical Stimulation - Brain-Computer Interface - telerehabilitation platforms, - sensors for monitoring motor functions both for upper and lower limbs, - platforms for cognitive rehabilitation
3. Rehabilitation Technology Access, Usage, and Training	Ten questions (multiple choice questions, visual analogic scale, or Likert-scale-based questions)	Opinion about the level and the importance: - of integration of technology with the rehabilitation individual project - of specific training in technology

exhibiting a relative standard error of 5.37%, that correspond to the 5% of the true estimate in the population with a confidence level (α) of 90%, using a simple random method sampling approach and with a population proportion set at 50%. The Socio-demographic and professional characteristics of the whole group of Responders (Survey Sect. 1) and the access, usage and training (Survey Sect. 3) are showed in the research letter Capecci et al. [14], while in this paper we have focalized on the results of the 128 responders who declared they used technology to treat or assess subjects undergoing rehabilitation. Therefore, the detailed analysis of the survey second section, about *Rehabilitation Technology Usage: Trends, Applications, and Outcomes,* were reported.

Data analysis

The data from the Survey Monkey platform were downloaded into Excel spreadsheets and reviewed for accuracy and completeness. A questionnaire was deemed incomplete and excluded from the final analysis if it contained more than 20% missing data [15]. To ensure the statistical robustness of our findings, we calculated the margin of error based on the respondent rate, using a 90% confidence interval (CI), which allowed us to assess the statistical significance for our study population. For questions that allowed a single choice, descriptive statistics (mean and standard deviation) were used to summarize continuous variables. Nominal and ordinal variables were analyzed using absolute frequencies and percentages. For questions that permitted multiple responses, we calculated the absolute frequency and percentages for each unique combination of answers provided by the participants. Heatmaps of the frequencies (%) of treated clinical conditions and expected outcomes across technologies were reported. We utilized chi-square statistics for the relationships between various monitored variables (such as geographical origin, level of expertise, etc.) and responses concerning the prevalence and use of technology. Correlation values greater than 0.60 were considered meaningful and were duly reported with the result of statistical comparison. Additionally, the Wilcoxon signed-rank test was employed for comparing continuous data in specific contexts, such as determining whether technology is more frequently used in neurological conditions compared to other contexts. The level of significance was set at 0.05. All statistical analyses were conducted using SAS StatView 5.0, ensuring the application of rigorous and standardized statistical methods.

Results

One hundred twenty-eight clinicians (69%) out of 186 respondents stated that they use rehabilitation technology. All respondents are physicians registered in SIMFER. Most of the technologies are used in Northern Italy (Chi2 = 249; $p < 0.0001$). Most of clinicians have more than 10 years of experience in the use of technology and belonged to public health centers. Table 2 shows demographic characteristics and expertise of clinicians who use technology for rehabilitation.

Rehabilitation technology usage: trends, applications, and outcomes

Balance training was the most frequently employed technology by 64% of the respondents. This was closely followed using robots and electromechanical systems for lower and upper limb rehabilitation, each favored by 46% of the respondents. Virtual Reality (VR) and computerized platforms for cognitive rehabilitation were also widely used, each by 33% of the respondents.

Functional Electrical Stimulation (FES) was chosen by 30% of respondents, and 23% utilized telerehabilitation platforms. Exergaming, which combines physical exercise with interactive gaming, was adopted by 22% of the respondents. Non-invasive brain stimulation (NIBS) was employed by 21% of the respondents. Only one respondent used brain-computer interfaces.

Many respondents have access to multiple types of these technologies, suggesting a versatile and integrative approach to rehabilitation.

There was a notable preference for using technology-assisted rehabilitation for disorders related to neurological diseases over musculoskeletal diseases, as evidenced by a significant statistical finding (Z = −2.3; p = 0.01). The most treated neurological condition was stroke, with 80% followed by traumatic brain injury (61%). Multiple sclerosis and spinal cord injuries, along with Parkinson's disease, were also significant areas of focus, each being treated using rehabilitation technology by 41% and 38% of respondents, respectively. Beyond these, musculoskeletal diseases treated were hip-related problems (28%), knee issues (31%), ankle ailments (26%), and shoulder problems (22%), albeit at lower frequencies. Additionally, 20% of respondents use technology for spinal musculoskeletal injuries and neuromuscular disorders, while dementia and rheumatological disorders were treated by 12% and 9% of respondents, respectively. 11% of the respondents addressed other unspecified disorders using rehabilitation technology.

Dexterity recovery led the list of functions and activities for which rehabilitation technology is employed, with 69% of respondents using technology. Dexterity enhancement was primarily trained through robots, virtual reality (VR), exergaming systems, telerehabilitation, and cognitive rehabilitation platforms, indicating a broad application of these technologies. This was closely followed by strength restoration, which was utilized by 66% of

Table 2 Demographic characteristics and expertise of clinicians declaring to use technology for rehabilitation

		Answers	Years of work experience (N)			Type of hospital/ clinic (N)		
		N (% out of total responses with respect to 128)	< 5	05–10	> 10	Public center	National system accredited private center	Private, non-accredited center
Nord	**Emilia-Romagna**	**14(11)**	2	1	11	12	4	5
	Friuli-Venezia Giulia	**3(2.3)**	1	0	2	3	1	0
	Trentino-Alto Adige	**3(2.3)**	0	0	3	2	1	0
	Veneto	**15(11.7)**	1	5	9	9	7	2
	Liguria	**2(1.6)**	0	0	2	1	1	0
	Lombardy	**19(14.8)**	2	3	14	7	20	1
	Piedmont	**14(11)**	2	0	12	16	5	2
Center	**Latium**	**13(10.1)**	0	6	7	10	5	1
	Marche	**4(3.1)**	1	1	2	3	1	0
	Tuscany	**5(3.9)**	0	1	4	5	1	3
	Umbria	**2(1.5)**	0	0	2	2	1	0
South	**Basilicata**	**3(2.3)**	0	0	3	2	1	0
	Calabria	**5(3.9)**	2	0	3	4	3	0
	Campania	**5(3.9)**	0	2	3	6	3	0
	Apulia	**5(3.9)**	1	0	4	4	5	0
	Sardinia	**2(1.59**	0	0	2	6	3	0
	Sicily	**11(8.6)**	2	0	9	6	8	0
	Abruzzo	**3(2.3)**	0	0	3	3	0	1
North		**70(21)**	**8**	**9**	**53**	**33**	**29**	**8**
Center		**27(55)**	**1**	**8**	**5**	**18**	**7**	**2**
South		**31(24)**	**5**	**2**	**24**	**16**	**14**	**1**
Total		**128(100)**	**14**	**19**	**82**	**67**	**50**	**11**

respondents, and sensory function improvement, which was chosen by 60%.

Cognitive skill improvement was another significant area, with 65% of respondents employing technology. Balance was a focus for 58% of the respondents, while gait rehabilitation and gait endurance improvement were targeted by 55% and 53% of respondents, respectively. Non-immersive and immersive VR (albeit less common) were applied to enhance balance and cognitive skills. Exergaming systems, aligning closely with VR, were indicated for similar rehabilitation purposes, except sensory function recovery. In addition, NIBS was expected to contribute to improving cognitive abilities.

Muscular tone was addressed by 37% of respondents, and joint range of motion was a focus for 41%. Pain control is another area where technology was applied, with 23% of respondents using it.

Independence in Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) were targeted by 46% and 24% of respondents, respectively. VR systems and electromechanical and robotic devices were supposed to increase the patient's independence in daily life. Social participation was addressed by 14% of respondents. Additionally, 19% of respondents reported using technology for other purposes not specifically listed.

Figure 1 reports a visual representation of the distribution and prevalence of the technologies identified in the survey, the most frequent treated conditions and the expected outcomes.

The interactions between different technologies, clinical contest and expected outcomes are showed through heatmaps. In the Figs. 2 and 3, the heatmaps report the distribution of the different treated conditions and of the expected outcome with respect the technologies used. Technology-aided rehabilitation resulted proposed mainly to subjects with neurological-related disabilities, throughout all the different technologies. In particular, stroke patients experimented all types of rehabilitation technologies listed as well as subjects with traumatic brain injuries. Subjects with Parkinsons's disease experimented in particular robotic devices for the lower limbs and systems for balance recovery. In order to improve disabilities related to

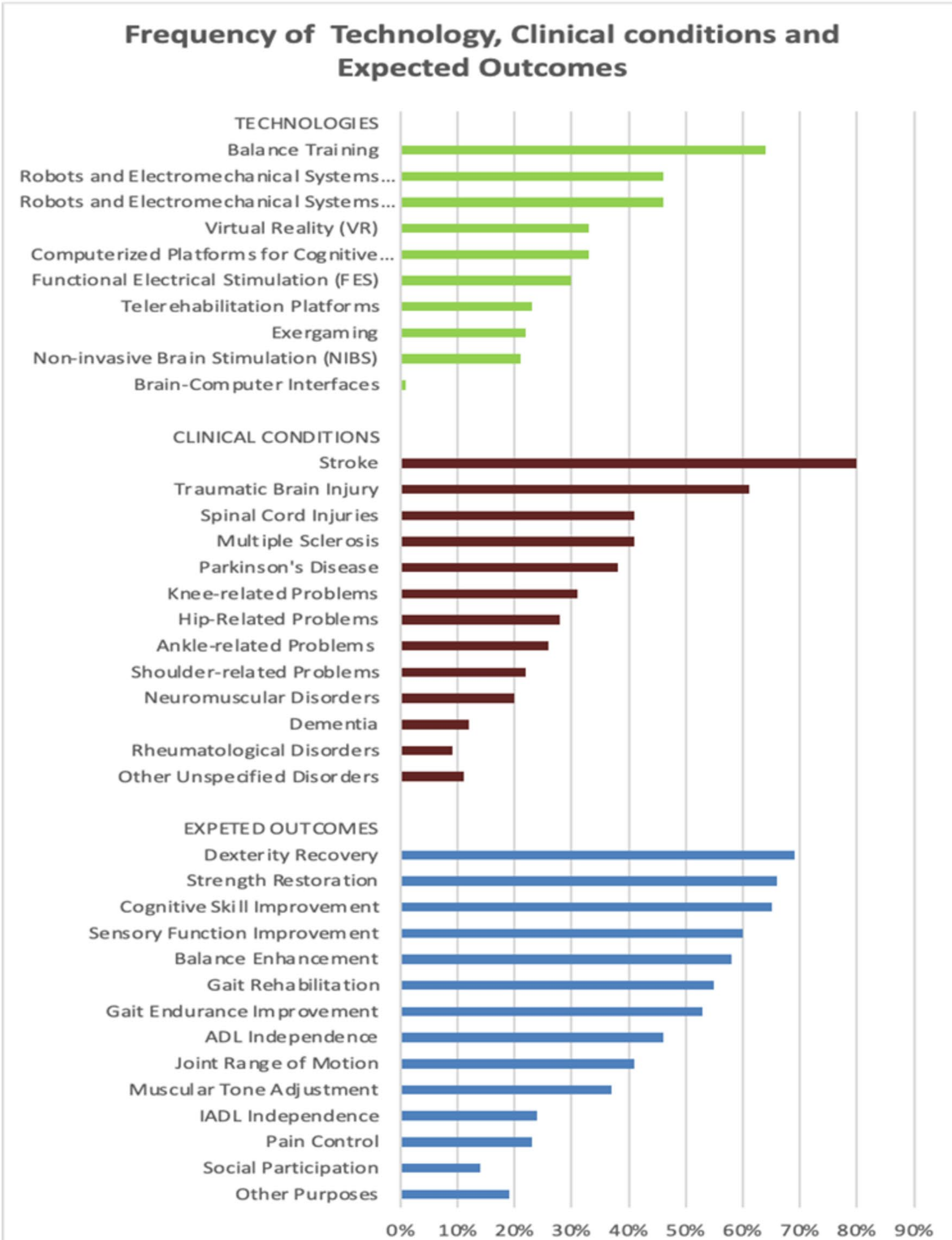

Fig. 1 Frequency of technology (green), clinical conditions (red) and expected outcomes (blue)

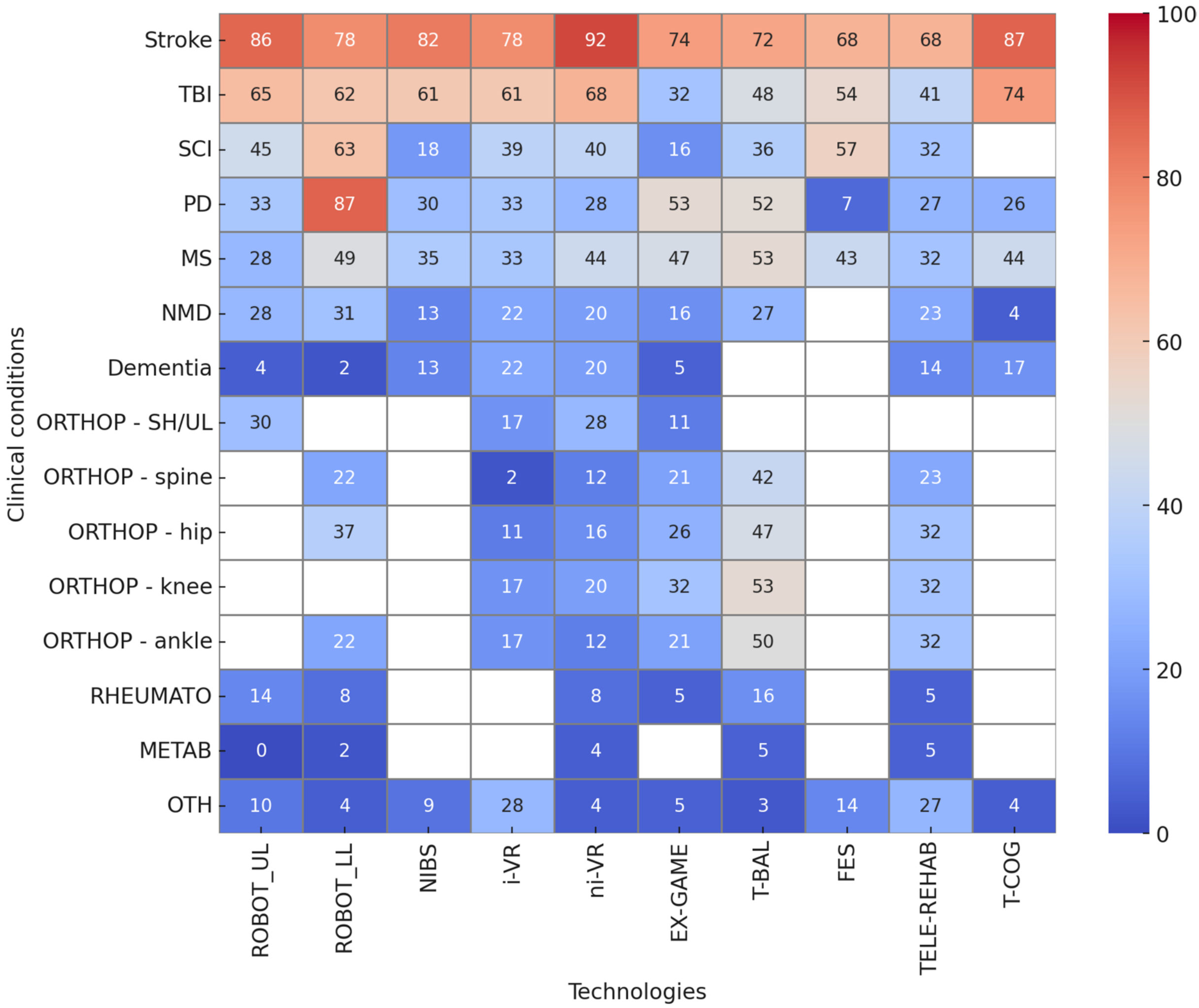

Fig. 2 Heatmap of frequency (%) of different treated conditions with respect to Technologies. Legend: TBI: Traumatic Brain Injury; SCI: Spinal Cord Injury; PD: Parkinson's Disease and Parkinsonism; MS: Multiple Sclerosis; NMD: NeuroMuscular Disease; Ortho: Orthopedic; SH: Shoulder; UL: Upper Limb; LL: Lower Limb; RHEUMATO: Rheumatologic disorders; METAB: Disorders of Metabolisms; ROBOT_UL: Robotic devices for Upper Limbs; ROBOT_LL: Robotic devices for Lower Limbs; NIBS: Non Invasive Brain Stimulation; i-VR: immersive Virtual Reality; ni-VR: non immersive Virtual Reality; EX-GAME: Exergaming; T-BAL: Technologies for BAlance Rehabiltiation FES: Functional electrical stimulation; TELE-REHAB: Telerehabilitation platforms; T-COG: Technologies for Cognitive Rehabilitation

orthopedic conditions, the most used technologies are those for balance recovery, robot for upper limb and telerehabilitation systems.

Although, strength and sensory functions are outcomes always reported across the different technology-aided rehab trainings, the heatmap in the Fig. 3 shows that the most frequent expected outcome is specific with respect to the used technology and mainly focused on selective or global activities: i.e. recovery of dexterity and independence in ADL in the case of robot for upper limb, recovery of gait when robot for lower limb is used. In the case of tele-rehabilitation systems, there is a distribution of expected outcomes between functions, activities and participation recovery, although dexterity is the most frequently expected outcome.

A detailed description of the respondents' answers for all the different technologies (robotic devices for upper or lower limbs, non-invasive brain stimulation, virtual reality (immersive or non-immersive), exergaming, technological systems for balance rehabilitation, functional electrical stimulation (FES), brain-computer interface (BCI), telerehabilitation platforms, platforms for cognitive rehabilitation) can be found in Appendix 2, where the frequencies of the treated population,

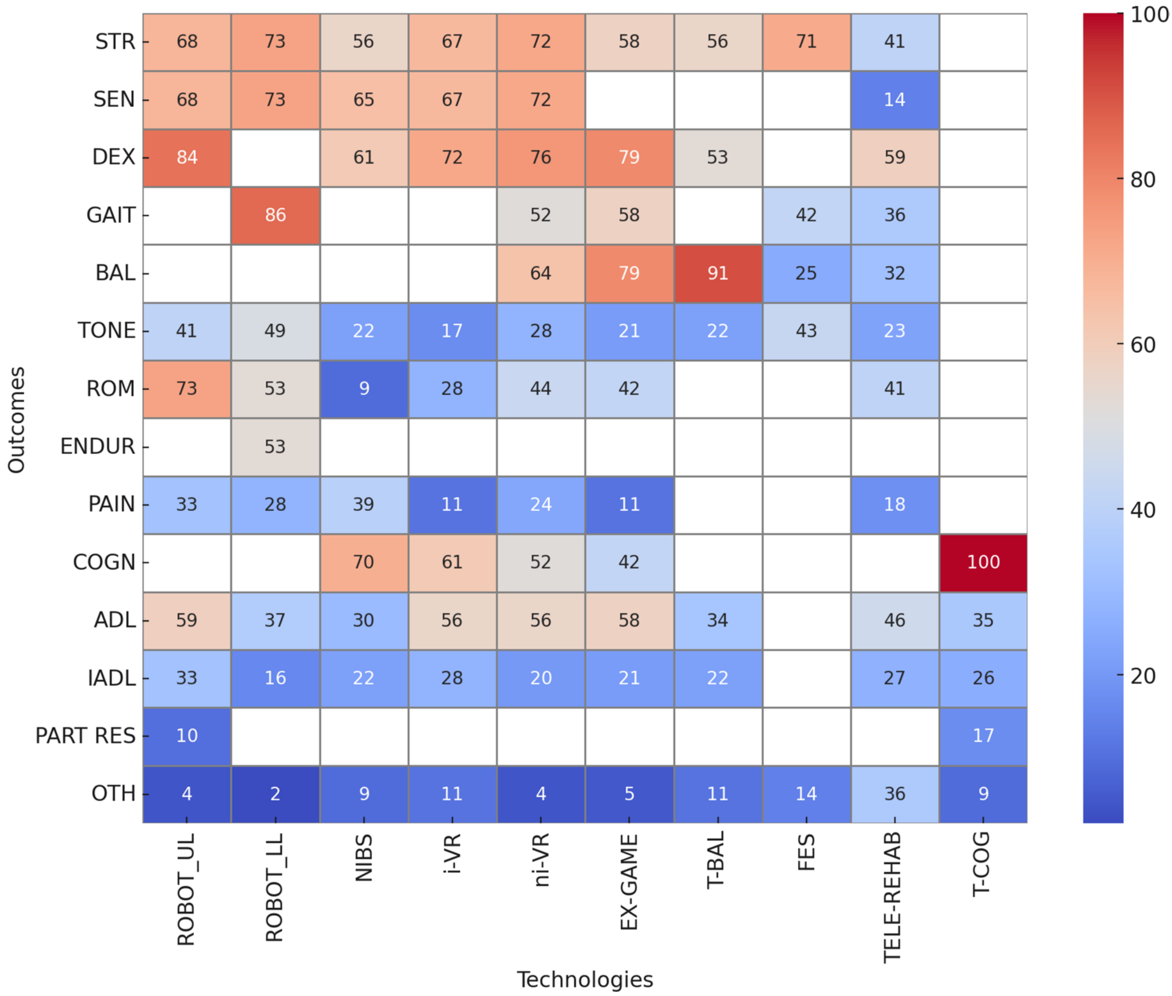

Fig. 3 Heatmap of frequency (%) of expected rehabilitation outcomes with respect to Technologies. Legend: STR: Strength; SEN: Sensory; Dex: Dexterity; BAL: Balance; TONE: Muscular Hypertone; ROM: Range of Motion; ENDUR: Endurance; COGN: Cognitive Skills; ADL: Activity of Daily Living; IADL: Instrumental Activity of Daily Living; PART RES: Participation Restriction; ROBOT: Robotic devices; UL: Upper Limb; LL: Lower Limb; NIBS: Non Invasive Brain Stimulation; i-VR: immersive Virtual Reality; ni-VR: non immersive Virtual Reality; EX-GAME: Exergaming; T-BAL: Technologies for Balance Rehabiltiation; FES: Functional electrical stimulation; TELE-REHAB: Telerehabilitation platforms; T-COG: Technologies for Cognitive Rehabilitation

the selected goals/expected outcomes and the type of devices (i. e. brand) with respect to each technology.

The survey also investigated the use of sensors for monitoring motor functions of the upper or lower limbs: twenty-two participants (17%) reported using Remote Monitoring Systems (RMS) during the rehabilitation program. In 100% of the cases, wearable sensors were used at the clinical center, in 29% also at the patient's home, and in one case (5%), a non-wearable sensor at the hospital. In 86% of the cases, the systems were CE-marked medical devices, 24% were CE-marked commercial devices and in 10%, the physicians used experimental devices. In 9 (10%) centers, RMS was used to monitor the upper limb in subjects with stroke (56%), traumatic brain injury (44%), spinal cord injury (33%), Parkinson's disease, and parkinsonism (33%), multiple sclerosis (22%), neuromuscular disease (11%), orthopedic shoulder/upper limb disease (44%), and rheumatological disorders (5%). This technology was used to monitor upper limb function (100%), involuntary movement disorders (44%), non-motor characteristics (i.e., skin conductance, heart rate) (11%), and emotions (11%).

In 11 (50%) centers RMS was used to monitor the lower limbs in subjects with stroke (60%), traumatic brain injury (30%), spinal cord injury (30%), Parkinson's disease and parkinsonism (40%), multiple sclerosis (10%), neuromuscular diseases (10%), orthopedic hip (03%), knee (30% = and ankle (30%), rheumatological disorders (10%). This technology was used to monitor the recovery of walking (100%) and recovery of basic ADL/IADL (30%).

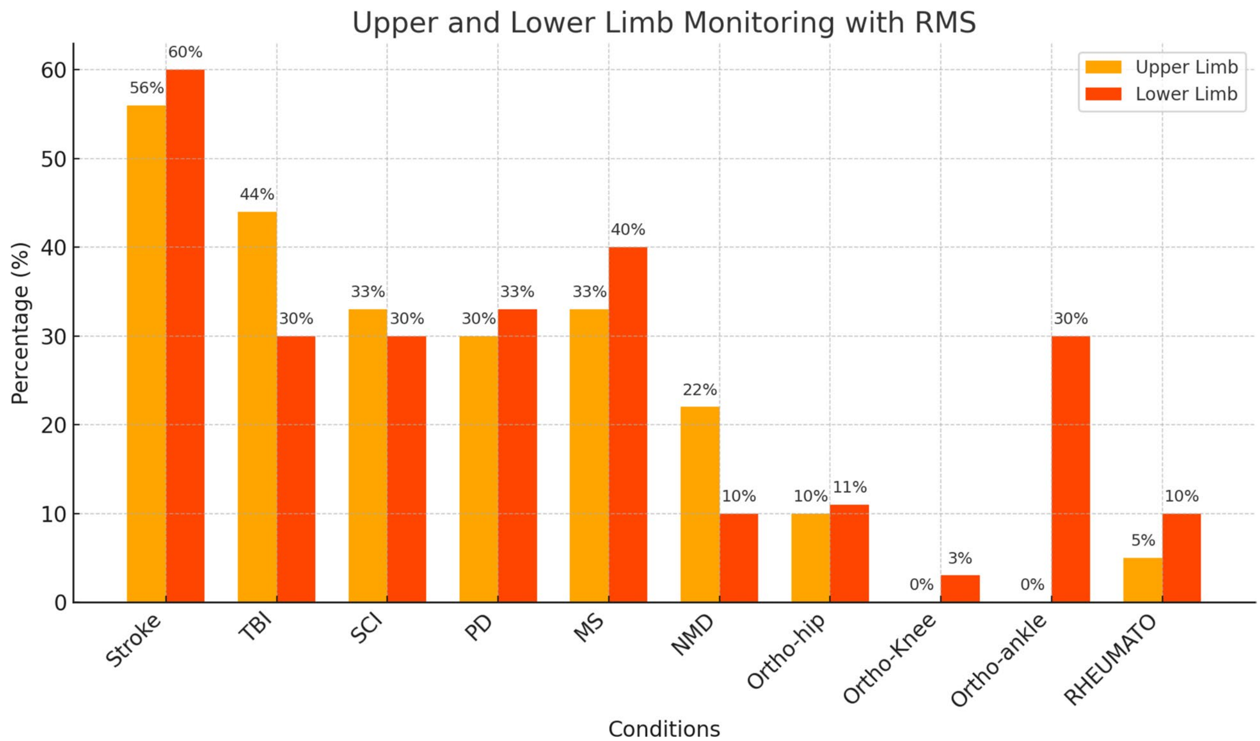

Fig. 4 Upper and Lower Limb Monitoring with RMS. Legend: Note that the 17% of survey respondents declared they use the technology for movement monitoring, of which 50% for lower limbs and 10% for upper movements. TBI: Traumatic Brain Injury; SCI: Spinal Cord Injury; PD: Parkinson's Disease and Parkinsonism; MS: Multiple Sclerosis; NMD: NeuroMuscular Disease; Ortho: Orthopedic Disease; RHEUMATO: Rheumatologic disorders

Figure 4 shows upper and lower limb monitoring with RMS.

In eleven cases (50%) respondents reported using wearable inertial measurement units (IMUs) for motor function monitoring without specifying which one it was, in other six cases (27%) the G-sensor (G-walk—BTS Bioengineering Italia) was used, in two others (9%) the Freemg (BTS Bioengineering Italia), in another (4. 5%) the IMU OPAL and finally the sensors embedded in the rehabilitation architectures Riablo Balancing Platform (Euleria srl Company TN Italy), Tyromotion (GmbH, Grav. Austria) and the stimulator Phenix (12.5%), were used respectively.

Discussion

This survey represents an innovative effort to compile a comprehensive overview of the prevalence, professional characteristics, and various aspects of technology usage, including trends, applications, outcomes, and training among Physical Medicine and Rehabilitation (PMR) medical doctors in Italy. Despite the modest participation rate, the survey produced reliable data, as indicated by a relative standard error of 5.37%, making it suitable for a thorough analysis [16].

The findings of the survey are diverse and revealing. A key insight is respondents' extensive access to technological devices in clinical settings, demonstrating a significant integration of technology in PMR practices. However, respondents were primarily technology users. Additionally, the respondents' depth of experience, with many having over ten years in PMR, enriches this integrationand enhances the value of the results obtained.

The survey also sheds light on the primary use of technological devices in managing neurological conditions [17–21], particularly in enhancing functions and activities within the scope of the International Classification of Functioning, Disability and Health (ICF), focusing on balance and dexterity. Given the frequent occurrence of balance issues in both musculoskeletal and neurological rehabilitation, technology targeting these problems is likely among the earliest to be extensively available and researched. There's compelling evidence of technology's efficacy in improving balance and reducing falls in various patient groups [22–31].

A rising trend was observed in using these technologies for non-neurological conditions like musculoskeletal diseases, cognitive improvement, and pain management. This evolution indicates an expanded use of technology in rehabilitation, moving beyond physical treatment in neurological conditions to include musculoskeletal disturbances and cognitive elements, signifying a progressive approach to comprehensive patient care. Our survey findings align with the recent trends observed in the literature, particularly in the growing demand within the orthopedic field. This increase in demand has been matched by the development of advanced rehabilitation technologies specifically tailored for orthopedic care. According to a comprehensive review by Kuroda et al. [32], in hospital settings, the most used technologies for orthopedic rehabilitation include continuous passive motion devices, robotic devices, and electromagnetic sensors for assessing the movement of upper and lower limbs during rehabilitation [5, 32, 33].

A particularly interesting finding is that nearly half of the respondents use technology to improve patients' independence in daily activities, employing innovative methods like virtual reality. This approach represents a forward-thinking and all-encompassing strategy in rehabilitation, positioning technology not merely as a means for physical or cognitive therapy but also as a tool for enhancing patients' autonomy and overall quality of life.

Following robotics, exergaming and virtual reality (VR) emerge as the most popular technologies in rehabilitation, as confirmed by both our survey respondents and existing literature [20, 34, 35]. These technologies are employed for training motor and cognitive functions, utilizing the engaging aspects of gamified therapy [34]. Tosto-Mancuso et al. clearly distinguishes between exergaming and serious games [34]. Exergaming involves interactive games where movement drives gameplay, typically using low-cost, commercially available systems like Microsoft Kinect, Nintendo Wii, or Logitech Adaptive Controller. These systems can be used for both rehabilitation and recreational purposes. In contrast, serious games are tailored specifically for rehabilitation, with limb movements controlling actions, often in conjunction with robotic devices or within immersive VR environments [33].

The increasing prevalence of the use of technology for cognitive impairment can be supported by the increasing prevalence of cognitive impairments in neurological and non-neurological patients. Indeed, aging and neurodegeneration underscores the need for effective, accessible, and engaging cognitive interventions for the elderly. In this regard, serious video games and virtual reality (VR) systems are promising tools. Their appeal lies in their engaging nature, empowerment potential, user-friendly design, and widespread availability [34]. Research, including well-designed, randomized controlled trials, has shown encouraging results from cognitive interventions using serious video games and VR. These technologies have demonstrated efficacy in enhancing cognitive functions, leveraging their interactive and immersive capabilities. However, the cognitive benefits of exergames—games that combine physical exercise with cognitive challenges—are not as clear-cut. While these systems are popular, used by 22% of our survey respondents, and offer advantages like affordability, high availability, and home usability, they fall short in comparison to specialized medical devices. Exergames generally lack the specificity, adaptability, and safety features of devices specifically designed for addressing disabilities.

This contrast highlights a critical aspect of technology choice in cognitive rehabilitation. While more accessible technologies like exergames have their place, especially in terms of user engagement and ease of use, there is a trade-off regarding their therapeutic precision and adaptability to individual patient needs. The decision to use one type of technology over another thus depends on various factors, including the specific goals of the intervention, the user's capabilities, and the resources available.

The survey has brought to light emerging areas in rehabilitation technology, notably Non-invasive Brain Stimulation (NIBS) and Brain-Computer Interfaces (BCI). NIBS, as reported by 19% of our respondents, encompasses various techniques that use electrical or magnetic stimulation to modulate brain activity, potentially influencing synaptic connectivity processes like long-term potentiation and depression, key to neural plasticity. In rehabilitation, NIBS aims to enhance motor and non-motor (cognitive or affective) recovery, particularly following brain injury or in neurodegenerative disorders. The impact of NIBS depends on the stimulation's nature and the targeted brain region. Among NIBS techniques, transcranial direct current stimulation (tDCS) is more frequently used than repetitive Transcranial Magnetic Stimulation (rTMS), largely due to its minimal side effects, affordability, and portability, which enhance its suitability for home use [35]. Research indicates tDCS's effectiveness in improving gait, balance, and lower limb motor functions in stroke survivors, with bilateral stimulation proving more beneficial than unilateral [36]. However, the clinical routine use of NIBS faces several obstacles and is predominantly confined to research settings under specific protocols.

In contrast, only a single respondent reported using BCI, which represents an emerging frontier in neurological rehabilitation. BCIs are employed for controlling neuroprosthetic devices or facilitating alternative communication methods. Beyond these applications, there's ongoing research into non-invasive BCIs as therapeutic tools for enhancing motor recovery and inducing neuroplasticity post spinal cord injury, stroke, or in cognitive rehabilitation [36–38]. Despite a decade of progress and a growing body of evidence supporting BCI's clinical efficacy in motor rehabilitation, its widespread integration into clinical practice remains an ongoing endeavor.

Despite having access to technological devices for an extended period, with many responders indicating availability for more than ten years, they reported only modest self-assessments regarding integrating these technologies into patients' rehabilitation projects and their proficiency in using these tools. This modest self-perception aligns with their educational experiences, as nearly half of the respondents reported attending training courses that lasted less than 5 h. Additionally, they were more interested in further developing their skills and knowledge. These observations collectively point to a substantial eagerness among professionals to deepen their understanding and expertise in applying rehabilitation technology, highlighting an area for potential growth and development in this field. It suggests the importance of implementing specific educational programs starting from the specialization degree. On the other hand, the low self-assessment rate could be related to the complexity of some technological techniques used in the clinical practice, such as NIBS or BCI [39].

In recent years, rehabilitation professionals have faced many challenges due to the restrictions imposed by the covid 19 pandemic. Therefore, they had to find new methods to ensure that as many patients as possible had access to rehabilitation care and treatment: telerehabilitation was one of them. However, the results of our survey showed that only about 23% of the respondents used dedicated platforms. Recently, the European Board of Physical and Rehabilitation Medicine (UEMS – PRM Section) published an Evidence-based position paper on Physical and Rehabilitation Medicine professional practice on telerehabilitation shedding light on facilitators and barriers to its use. In particular, the experts emphasised the importance of providing telerehabilitation services whenever possible to benefit the patient and his or her family [40]. Considering this, it would be interesting to see whether the percentage of those using rehabilitation platforms has increased over the last three years in Italy.

Comparing our data with existing literature is challenging, as, to the best of our knowledge, this study is pioneering in its focus on Italian clinicians. Furthermore, there is a need for more similar studies within the European context, making direct comparisons or contextual evaluations with other researches difficult. This gap underscores our study's unique contribution to exploring this area. In contrast, the telephone survey by Ruiz Morilla et al. on technology implementation obtained a higher adherence rate [9].

The survey has many limitations due to the study design and bottom-up approach. The survey represents a first summary description of the use of new technologies in rehabilitation in a nation that could be illustrative of other international realities as a starting point for promoting networking to share experiences, expertise, needs, protocols, and guidelines within a cross-cultural context. The survey highlighted some critical issues, such as the discrepancies between the widespread use of technology and the low rate of existing objective evidence of effectiveness at the international level for treating with technologies neurological-related or orthopedics-linked disabilities.

Some questions remain unanswered, opening broad research perspectives. Despite the widespread use of the technology, its impact on the amount of healing observed is unclear. The perception of the respondents indicates varying levels of understanding and acceptance. There appears to be an additional workload for the team, and there is likely a learning curve associated with the implementation of the technology. Additionally, the rehabilitation training program may not be sufficiently focused on the utilization of technological devices in terms of the allocated time.

Finally, if the technology is so widespread and evidence of efficacy is lacking, there is plenty of material to promote large multicenter retrospective studies subject to shared evaluation protocols among patients using the same measurement tools. Moreover, implementing rehabilitation monitoring and treatment technologies into routine clinical practice requires activating the health policy system to establish legislative regulations regarding indications, ethics, safety, and reimbursement [10, 16].

Conclusion

Over the past decade, there has been a significant increase in technology integration into rehabilitation practices, a development with important implications for public health globally. Our survey primarily focuses on using this technology to enhance functional recovery in neurological disorders, especially post-stroke, where its effectiveness is well-documented. Additionally, its application extends beyond neurological conditions to various non-neurological disorders, a field that demands further research to confirm efficacy. Technology for monitoring appeared comparatively less prevalent. Open questions remain regarding dispersion, costs, and ethics.

From a public health perspective, this work lays the foundation for cross-country and cross-cultural experiences, inviting similar studies in other countries and cultures. This approach can enrich our understanding of how different health systems and cultural contexts influence the integration and effectiveness of rehabilitation technology.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-024-11991-0.

Supplementary Material 1.

Supplementary Material 2.

Acknowledgements
The study has been promoted by the HTA (Health Technology Assessment) section of the Italian Society of Physical and Rehabilitation Medicine (SIMFER, Società Italiana di Medicina Fisica e Riabilitativa). We would thank members of the "Ufficio Di Presidenza" SIMFER of the year 2017-2021 and 2021-2024. We thank Guido Mondaini Baroncini, the study project manager, for the support in preparing the survey.

Authors' contributions
Conceptualization: Marianna Capecci, Donatella Bonaiuti, Giovanni Morone, Sofia Straudi, Marialuisa Gandolfi; Rocco Salvatore Calabrò methodology and data curation: Marianna Capecci, Donatella Bonaiuti, Giovanni Morone, Sofia Straudi, Marialuisa Gandolfi; Rocco Salvatore Calabrò; data acquisition: Donatella Bonaiuti; data synthesis: Marianna Capecci, Nicolò Baldini, Lucia Pepa, Elisa Andrenelli Nicola Smania, Maria Gabriella Ceravolo; writing-original draft: Marianna Capecci, Nicolò Baldini, Lucia Pepa, Elisa Andrenelli; writing-review and editing: All Authors. All authors contributed to the manuscript and read and approved the final version of the manuscript.

Funding
None.

Data availability
The datasets for this study are available upon request. Interested parties can obtain them by contacting the Authors.

Declarations

Ethics approval and consent to participate
The paper was approved by the Local Ethics Committee of the IRCCS Centro Neurolesi "Bonino-Pulejo"; code number: IRCCSME 12/23.
All participants gave informed consent to enter the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Experimental and Clinical Medicine, Neurorehabilitation Clinic, University Hospital of Marche, University Politecnica Delle Marche, Ancona, Italy. [2]Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy. [3]Neuromotor and Cognitive Rehabilitation Research Centre (CRRNC), University of Verona, Neurorehabilitation Unit, Verona, Italy. [4]Department of Neuroscience and Rehabilitation, University of Ferrara, Ferrara, Italy. [5]IRCCS Centro Neurolesi "Bonino Pulejo", Messina, Italy. [6]Department of Information Engineering, University Politecnica Delle Marche, Ancona, Italy. [7]Department of Life, Health and Environmental Sciences, University of L'Aquila, L'Aquila, Italy. [8]San Raffaele Institute of Sulmona, Sulmona, Italy. [9]Golgi Redaelli Istitute, Milan, Italy.

Received: 8 January 2024 Accepted: 22 November 2024
Published online: 19 December 2024

References

1. GBD 2016 Neurology Collaborators. Global, regional, and national burden of neurological disorders, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. 2019;18(5):459–80.
2. Ding C, Wu Y, Chen X, Chen Y, Wu Z, Lin Z, et al. Global, regional, and national burden and attributable risk factors of neurological disorders: the global burden of disease study 1990–2019. Front Public Health. 2022;10:952161.
3. Wade DT. Describing rehabilitation interventions. Clin Rehabil. 2005;19(8):811–8.
4. Wade DT. What is rehabilitation? An empirical investigation leading to an evidence-based description. Clin Rehabil. 2020;34(5):571–83.
5. Cieza A, Causey K, Kamenov K, Hanson SW, Chatterji S, Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2021;396(10267):2006–17.
6. PrvuBettger JA, Stineman MG. Effectiveness of multidisciplinary rehabilitation services in postacute care: state-of-the-science. A review Arch Phys Med Rehabil. 2007;88(11):1526–34.
7. Economic Cost of Rehabilitation with Robotic and Virtual Reality Systems in People with Neurological Disorders: A Systematic Review - PMC. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10971291/. Cited 2024 Aug 26.
8. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet e-surveys (CHERRIES). J Med Internet Res. 2004;6(3):e132.
9. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ. 2007;335(7624):806–8.
10. Ruiz Morilla MD, Sans M, Casasa A, Giménez N. Implementing technology in healthcare: insights from physicians. BMC Med Inform Decis Mak. 2017;17(1):92.
11. Hox EDDL Joop J. Survey Mode and Mode Effects. In: Improving Survey Methods. Routledge; 2014.
12. Fan W, Yan Z. Factors affecting response rates of the web survey: a systematic review. Comput Hum Behav. 2010;26(2):132–9.
13. Diventa socio. SIMFER. Available from: https://simfer.it/diventa-socio/. Cited 2024 Aug 26.
14. Capecci M, Gandolfi M, Straudi S, Calabrò RS, Baldini N, Pepa L, et al. Shaping the future: an Italian survey unveils the unmet need to empower physical medicine and rehabilitation professionals with technological skills. Eur J Phys Rehabil Med. 2024;60(3):540–5.
15. Lau C, Chitussi D, Elliot S, Giannone J, McMahon MK, Sibley KM, et al. Facilitating community-based exercise for people with stroke: cross-sectional e-survey of physical therapist practice and perceived needs. Phys Ther. 2016;96(4):469–78.
16. Shirota C, Balasubramanian S, Melendez-Calderon A. Technology-aided assessments of sensorimotor function: current use, barriers and future directions in the view of different stakeholders. J Neuroeng Rehabil. 2019;16(1):53.
17. Agostini M, Moja L, Banzi R, Pistotti V, Tonin P, Venneri A, et al. Telerehabilitation and recovery of motor function: a systematic review and meta-analysis. J Telemed Telecare. 2015;21(4):202–13.
18. Picerno P, Iosa M, D'Souza C, Benedetti MG, Paolucci S, Morone G. Wearable inertial sensors for human movement analysis: a five-year update. Expert Rev Med Devices. 2021;18(sup1):79–94.
19. Gandolfi M, Valè N, Posteraro F, Morone G, Dell'orco A, Botticelli A, et al. State of the art and challenges for the classification of studies on electromechanical and robotic devices in neurorehabilitation: a scoping review. Eur J Phys Rehabil Med. 2021;57(5):831–40.
20. Tieri G, Morone G, Paolucci S, Iosa M. Virtual reality in cognitive and motor rehabilitation: facts, fiction and fallacies. Expert Rev Med Devices. 2018;15(2):107–17.
21. Demeco A, Zola L, Frizziero A, Martini C, Palumbo A, Foresti R, et al. Immersive virtual reality in post-stroke rehabilitation: a systematic review. Sensors (Basel). 2023;23(3):1712.
22. Kerber KA, Callaghan BC, Telian SA, Meurer WJ, Skolarus LE, Carender W, et al. Dizziness symptom type prevalence and overlap: a US nationally representative survey. Am J Med. 2017;130(12):1465.e1-1465.e9.
23. Nardone A, Schieppati M. The role of instrumental assessment of balance in clinical decision making. Eur J Phys Rehabil Med. 2010;46(2):221–37.
24. Cesari M, Landi F, Torre S, Onder G, Lattanzio F, Bernabei R. Prevalence and risk factors for falls in an older community-dwelling population. J Gerontol A Biol Sci Med Sci. 2002;57(11):M722-726.

25. Zampogna A, Mileti I, Palermo E, Celletti C, Paoloni M, Manoni A, et al. Fifteen years of wireless sensors for balance assessment in neurological disorders. Sensors (Basel). 2020;20(11):3247.
26. Abdo N, ALSaadawy B, Embaby E, Youssef Rehan A. Validity and reliability of smartphone use in assessing balance in patients with chronic ankle instability and healthy volunteers: a cross-sectional study. Gait Posture. 2020;82:26–32.
27. Baselizadeh A, Behjat A, Torabi A, Behzadipour S. Using robotic mechanical perturbations for enhanced balance assessment. Med Eng Phys. 2020;83:7–14.
28. Papalia GF, Papalia R, Diaz Balzani LA, Torre G, Zampogna B, Vasta S, et al. The effects of physical exercise on balance and prevention of falls in older people: a systematic review and meta-analysis. J Clin Med. 2020;9(8):2595.
29. Nardone A, Godi M, Artuso A, Schieppati M. Balance rehabilitation by moving platform and exercises in patients with neuropathy or vestibular deficit. Arch Phys Med Rehabil. 2010;91(12):1869–77.
30. Berton A, Longo UG, Candela V, Fioravanti S, Giannone L, Arcangeli V, et al. Virtual reality, augmented reality, gamification, and telerehabilitation: psychological impact on orthopedic patients' rehabilitation. J Clin Med. 2020;9(8):2567.
31. Vogt S, Skjæret-Maroni N, Neuhaus D, Baumeister J. Virtual reality interventions for balance prevention and rehabilitation after musculoskeletal lower limb impairments in young up to middle-aged adults: a comprehensive review on used technology, balance outcome measures and observed effects. Int J Med Informatics. 2019;1(126):46–58.
32. Kuroda Y, Young M, Shoman H, Punnoose A, Norrish AR, Khanduja V. Advanced rehabilitation technology in orthopaedics-a narrative review. Int Orthop. 2021;45(8):1933–40.
33. Edwards D, Williams J, Carrier J, Davies J. Technologies used to facilitate remote rehabilitation of adults with deconditioning, musculoskeletal conditions, stroke, or traumatic brain injury: an umbrella review. JBI Evid Synth. 2022;20(8):1927–68.
34. Tosto-Mancuso J, Tabacof L, Herrera JE, Breyman E, Dewil S, Cortes M, et al. Gamified neurorehabilitation strategies for post-stroke motor recovery: challenges and advantages. Curr Neurol Neurosci Rep. 2022;22(3):183–95.
35. Maggio MG, Latella D, Maresca G, Sciarrone F, Manuli A, Naro A, et al. Virtual reality and cognitive rehabilitation in people with stroke: an overview. J Neurosci Nurs. 2019;51(2):101–5.
36. Sudbrack-Oliveira P, Razza LB, Brunoni AR. Non-invasive cortical stimulation: transcranial direct current stimulation (tDCS). Int Rev Neurobiol. 2021;159:1–22.
37. Morone G, Pichiorri F. Post-stroke rehabilitation: challenges and new perspectives. J Clin Med. 2023;12(2):550.
38. Pichiorri F, Mattia D. Brain-computer interfaces in neurologic rehabilitation practice. Handb Clin Neurol. 2020;168:101–16.
39. Carelli L, Solca F, Faini A, Meriggi P, Sangalli D, Cipresso P, et al. Brain-computer interface for clinical purposes: cognitive assessment and rehabilitation. Biomed Res Int. 2017;2017:1695290.
40. Zampolini M, Oral A, Barotsis N, AguiarBranco C, Burger H, Capodaglio P, et al. Evidence-based position paper on Physical and Rehabilitation Medicine (PRM) professional practice on telerehabilitation. Eur J Phys Rehabil Med. 2024;60(2):165–81.

Publisher's Note