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Healthcare practitioners and robotic-assisted rehabilitation: understanding needs and barriers

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Abstract

Backgrounds In recent years, numerous robotic devices, together with allied technologies, have been developed to support rehabilitation, both in research settings and industry. Although robotic-assisted rehabilitation and related technologies hold significant promise for supporting healthcare practitioners and enhancing patient care, their use in clinical practice remains limited. One of the motivations could be that final users' needs have not been given due consideration so far. As a matter of fact, understanding user needs and perceptions is crucial for designing these technological devices and for creating new organizational models within hospitals aiming to establish and maintain robotics-assisted rehabilitation gyms.

Methods We developed and distributed an online survey to the Italian community of healthcare practitioners working in rehabilitation, to depict the current landscape of robotic-assisted rehabilitation and to understand their opinions and demands across various domains and diseases. The questionnaire is divided into two main parts. The first section pertains to the respondents' demographics and professional experience. The second part includes questions about eight different categories of rehabilitative devices. For each category, practitioners can indicate whether they use a device in their practice, their perceptions, and any perceived barriers. Additionally, they can fill out a System Usability Scale for a specific device in that category.

Results We collected answers from 423 Italian rehabilitation professionals, including various clinical roles, that revealed significant insights into the use of robotics in rehabilitation. Gender distribution shows a high prevalence of female professionals. 40% of respondents reported being unfamiliar with any robotics devices. Advanced treadmills are the most known and used robots. Generally, usage and experience with devices are associated with positive attitudes towards robotics-assisted rehabilitation. Lack of financial resources and scientific evidence, as well as lack of opportunities and training, are the most reported barriers.

Conclusions Despite a general positivity towards technology, there is a substantial lack of awareness about rehabilitation devices among professionals. The survey highlights the need for enhanced training and education on robotics in rehabilitation programs. Additionally, the limited focus on home rehabilitation is noted. The study emphasizes the importance of verifying both the effectiveness and economic sustainability of robotic devices in clinical practice.

Keywords User needs, SUS, Survey, Technology adoption, Robots, Questionnaire

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Background and objective

Robots and Allied Digital Technologies (RADTs) hold the promise to enhance patient care and support healthcare practitioners (HCPs), by increasing the amount of therapy that a patient can perform [1], enabling telerehabilitation, and engaging patients during the treatment [2]. Yet, the current utilization rate of these technologies in clinical practice remains low [3]. Various types of barriers that prevent the spreading of robotics-assisted rehabilitation have been identified, broadly related to costs, limited adaptability to patients' needs, and the requirement of trained practitioners, as too often sophisticated RADTs are designed without enough attention to usability [1, 4, 5]. Moreover, the lack of conclusive scientific evidence prevents the clinical translation of robotic-assisted rehabilitative programs. Yet, to reach scientific evidence, extensive clinical trials should be performed, but most hospitals lack adequate information systems able to integrate emerging technologies and the treatment outcomes within the patient's Health Care Record. Therefore, barriers vary across different types of stakeholders, such as patients, caregivers, HCPs, policymakers, and payers. Identifying specific barriers and stakeholders' needs, which may vary in the different countries as they are also related to regulation and legal assets, is crucial to fostering the translation of robotic-assisted rehabilitation from bench to bedside. In this context, national initiatives are currently undergoing. For instance, in Switzerland, the SwissNeuroRehab project (https://www.swissneurorehab.ch) aims at developing and validating an effective and efficient model of neurorehabilitation, while in Italy, the Fit4Medical Robotics (Fit4MedRob, https://www.fit4medrob.it) Initiative aims at producing scientific evidence of RADTs effectiveness and proposing a new organization model(s) that can be implemented into the national health system.

Understanding HCPs' needs and barriers is crucial to better design clinical trials, driving research on new robotics devices, and improving the existing ones, by detecting their possible pitfalls. It is commonly agreed that human-centered design principles should be employed to ensure that these technologies are intuitive, user-friendly, and aligned with the specific needs of final users [6]. In this scenario, surveys and questionnaires are useful tools to understand HCPs' needs and barriers.

Previously developed surveys in this area were focused on specific diseases, in particular stroke [1, 4–7] and on the motor domain [4–6, 8–11]. Moreover, they involved a limited number of respondents. For example, Li et al. [1] illustrate a survey on professionals' views and experiences about robot-based rehabilitation involving 100 participants, with only 37 showing experience in robotics; Nhuyen et al. [12] describe a survey involving 109 operators (physical therapists and occupational therapists) about telerehabilitation; Coeckelbergh et al. [13] depict a survey about robot-assisted therapy for children involving 416 respondents, but only 17% of respondents were HCPs.

To overcome the limitations of previously developed surveys, in the context of the Italian Fit4MedRob Initiative we have developed a comprehensive survey (i) able to reach a high number of healthcare professionals in Italy to depict the national landscape; (ii) general enough so that it can address various pathologies; (iii) not specific to a particular robot but allowing HCPs to give their opinions based on the robots familiar to them, across different domains (motor, cognitive, and assistive).

Specifically, we aim to address the following research questions:

- RQ1: what is the current landscape of robotics-assisted rehabilitation in Italy?
- RQ2: what are the attitudes of HCPs towards robotic devices in rehabilitation?
- RQ3: what are the HCPs' needs and the barriers to the spread of robotic rehabilitation?
- RQ4: are there differences in attitudes among different HCP groups? HCPs can be stratified according to different characteristics, including: (i) gender, (ii) age, (iii) experience, (iv) professional category

In the following sections, we present the design of the survey, which can be adapted and shared with other HCPs populations. We then present the analysis of the collected data from 423 Italian HCPs who agreed to participate in the survey.

Methods

Survey instrument development

The survey was designed leveraging the above-mentioned scientific literature, as well as existing, validated models and questionnaires, such as Technology Acceptance Model (TAM) [14] and Software Usability Scale (SUS). We also leveraged comparable (albeit more narrow-scoped) studies like European Academy of Childhood Disability (EACD) [15] and RehaTech4Child Survey [16]. Drawing from the aforementioned experiences, we developed a new, ad-hoc set of questions for tackling specific aspects related to robotics-assisted rehabilitation and answered the defined research questions.

A draft of the survey was presented and discussed during a workshop in September 2023, where we invited representatives of Italian scientific societies and patients' associations in the rehabilitation area. They provided important feedback for refining the questionnaire that eventually reached the overall consensus.

In the following, we present in detail the design and the main results of the survey. The survey was implemented by using the Kobotoolbox tool (https://ee.kobotoolbox.org/preview/H2o5e3Nl). This instrument was selected because it offers a wide choice of question/answer modalities and implementation of branching and compound logic (which is essential to ensure the quality of collected data), and it allows for a very large number of question items. Data are collected online in the Kobotoolbox cloud and can be downloaded in different common formats, such as Excel and CSV.

The overall structure of the questionnaire is depicted in Fig. 1. The survey is divided into two main parts.

In order to answer RQ1, the first section asks for the HCP profile including the gender and age class, the years of experience in rehabilitation and in robotic-assisted rehabilitation, their specialty (physiotherapy, speech therapy, etc.), and the work setting, along with the age range and clinical pictures of treated patients. These data will also enable stratified analyses to address RQ4.

The second part of the survey aims to collect HCPs opinions about different device categories that may be available to them, and will enable us to address RQ2, RQ3 and RQ4. Given the high number of devices available on the market, for the purpose of the survey we have defined the following 8 functional categories:

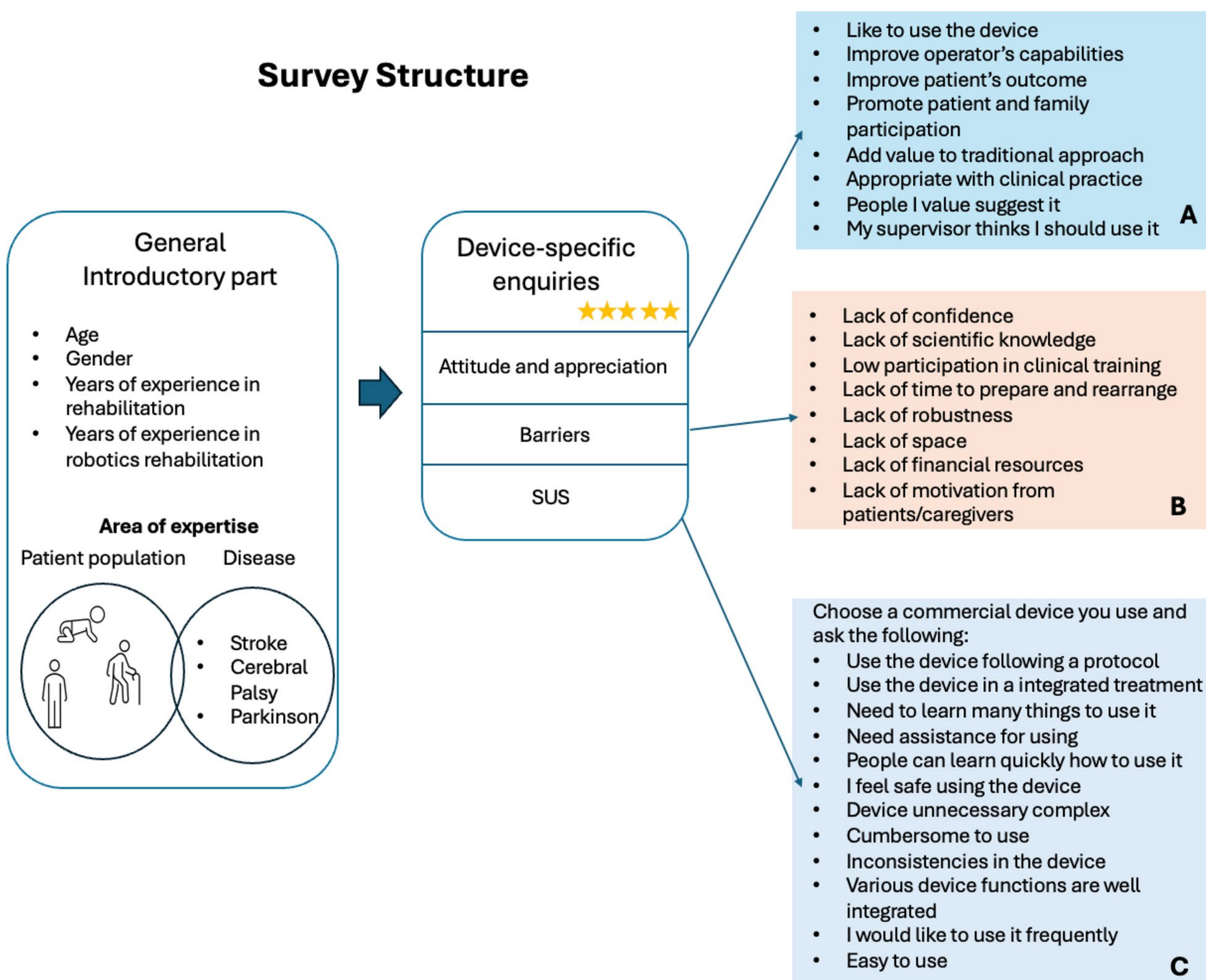

Fig. 1 Structure of the survey: after a general introductory part, where healthcare professionals are asked questions related to their age, gender, and working experience, three sets of questions are asked for each device category. The first set of questions is related to the attitude to use and the appreciation (**A**). The second set of questions pertains to the barriers listed in **B**. The third set of questions is drawn from the System Usability Scale (**C**)

- Assistive (generic) and mobile servants, such as technological wheelchairs, devices for self-care or eating, eye tracking communicators and humanoid robots.
- Advanced treadmill, showing enhanced functionalities such as visual feedback, motion capture system, or body weight support
- Upper limb exoskeleton, anthropometric robots that support the partial/full range of motion of the human arm.
- Lower limb exoskeleton: anthropometric robots that support the partial/full range of motion of the human leg.
- Lower limb end effector, which controls and supports the movement of the most distal segment of the lower limb extremity
- Upper limb end effector, which controls and supports the movement of the most distal segment of the upper limb extremity
- Proprioceptive/stabilometric/balance platform, allowing for evaluation and training of balance, coordination, and proprioception
- Sensor-based devices, with or without Virtual Reality, permitting both physical and cognitive exercises, including systems exploiting virtual reality and exercises for improving motor and/or cognitive deficits, such as those affecting attention, memory and problem solving, without providing movement support.

Identification of device categories was facilitated by a census of the RADTs available within the Fit4MedRob consortium, which was performed at the very beginning of the project.

For each category, the survey participants state whether: (i) they use/have used devices of that category, or (ii) they never used those devices, but they know them (for example they heard about them from colleagues, they saw demonstrations, etc.), or (iii) they do not know anything about those devices (RQ2).

If the HCPs use/used/know about devices belonging to that category, they are asked to answer a series of 5-point Likert scale questions about their attitudes and appreciation for them (RQ2) (Fig. 1a), as well as perceived potential barriers to their introduction in the clinical practice (RQ3). (Fig. 1b).

At the end of the questions about each device category, the respondent is asked to choose one of the commercial devices belonging to that category, and on which they had experience, and to fill in a System Usability Scale (SUS) [17, 18] Fig. 1c). The SUS allows for furthering answer RQ3, as one barrier might be the poor usability of devices. At the end of the presentation of all device categories, there is the possibility to fill in one "extra" SUS for a specific device chosen by the respondents (e.g., a device the operator is particularly experienced with).

At the end of the questionnaire, they can add comments, feedback, guidance, or anything they feel like sharing with us.

The full questionnaire is available at the following links: https://ee.kobotoolbox.org/preview/I9U2jdvu (Italian version), and https://ee.kobotoolbox.org/preview/H2o5e3Nl (English version). Raw data containing the survey's answers are available on Zenodo,[1] and the associated Data Note publication.[2]

Survey distribution

The survey was distributed among the Fit4MedRob HCPs through the consortium network, and, in parallel, among external HCPs, thanks to promotion carried out by national scientific societies that operate in the rehabilitation area and that, as previously mentioned, agreed to collaborate. This allowed us to depict a global overview of the Italian situation.

Being data completely anonymous, no ethical committee review was required.

Statistical analysis

We computed descriptive statistics to answer RQ1, RQ2, and RQ3. Chi-squared test was performed to compare proportions. Regarding usability, we have transformed each compiled SUS into a SUS score between 0 and 100 [17, 18], and we analyzed the SUS mean and standard deviation across different robotics devices.

To answer RQ4, we performed a stepwise multivariable linear regression using R to model the relationship between the attitude towards robotics on the following relevant covariates: age, gender, year of experience in rehabilitation, year of experience in robotics rehabilitation, actual usage of the device, profession, and whether the respondent is working for a clinical center that is part of the Fit4MedRob project. This last variable will make us understand whether there is a bias in the attitude towards robotics when the respondent is working for an institution clearly interested in the field. The attitude towards robotics, which is the predicted variable, is represented by a score we computed based on the answers to the "attitude and appreciation" section of the survey (Fig. 1A). We excluded the two last questions related to the opinion of the supervisors and colleagues, as we are interested in the personal attitude of each HCP. For each question, we converted the Likert scale to score from 1 to 5, and we summed the scores over the six attitude questions (usage

[1] Nicora [19].

[2] Nicora et al. [20].

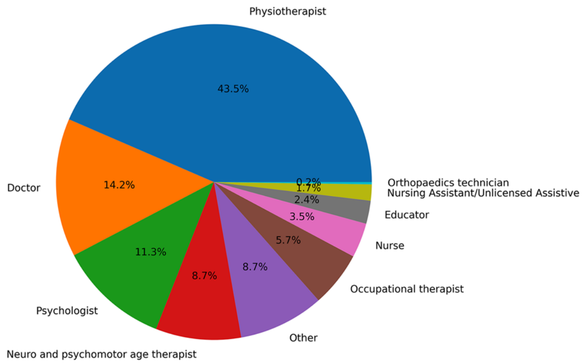

Fig. 2 Percentage of respondents for each profession

of the device, improvement of the HCP performance, improving the patient's health status, promotion of participation, whether the robotics rehabilitation adds value to a traditional approach and whether it is appropriate with clinical practice).

To analyse free-text answers, we performed a thematic analysis. Thematic analysis allows for the identification and interpretation of patterns or themes in text data [21]. Specifically, we carried out a thematic analysis to identify elements related to our research questions. For instance, further barriers, specific HCPs attitudes, or needs could emerge from free text. For each free comment, we identify keywords. Each keyword was then related to higher-level codes that were mapped to the themes of interest, namely "Attitude", "Need" and "Barrier".

Results

The survey was made publicly available on January 10th, 2024, and it was closed at the end of February 2024. Within this period, a total of 423 HCPs filled in the survey. The median time for completing the questionnaire was 6.8 min (interquartile range 3.6—13.7 min). The statistics were performed by developing Python and R scripts, that are available on GitHub (https://github.com/bmi-labmedinfo/Fit4MedRob_Surveys/).

Current landscape of robotics rehabilitation in Italy

The pie chart in Fig. 2 shows the percentage of the different professional categories that answered the survey. Most respondents were physiotherapists (almost 45%), while around 15% were physicians. A non-negligible fraction of the respondents were psychologists (12%). Around 9% were Neuro and Psychomotor age therapists, almost 6% were occupational therapists, 3.5% were nurses, 2.4% were educators, and almost 2% Nursing Assistant/ Unlicensed Assistive Personnel. Almost 9% did not precisely indicate their professions. Among the "Other" answers, 78% specified that they are speech therapist.

Regarding the age of the respondents, nearly 23% were between 21 and 30 years old, almost 30% were between 31 and 40, 21% were between 41 and 50, 21% were between 51 and 60 and 5% were above 60 years old. Thus, we have a prevalence of young operators.

As for gender distribution, notably, most of the HCPs were females (73%), 26% were males, and the remaining preferred not to declare.

Considering the physiotherapists, who represent the majority class of our answers, we found that age and gender were distributed very similarly to the reported statistics of the general physiotherapist population in Italy. In particular, the national physiotherapist society (FNOFI, Federazione Nazionale Ordine Fisioterapisti Italiani) reported that in 2023 the percentage of females was 58,9%, and 42,03% of the Italian physiotherapists were under 40 years old [22]. In our sample, we have a proportion of 61% of females, and 43% under 40, which reflects the general population.

We then stratified the respondents across years of experience in rehabilitation (in general), and years of experience in robotic-assisted rehabilitation (Table 1). Among professionals with less than one year of experience in rehabilitation, 82% have no experience with robotic devices. Among participants with 2 to 5 years of experience in rehabilitation, most of them (67%) have no experience with RADTs. Among the 33% of respondents with experience with RATDS, almost 20% of them throughout all their working experience (from 2 to 5 years). Only 10% of the respondents have been working with RADTs since the beginning of their careers.

Figure 3 shows the landscape of the respondents' settings of work. Among them, 35% work with outpatients, 33% are in post-acute hospital rehabilitation, 6% are in acute care units or research laboratories, and about 5% are involved in home rehabilitation.

We then evaluated the clinical experience of the various professional categories in terms of the pathologies of the patients they work/worked with (Fig. 4).

HCPs attitude towards robotics devices in rehabilitation

Table 2 reports, for each device category, the number of respondents who use devices from that category, the number of respondents who know the devices but never used them, and the number of respondents who are unaware of those devices.

In the following, we report the results of the survey across the 8 different functional device categories, stratifying according to the respondents that use/have used the device or know the devices but never use them. For

Table 1 Percentages of respondents with different experience in robotics (on the columns), stratified by years of experience in rehabilitation (on the rows)

		Years in robotics						
		Less than 1 year	**From 2 to 5 years**	**From 6 to 10 years**	**From 11 to 20 years**	**More than 20 years**	**No experience**	**Total**
Years in rehabilitation	**Less than 1 year**	2 (18%)	0%	0%	0%	0%	9 (82%)	11 (2.6%)
	From 2 to 5 years	16 (15%)	19 (18%)	0%	0%	0%	71 (67%)	106 (25.1%)
	From 6 to 10 years	10 (15%)	13 (20%)	7 (11%)	0%	0%	36 (54%)	66 (15.6%)
	From 11 to 20 years	16 (15%)	12 (11%)	15 (14%)	5 (5%)	0%	58 (55%)	106 (25.1%)
	More than 20 years	5 (4%)	17 (13%)	13 (10%)	22 (16%)	3 (2%)	74 (55%)	134 (31,7%)
		49 (11.6%)	61 (14.4%)	35 (8.3%)	27 (6.4%)	3 (0.7%)	248 (58.6%)	423 (100%)

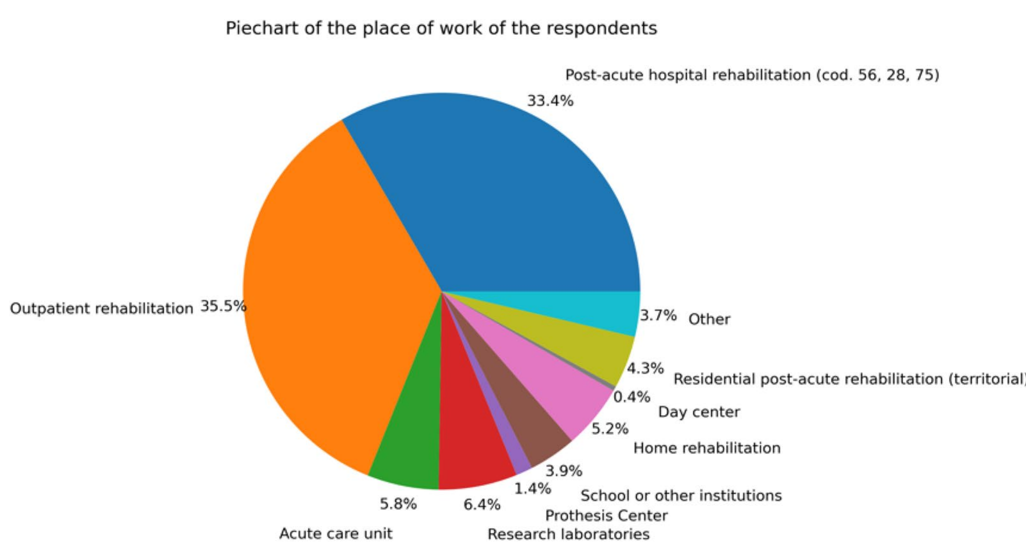

Fig. 3 Working settings of the respondents

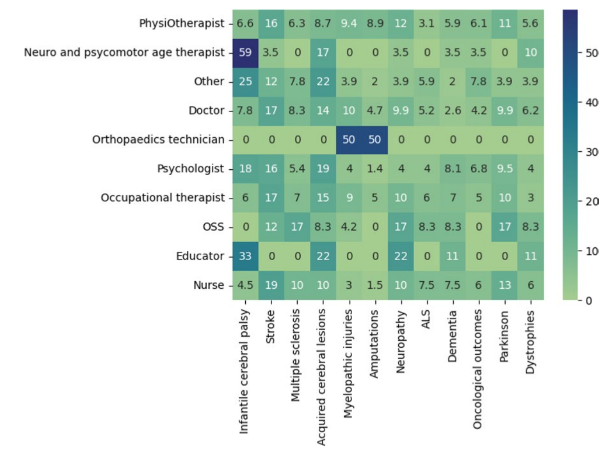

Fig. 4 Heatmap showing, for each professional type, the percentage of answers that indicate to work with a specific clinical picture

each question, the answer was given on a 5-level Likert scale (Strongly Disagree, Disagree, I do not know, Agree, Strongly Agree).

For the analysis, we grouped "Strongly disagree" and "disagree" into "I disagree". The same logic is applied to "Strongly agree" and "Agree". Specifically, the respondent is asked to answer eight questions (RQ2), related to:

- Usage of the device: whether they like to use or prescribe the device.
- Improving the practitioners' work: whether the device has improved the capabilities of the operators.
- Improving the patient's health status: if they believe that the device has the potential to improve patients' clinical outcomes.
- Promote participation: whether the device can augment patients' and/or relatives' participation in the therapy.
- Adding value to standard rehabilitation: whether the device can add value in comparison with a traditional rehabilitation.
- Appropriateness within current clinical practice: whether the usage of a device is appropriate within your current clinical practice.
- Opinion of colleagues: whether trusted colleagues think that they should use the device.
- Opinion of supervisors: whether their supervisor believes that they should use the device.

Figure 5 shows the percentage of respondents who agree with a specific statement among those who currently use the device and those who do not use the device but know about it. As expected, most of the respondents who know the devices but do not use them, are not able to express an opinion (Table S2–S9).

The proportion of HCPs who express satisfaction with using the devices is consistently high, always exceeding 80% (see Table S2 for specific details). The highest percentage is achieved by sensor based/VR/cognitive systems that reached 95% of satisfaction, while the lowest percentage is related to Assistive UL or UL end effector (81.25). A very few respondents (from 1 to a max of 3) are not satisfied with some devices (Table S2).

Exoskeletons, followed by end effectors, are the devices with the highest percentage of "I do not know" answers.

For the devices users, the majority agree that the device can improve their work capabilites, between 78 to 93%, depending on the type of device (Table S3). Only a few people answered that their capabilities are not improved using the device (1 to 3%). For 3 types of devices (assistive and mobile servant/Proprioceptive-stabilometric-balance platform/Sensor based-VR-Cognitive), the respondents' opinion of non-users is close to the actual users' opinion:

Table 2 For each device class, the number of respondents who use those devices, know about them without using them, and do not know them at all

	Use the device	Know the device but not use it	Do not know the device
Assistive (generic) and mobile servant	27 (6%)	73 (17%)	323 (76%)
Advanced treadmill	81 (20%)	65 (15%)	277 (65%)
UL exoskeleton	25 (6%)	79 (19%)	319 (75%)
LL exoskeleton	31 (7%)	64 (15%)	328 (76%)
LL end effector	23 (5%)	44 (11%)	356 (84%)
Assistive UL or UL end effector	32 (7.5%)	25 (6%)	366 (86.5%)
Proprioceptive/stabilometric/balance platform	66 (16%)	50 (12%)	307 (72%)
Sensor based/VR/Cognitive	60 (14%)	50 (12%)	313 (74%)

UL upper limbs, *LL* lower limbs

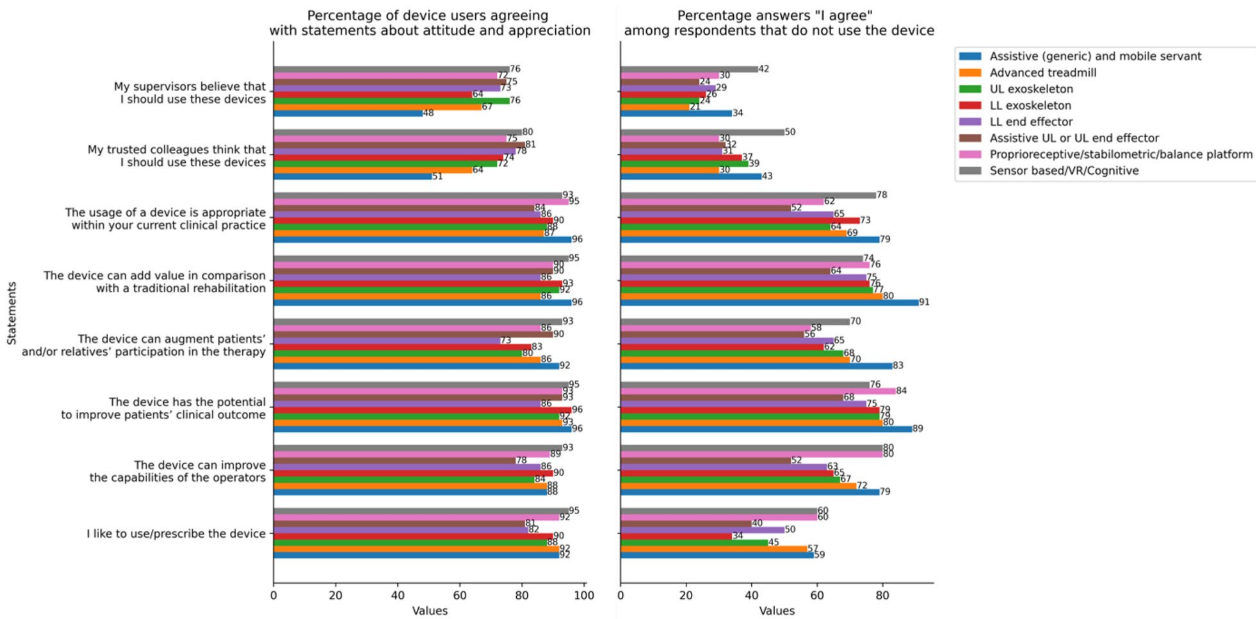

Fig. 5 Histogram showing the percentage of device users agreeing with each statement on their attitude and appreciation for the device (left pane) and percentage of answers "I agree" among respondents that do not use the device (right pane)

80% of them think the use of the devices could improve their capabilities.

Most of the respondents agree that the devices can improve patient's clinical outcome, whether they use or know the device (from 68 to 96%). Among the users, a maximum of 2 professionals do not agree and a maximum of 4 respondents do not have an opinion (Table S4).

The majority of users agree that each device can promote participation (Table S5). We can notice that for two categories of devices (Advanced treadmill and LL exoskeleton), the number of users that disagree is slightly higher (respectively 6 and 4 persons).

Table S6 shows that, in general, respondents agree that the RADTs can add value in comparison with a traditional rehabilitative approach. For the users, the percentage is always ≥ 86% across the device categories, but also for non-users at least 64% of the answers are positive. Considering the 2 groups of respondents, only a few of them (maximum 6) disagree with the claim.

Across the different types of devices, more than 84% of the users expressed that using robotics is appropriate within their clinical practice (Table S7). Higher negative perception is related to lower limb end effector (13%) and exoskeletons (8–10%).

Regarding the opinion of colleagues, the rate of 'I don't know' answers is important across the devices, also for users (Table S8).

As for the colleagues' opinions, the rate of uncertainty is high also regarding the opinion of supervisors (Table S9).

We then analyzed the relationship among HCPs subgroups and their attitude toward robotics (RQ4) using a stepwise linear regression. Subgroups have been identified through the profiling attributes indicated in the first section of the survey (inlcuding age, gender, and profession). Table 3 reports, for each device category, the covariates whose estimated coefficient has a p-value < 0.05.

Needs and barriers

The second set of questions is related to the perceived barriers to the spreading of each device category in clinical practice (Table 4).

Lack of financial resources is perceived as a barrier to the usage of all devices in clinical practice, especially for lower limb devices such as exoskeletons and end effectors. On the contrary, the motivation of patients and/or caregivers, as well as the robustness of the device is not seen as an impediment. Lack of training prevents the usage of assistive mobile servants, but it is significant also for other devices. Lack of trust is seen as a barrier by 43% of respondents for LL end effector and by almost 42% for sensor-based, VR and cognitive. For the other devices, lack of trust is seen as an impediment in less than 30%. 32% of participants do not have a clear opinion about the lack of trust in UL exoskeleton.

Table 3 For each device, relevant covariates associated with the attitude towards robotics according to the stepwise linear regression

Device	Covariates	Estimate	p-values
Assistive (generic) and mobile servant	Years in robotics rehabilitation	2.7	5.9 e–05***
	Use the device = Yes	0.62	0.005**
Advanced treadmill	Use the device = Yes	2.3	0.003**
	Is working for a project partner	1.8	0.03*
UL exoskeleton	Use the device = Yes	2.16	0.004**
	Is working for a project partner	1.5	0.02*
LL exoskeleton	Use the device = Yes	3.3	0.0004***
	Age	1.5	0.01*
LL end effector	Profession = Physiotherapist	−3.7	0.001**
	Profession = Neuro and psychomotor age therapist	−8.95	0.004**
	Years in robotics rehabilitation	0.9	0.02*
Assistive UL or UL end effector	Profession = Physiotherapist	−3.72	0.0004***
	Is working for a project partner	3.33	0.009**
	Years in robotics rehabilitation	0.98	0.02*
Proprioceptive/stabilometric/balance platform	Use the device = Yes	3.06	0.0003***
Sensor based/VR/cognitive	Is working for a project partner	2.78	0.0003***

For each significant covariate, it is reported the estimated coefficient and the associated p-value. Significance code: '*' $p < 0.05$, '**' $p < 0.01$, '***' $p < 0.001$

Table 4 Perception of the barriers for different types of devices for respondents that use the device

Lack of	Assistive mobile servant		Adv treadmill		UL exosk		LL end eff		LL exosk		Assistive UL or UL end eff		Proprioceptive/ stabilometric/ balance platform		Sensor-based/VR/ cognitive	
Financial resources	66.7	14.8	56.8	21	60	16	78.3	8.7	74.2	16.1	65.6	21.9	56.1	21.2	58.3	13.3
Motivation of patients/caregivers	25.9	14.8	19.8	13.6	16	8	4.4	8.7	12.9	12.9	6.2	15.6	18.2	18.2	13.3	11.7
Opportunities/participation/training	59.3	11.1	50.6	14.8	48	20	56.5	13	51.6	12.9	40.6	18.7	46.9	12.1	55	8.3
Robustness	33.3	25.9	14.8	16.1	12	32	21.7	8.7	16.1	16.1	6.2	34.4	9.1	22.7	18.3	23.3
Scientific literature	62.9	7.4	44.4	23.4	44	12	47.8	21.7	54.8	6.5	37.5	18.5	36.4	22.7	50	13.3
Space	40.7	14.8	44.4	11.1	52	12	69.6	8.7	41.9	12.9	56.2	9.4	39.4	16.7	46.7	5
Time to prepare and re-establish	74.1	0	42	20	44	8	52.2	0	45.2	9.7	37.5	15.6	42.4	7.6	46.7	16.7
Trust	29.6	14.8	28.4	20	20	32	43.5	8.7	29	3.2	25	16.6	28.8	21.2	41.7	13.3

For each device, we report on the left the percentage of operators that perceived the issues reported in the row as a barrier. On the right, we report the percentage of participants that did not have a clear opinion

The scarcity of scientific literature supporting the usage of the device is observed as a barrier across devices, with a higher percentage for assistive and mobile servants. Lack of space is perceived as a strong barrier, especially for lower limb end effectors. Also, time to prepare and re-establish technological stuff before and after the rehabilitation sessions can represent an obstacle to the spreading of the devices, especially for assistive mobile servants. Notably, in this case, no participants declare not to have an opinion. Also, for lower limb end effector all the respondents gave an opinion (either "I agree" or "I do not agree"), but in this case, the proportion of the two answers is similar (52% vs 48%).

Through the analysis of the perceived barriers among participants who do not use the devices but know them, the percentage of answers without a clear opinion ("I do not know") is not surprisingly higher (Table S10). The results, however, seem to reflect the views of users respondents.

Usability of robotics devices in rehabilitation

Here, we report the SUS results. Low usability might become a barrier. Table 5 reports the number of participants who were confident about the usage of the device and agreed to fill in the SUS, along with the mean and standard deviation of the SUS score. Table 5 reports the detailed answers to each SUS questions for the three

Table 5 Number of respondents that filled in the SUS for each device category

	Number of participants that compiled the SUS	Mean SUS score (standard deviation)
Assistive (generic) and mobile servant	27 (6%)	57 (9)
Advanced treadmill	76 (18%)	63 (13)
UL exoskeleton	25 (6%)	64 (14)
LL exoskeleton	31 (7%)	55 (13)
LL end effector	23 (5%)	57 (15)
Assistive UL or UL end effector	31 (7%)	64 (10)
Proprioceptive/stabilometric/balance platform	61 (15%)	65 (14)
Sensor based/VR/cognitive	60 (14%)	64 (13)

categories of devices, i.e. Advanced treadmill, Proprioceptive/stabilometric/balance platform, and Sensor based/VR/Cognitive, for which we collected the higher number of answers in our population (Table 5). The SUS results for the remaining categories are reported in Table S11 and Table S12.

Most respondents indicate that Proprioceptive/stabilometric/balance platforms are easy to use but you need to learn a lot to be able to use them. They are also willing to use these devices frequently (73%). Overall, they feel safe using the devices. A high percentage of respondents (greater than 80%) appreciate Sensor based/VR/Cognitive devices, as they would like to use them frequently, and stated that they are easy to use (Table 6). Proprioceptive and balanced platforms are those with higher mean SUS scores (Table 5, Figure S1), equal to 67.5.

Free text comments

At the end, the questionnaire included a free text field that respondents might use to provide a comment. Even if there could be some bias (often comments are written mostly by people who have a negative feeling), free-text comments may provide details revealing issues that cannot be identified using purely quantitative/multiple choice questions.

Twenty-eight (6.6%) respondents used the free text field at the end of the survey to write a comment. Some of them commented on more than one issue.

Comments have been analyzed through thematic analysis and summarized in the themes “Barrier”, “HCP attitude” and “Needs” (Figure S2). Note that “barriers” was one of the questionnaire sections. This means that some operators, in addition to filling in that section, felt the

Table 6 Results of the SUS for advanced treadmill devices, Proprioceptive/stabilometric/balance platforms and for sensor based/VR/Cognitive devices

	Advanced treadmill		Proprioceptive/stabilometric/balance platform		Sensor based/VR/Cognitive	
	I agree	I disagree	I agree	I disagree	I agree	I disagree
Need to learn a lot	45 (58%)	24 (31%)	40(62%)	17(26%)	31(52%)	21(35%)
Need assistance	26 (34%)	42 (54%)	14(22%)	40(62%)	13(22%)	36(60%)
Learn quickly	46 (60%)	15 (19%)	37(57%)	17(26%)	40(67%)	10(17%)
Feel safe	63 (82%)	2 (3%)	54(83%)	2(3%)	54(90%)	3(5%)
Complex	7 (9%)	56 (73%)	9(14%)	41(63%)	7(12%)	43(72%)
Cumbersome to use	12 (16%)	51 (66%)	7(11%)	43(66%)	11(18%)	40(67%)
Inconsistencies	5 (6%)	46 (60%)	6(9%)	37(57%)	14(23%)	32(53%)
Well integrated	46 (60%)	5 (6%)	47(73%)	4(6%)	39(65%)	10(17%)
Would like to use it frequently	48 (64%)	11 (14%)	47(73%)	3(5%)	49(82%)	4(7%)
Easy to use	54 (70%)	10 (13%)	46(71%)	7(11%)	48(80%)	6(10%)

need to better specify their opinion by exploiting the free text field.

- Barriers (12 respondents, 43%):
    - Too complicated compared to traditional rehabilitation (e.g., wearing the device);
    - Lack of training (also complained by operators working in robotics-intensive centers);
    - Lack of motivation for therapists (also due to lack of knowledge);
    - Lack of scientific evidence that does not justify the *enthusiasm* of robotics supporters;
    - Too time-expensive, also due to technical issues, causing discontinuity of usage, so that the therapist cannot achieve good confidence with the device in a reasonable time;
    - Lack of opportunities: distrust in the possibility of using robotics by HCPs operating in peripherical centers ("it's only for research centers") (4 respondents, 15%).
    - Poor adaptability to pediatric patients (1 respondent) and to home-care setting (1 respondent).
- HCPs attitude, i.e., how they relate to robotics (12 respondents, 43%)
    - Operators are in favor of robotics only if it is a companion to the traditional rehabilitation, as robotics alone is insufficient;
    - The physiotherapist must be the final decision-maker, to deem if a patient may undergo robotic-assisted rehabilitation, because the health outcome is highly patient-dependent;
    - Fear of being left out "if you don't use robotics".
- Needs (14 respondents, 50%)
    - Desire to better know about robotics (5 respondents, 18%), also because, as two respondents said, if the device is not sufficiently known, it is underused. Operators are conscious of that, which is the cause of frustration.
    - One respondent highlighted the need for better integration into clinical practice
    - Three respondents believe that it is important to tailor the treatment to the specific type of patient.
    - Three respondents made comments related to how they are using the device, for example stating that they are not using the robots at their full potential
    - Usability has also been highlighted by 2 respondents
    - Seven HCPs highlighted the need for learning, also to increase therapists' motivation.
    - One respondent raised the need for better integration among the different HCPs in the usage of robotics, calling for multidisciplinarity.
    - One respondent reported the need for sustainability

Discussion

Thanks to the involvement of scientific societies, we have gathered information from 423 rehabilitation professionals working in Italy, including physicians, physiotherapists, psychologists, nurses, educators, occupational therapists, psychomotor therapists and nursing assistant/unlicensed assistive personnel, i.e., representatives of all the clinical personnel involved in the management of patients undergoing rehabilitation treatment. We successfully reached healthcare professionals both within the Fit4MedRob Consortium (57%) and outside of it (43%). This enabled us to gain a comprehensive view of the current landscape and needs of HCPs across Italy, extending beyond a few research centers to include a wide range of hospitals. These numbers are very satisfactory, if compared with recent literature describing surveys of the same type [1, 8, 9].

The very low percentage of orthopedic technicians (0.2%) is motivated by the fact that another, purposely developed survey was administered to those HCPs since they mainly deal with prostheses for amputee patients, which represent a specific area with its own needs. Physiotherapists are working across different diseases, both paediatric and adult disorders. Stroke is the most represented disease (Fig. 3). The extremely low percentage of professionals working in home care settings confirms that home rehabilitation remains underdeveloped (Fig. 3). In fact, home-based rehabilitation has only recently gained traction due to the COVID-19 pandemic, and clinical evaluation remains limited. This aligns with the broader issue of insufficient resources for community-based healthcare, which has characterized the Italian context in recent years, resulting in a lack of programs or services that support this type of care. Moreover, there are challenges in integrating home care into existing healthcare systems. The disparity emphasizes the need for increased focus and investment in home rehabilitation to ensure comprehensive care options are available for patients at home.

Among the analyzed profiling characteristics (RQ1), the gender distribution of HCPs in Italy draws attention, revealing a high prevalence of female professionals, across all the various professional categories. This information is crucial since HCPs frequently encounter substantial physical burdens. This emphasizes the necessity of considering ergonomic aspects in developing such devices, also highlighted by free text comments.

Overall, HCPs exhibited positive attitudes toward the use of robotics and technology in rehabilitation (RQ2). However very high percentages of the professionals reached through this survey are unfamiliar with the devices: across all device categories, a significant majority of rehabilitation practitioners exhibit a lack of awareness even regarding the existence of these devices (Table 2) (from 65% for the advanced treadmills to 86.5% for Assistive UL or UL end effectors). 40% of the respondents do not know any of the robotic devices used in rehabilitation. Advanced treadmills are the most used devices (20%), followed by Proprioceptive/stabilometric/balance platforms (16%) and devices dealing with the cognitive sphere (14%), while all the other ones are used by a very low percentage of HCPs (from 5 to 7.5%). These figures indicate that robotics-assisted rehabilitation in Italy is still very limited and even unknown to a large set of the HCP population (RQ1).

When examining the factors that might influence HCPs' attitudes toward various robotic devices, we identified several findings (Table 3) (RQ4). First, gender does not appear to have any impact, whereas older age is associated with a more positive attitude toward LL exoskeletons. Physiotherapists, however, tend to hold negative attitudes toward LL end effectors and assistive UL or UL end effector devices. This could be attributed to the more complex setup required for these devices, as physiotherapists are typically responsible for preparing the sessions. Similarly, neuro and psychomotor-age therapists exhibit negative attitudes toward LL end effectors, potentially because these devices may not be well-suited for pediatric patients, as highlighted in a free-text comment. Across five of the eight device categories, actual usage of the device is strongly associated with more positive attitudes. This indicates that, despite the heterogeneity of devices, hands-on experience is a key factor in shaping favorable opinions. Additionally, positive attitudes are observed in four categories when respondents work in clinical centers affiliated with the Fit4MedRob project. While this might suggest a potential bias toward favoring the project, we believe this bias is mitigated by the survey's anonymity and the fact that not all HCPs in these centers are directly involved in the project. An alternative explanation is that HCPs in Fit4MedRob centers, given their clear focus on robotics, may have received more training and accumulated greater experience in the field. Finally, for two device categories—assistive (generic) and mobile servant robots, as well as LL end effectors—long-term experience with robotics is a predictor of positive attitudes, further reinforcing the importance of familiarity and practical engagement with the technology.

We also asked about the attitudes of trusted colleagues and supervisors about robotics. However, the high percentage of unknown answers might indicate a lack of discussion about this topic (Fig. 5).

We then identified several barriers to the usage of robotics in rehabilitation (RQ3). First, the lack of financial resources is perceived as a barrier across all the robotics devices (Table 4). Another issue, also reported in the free text comments, is the lack of opportunities, including training, and the lack of scientific evidence motivating the actual effectiveness of robotics. From a free text comment, it emerged a potential poor adaptability of robotic devices for pediatric patients. This seems to be also confirmed from our analysis of LL end effectors, where neuro and psychomotor-age therapists exhibit more negative attitudes that could be related to that issue.

From the question related to the usage of the devices, it emerged the preference for tools characterized by simplicity of use and minimal organizational impact, as they entail significantly shorter set-up times compared to the other devices (Table S2). The SUS results, in particular related to the need for learning a lot before using robotic devices, underscore the importance of proper training from expert healthcare professionals (Table 5). Although the mean SUS scores are lower than the threshold for benchmark [23], it is in line with the recently reported SUS scores for robotic devices in rehabilitation collected in France with a recruitment procedure similar to the one used in our survey [24]. Additionally, if compared with an adjective rating scale proposed in [25], the mean usability of RADTs devices, measured in our study seems to be acceptable as it is higher than 50.9. Usability was also highlighted by one free-text comment. However, free text comments were relatively few. The low percentage is probably due to two motivations. First, the questionnaire was quite long and quite exhaustive, thus many people did not have any further comment. Second, for the same reason, at the end of the questionnaire probably the respondents suffered from a certain fatigue, preventing them from making a further, optional, effort. Nonetheless, from free text comments, aspects that we did not explicitly consider in the structured part of the survey emerged, in particular, the need for multidisciplinarity, the adaptation to pediatric patients, and the lack of opportunities in peripheric centers. Comments highlight that (i) in some organisations, multidisciplinary teams are not adequately implemented yet, and this is perceived as a very concrete need by HCPs, (ii) medicine in the territory does not guarantee, so far, adequate device supply for home-based treatment, and (iii) some devices functionalities lack scientific foundations, probably because they are motivated from fields other than healthcare, for instance, gaming.

The analysis of practitioners' responses underscores two critical factors: the need to verify the effectiveness of robotics in rehabilitation and to ensure their economic sustainability. Consequently, it is essential to conduct trials that thoroughly explore both effectiveness and sustainability. Furthermore, the development of organizational models that support the integration of these systems into clinical practice is crucial. Such models should involve all stakeholders—healthcare professionals, bioengineers, patients, and their families—in a multidisciplinary approach.

Conclusion

Here, we report the development and the results of a survey that was shared within the Italian community of healthcare operators in rehabilitation, to assess their characteristics, attitudes and needs, and perceived barriers towards robotics. In comparison with previous studies, we report results on a higher number of respondents (more than 400), thus providing an overall picture of the current landscape of robotic rehabilitation in Italy. While positive towards the usage of new technologies, robotics-assisted rehabilitation is still poorly known by HCPs, which are also underlying the need for training in order to use robotics-assisted rehabilitation. This data highlights the limited adoption of this technology and underscores the need for comprehensive training from experienced therapists when institutions choose to incorporate it into their clinical pathways. The goal is to ensure that healthcare professionals are confident in using RADTs in their daily practice. One of the aims of future initiatives should be promoting schools, master's programs, doctoral programs, and training events to enhance specific skills in using robotics and technologies in rehabilitation. Additionally, efforts should be made to integrate tailored programs into the rehabilitation professionals' degree courses.

This survey can be applied in other healthcare settings or countries when institutions are planning to establish a robotics-assisted rehabilitation gym, to assess perceptions and identify barriers experienced by their healthcare practitioners.

Abbreviations

RADT	Robotics and Allied Technologies
HCP	Healthcare practitioners
VR	Virtual reality
SUS	System Usability Scale

Supplementary Information

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Supplementary Material 1.

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Availability of data and materials

The Italian version of the questionnaire is available at https://ee.kobotoolbox.org/preview/I9U2jdvu. The English version is available at https://ee.kobotoolbox.org/preview/H2o5e3Nl. The dataset will be shared upon publication on Zenodo and it will be described in a BMC Data Notes paper.

Declarations

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Consent for publication

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Competing interests

The authors declare no competing interests.

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