A Sustainable Approach to Telerehabilitation in Europe: Patients Are Ready, but Caregivers Are Essential

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Abstract. *Background*: Several studies have demonstrated the effectiveness of telerehabilitation. However, it remains unclear what proportion of people in need of rehabilitation can confidently use telecommunications networks and related devices. *Objectives*: The aim of this study is to estimate the proportion of patients who possess either the requisite digital literacy to perform telerehabilitation independently or have a family caregiver capable of providing effective support. *Methods*: Synthetic populations with a realistic kinship network (i.e. family trees) representative of European countries are built. Age, sex, and location-specific prevalence rates of rehabilitation needs and digital skills are combined to estimate the percentage of digitally literate patients and patients with digitally literate relatives. *Results*: In Europe, 86% of people in need of rehabilitation are potentially eligible for telerehabilitation. However, in four out of five cases, eligible patients over the age of 65 require caregiver support. *Conclusion*: Telerehabilitation has the potential to spread in Europe. Caregivers have an essential social role in ensuring sustainable access to telerehabilitation.

Keywords. Telemedicine, Telerehabilitation, Caregivers, Kinship Care, Sustainable Development.

1. Introduction

Although the concept of remote healthcare has been well-known for decades, the global impact of the COVID-19 pandemic accelerated the delivery of rehabilitation services at a distance. As we move past the crisis, it is critical to consider the future role of telerehabilitation in the broader healthcare landscape [1], especially in light of its contribution to the achievement of the Sustainable Development Goals (SDGs) [2].

Rehabilitation services encompass all interventions necessary when an individual faces limitations in physical, mental, or social functioning due to aging or a health condition. Telerehabilitation, the delivery of rehabilitative care via telecommunication or the Internet [3], has proven effective in numerous clinical trials [4]. However, a key question has yet to be addressed: how many people are truly ready to use this form of rehabilitation? Some patients may face accessibility challenges due to the severity of their conditions, but a broader barrier is a lack of familiarity with digital technologies and access to a reliable Internet connection [5]. This is particularly relevant given that a significant proportion of those in need of rehabilitation services are in the older

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demographic [6]. However, patients' lack of digital knowledge is often compensated for by caregivers who help them set up and conduct telerehabilitation sessions. Although patients can receive support from a variety of professionals, caregiving is often provided by family members [7]. Younger individuals typically have greater technological proficiency [8], thus sons and grandsons can often effectively assist patients in accessing telerehabilitation. In addition, the "demographic winter" experienced by most European countries results in families composed of fewer young people and more elderly individuals [9].

In this context, this work aims to estimate the percentage of people in Europe who require rehabilitation and are suitable candidates for telerehabilitation. This includes people who possess the digital skills necessary to access telerehabilitation services, as well as those who have relatives capable of effectively assisting them.

2. Methods

We developed a methodology based on a computational model to estimate the percentage of the population with rehabilitation needs who are eligible for telerehabilitation services (Figure 1). First, using microsimulation, we constructed virtual populations and kinship networks (i.e., family trees) reflecting European nations in 2023. Then, we randomly marked each person as either digitally skilled or not according to age-sex-location-specific rates from open data. Similarly, we marked the people in need of rehabilitation. Lastly, we calculated the proportion of those in need who are suitable candidates for telerehabilitation. We assumed that individuals are eligible if (a) they are digitally literate, or (b) they have a digitally literate relative. The R programming language was used to construct kinship networks, while Python was utilized for data preprocessing and analysis.
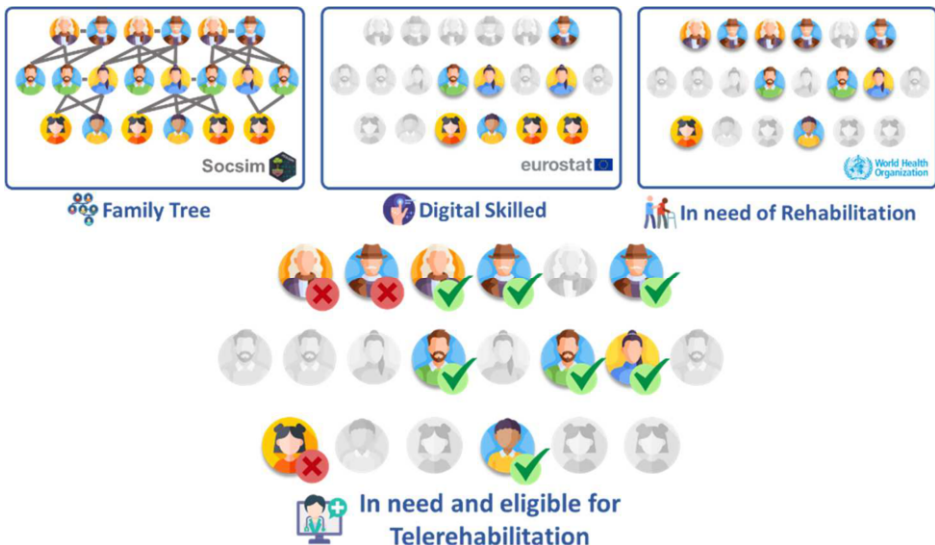

Figure 1. Conceptual framework of the proposed methodology.

2.1. Kinship network

We generated realistic family kinship networks using Socsim, a demographic microsimulation model developed at the University of California, Berkeley [10]. It generates a kinship network by iteratively simulating births and deaths in a synthetic population according to given age- and sex-specific rates. Model output can be combined with disease prevalence rates [11] to study care time demands [12]. Simulations began with a population of 20,000 individuals, initialized by simulating 100 years under the assumption of stable growth. Spanning from 1950 to 2023, the simulation incorporated historical age-specific and sex-specific life tables, fertility rates, and sex ratios at birth from the UN World Population Prospects [13]. To ensure consistency with Socsim's monthly time resolution, we converted the annual rates using Wachter's method [14]. The simulation considered the formation of new couples concurrent with women giving birth to their first child. For partner matching, we employed Socsim's "one-queue" system, which fits a target distribution of age differences between couple members. The mean age difference of couples was sourced from UNECE [15], while the standard deviation was derived from Insee [16]. In defining relatives, we considered the following: romantic partners, parents, offspring, siblings, grandparents, and grandchildren.

2.2. Prevalence of rehabilitation needs and digital skills

The prevalence rates of rehabilitation needs were determined using age, sex, and location-specific data from the World Health Organization (WHO) [6]. These rates are based on a set of diseases and conditions identified by WHO experts as causes of rehabilitation needs. To evaluate the digital literacy and Internet access of the population, we collected from Eurostat age- and sex-specific indicators of activities related to Internet and software use in European countries [8]. We assumed that individuals with at least a basic or higher level of digital literacy are capable of accessing telerehabilitation services. The raw data on digital literacy are available in 5-year age groups, which we interpolated into single-year age groups using second-degree splines smoothed with a first-order Savitzky-Golay filter. Since people in their early years are not expected to engage in self-reliant telerehabilitation, it is assumed that telerehabilitation skills do not materialize until the age of 14.

2.3. Estimation of telerehabilitation eligibility shares

Starting with the synthetic populations of countries as of 2023, we randomly assigned each individual two Boolean attributes representing (a) the need for rehabilitation and (b) digital literacy. The assignment relied on the demographic characteristics of the individuals. To achieve this, we drew from Bernoulli distributions parametrized with the rates previously described. Subsequently, for each nation, the percentage of individuals requiring rehabilitation with digital literacy skills was calculated, marking them as eligible for "self-reliant" telerehabilitation. In cases where individuals had a digitally literate caregiver, they were labeled as eligible "with family caregiving". The union of these two groups constituted the overall number of suitable candidates for telerehabilitation. This calculation was independently performed for all the nations included in the study. Ultimately, the average European proportion was determined by weighting each nation's share based on its population size as of 2023.

3. Results

On average, 86.2% of people in need of rehabilitation in Europe are potentially good candidates for telerehabilitation (Figure 2). Northern and Western countries lead the ranking (92.3% and 89.3%, respectively), while Southern and Eastern countries are below the European average (83.2% and 81.9%, respectively). The country with the highest potential access to telerehabilitation is the Netherlands, with nearly all patients eligible (97.5%). The Netherlands is also the country with the highest proportion of people eligible for "self-reliant" telerehabilitation (67.3%), while the European average is 38.2%. Self-sufficiency varies greatly by age. The percentage of independent patients is 58.0% in the 20-64 age group, 22.8% in the 65-80 age group, and 5.7% in the 80+ age group.
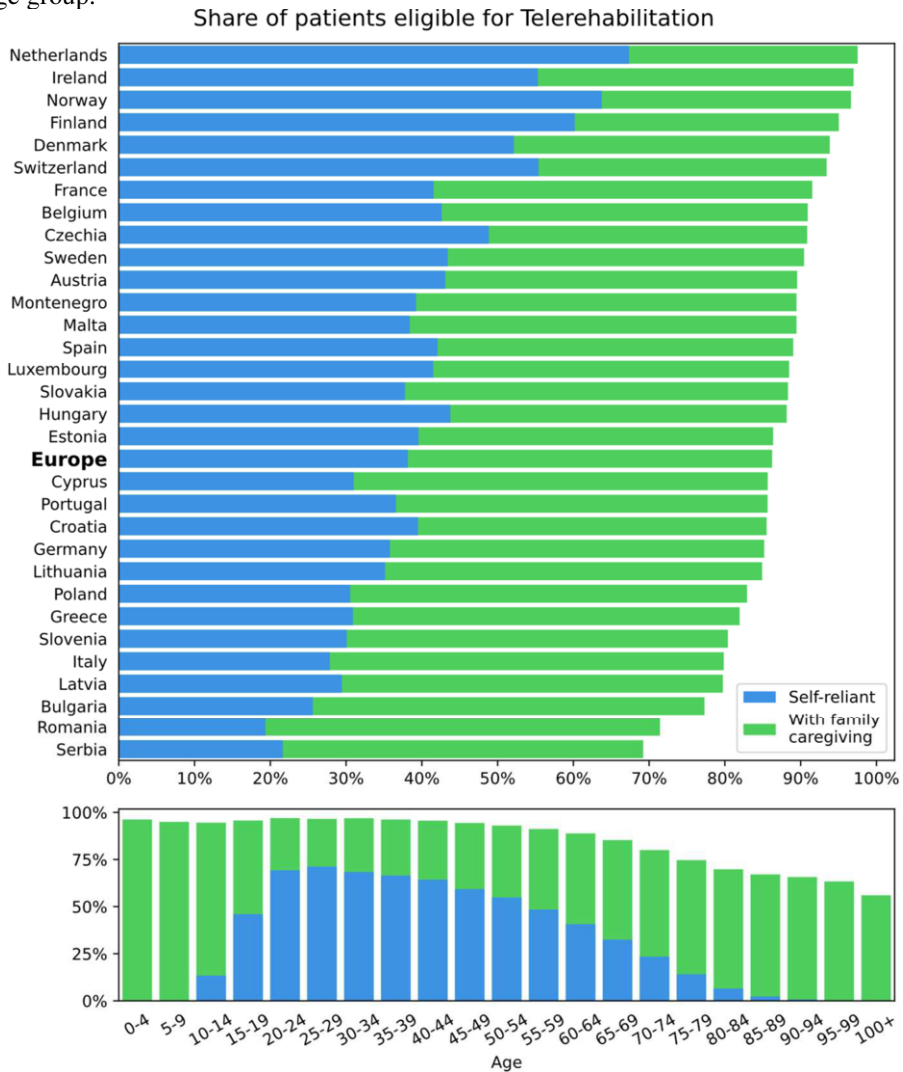

Figure 2. Percentage of people with rehabilitation needs who are potentially suitable for telerehabilitation in Europe. People with basic or above digital literacy are considered eligible for "self-reliant" telerehabilitation, whereas those with at least one digitally literate relative are eligible "with family caregiving".

4. Discussion

The results show that telerehabilitation could be a viable option for the vast majority of Europeans in need of rehabilitation, ranging from 71% to 98% depending on the country. This finding indicates that remote rehabilitative treatments have the potential to become widespread. Although 56% of EU citizens possess basic digital skills [8], we discovered that only an average of 38% of individuals in need of rehabilitation can independently perform telerehabilitation. This is not surprising since the majority of rehabilitation needs come from the elderly population, who also tend to have lower levels of digital literacy. However, it is important to note that the percentage of self-reliant telerehabilitation patients varies significantly among countries, ranging from 19% to 67%.

For patients over the age of 65, we found that nearly four out of five are eligible for telerehabilitation only with caregiver support. Previous studies have emphasized the valuable contribution of caregivers to the sustainability of the traditional health system [17]. Our results suggest that caregivers also play a crucial role in the sustainability of remote healthcare. However, to achieve a truly sustainable system, it is essential to consider that caregiving is associated with intense physical and psychological strain [18], which can lead to reduced care provision, lower quality of life, and physical and mental health deterioration [19]. Therefore, efforts must be made to reduce caregiver burden and improve health outcomes for both caregivers and patients [20]. Telerehabilitation can effectively reduce caregiver burden while improving their knowledge and competence [21], as well as providing significant financial and time savings [22].

The percentage of people eligible for telerehabilitation is influenced by two major factors. The first factor is the number of people who possess the digital literacy and connectivity needed to effectively use telecommunications networks and devices. The second factor is related to family composition, specifically the number of relatives each individual has. The likelihood of having a caregiver with digital skills increases with the size of the family. However, the relationship between the two factors is not linear. Here we present a methodology that takes both factors into account. Our results suggest that the ranking of countries by percentage of people potentially eligible for telerehabilitation is very similar to the ranking by digital skills, highlighting the importance of digital literacy for telehealth.

This work has limitations. Firstly, we used Socsim's kinship network to determine if patients had relatives who could assist with telerehabilitation, but we were unable to ascertain whether the need for care translated into actual caregiving efforts. Additionally, we did not explore the role of caregiver distance from the patient. Secondly, as with any simulation, some assumptions had to be made, resulting in a certain degree of approximation. We did not include marriage or divorce rates, and we assumed no cross-border migrations.

Our findings have implications for policymakers and healthcare providers. The increasing demand for long-term care, driven by population aging, poses a major challenge to the sustainability of public health services. The prevailing trend in Europe is to limit eligibility for institutional care, accompanied by an increasing reliance on family caregiving [23]. Policymakers should recognize telerehabilitation as a viable option for sustainable delivery of rehabilitation services, recognizing that a significant portion of the population can be effectively engaged. At the same time, the critical role of caregivers should be recognized and supported.

Acknowledgments

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