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REVIEWS

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The future of care and healthcare provision to community-dwelling disabled elderly people in an ageing society

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary The populations of all European countries are ageing at an increasing age, especially in rural areas, where the process overlaps with emigration to urban areas, which additionally depletes the elderly residents of social support while the ability to perform everyday activities becomes progressively limited with age. A literature review was been carried out in order to identify the characteristics of modern technology-based tools for providing care and healthcare to community-dwelling people sixty years old and older. Home-based care is preferred over institutional care, including in nursing homes, by about 90% of the elderly. Home-based care, diagnostics, and monitoring limit the financial and organizational pressure on the healthcare system. Care and rehabilitation procedures are carried out under the direct supervision of specialized medical staff at respective offices or centers while they can be evaluated and supervised remotely, without the need for scarce medical staff to be constantly present with the patient, and without the requirement for the patient to be transported back and forth. The problem of providing care and healthcare to the increasing number of disabled elderly within the constraints of the available budget and with scarce qualified staff can be resolved only through the broad application of solutions based on information technology (IT), which benefit from the dynamic growth of the Internet-of-Things, including the Internet-of-Medical-Things (IoMT) and Artificial Intelligence (AI). This will allow longer home-based care, which is not only preferred by the elderly to institutionalized care or hospitalization, but is also the cheapest of available solutions.
Key words: health services for the aged, disabled persons, health care economics and organizations, health equity, right to health.

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Background

The populations of all European countries are ageing at an increasing age. This is especially significant in rural areas, where the process overlaps with emigration to urban areas, which additionally depletes the elderly residents of social support [1]. The ability to perform everyday activities becomes progressively limited with age [2]. In Poland, around one fifth of the general population lives with some form of disability, which often impairs mobility and cognitive functions [3]. This results from the physiology of ageing, but most crucial problems typically arise from the presence of numerous comorbidities [4]. Consequently, elderly people will sooner or later fail to keep pace both physically and mentally with the rapidly evolving environment, which leads to various health risks, including suicide attempts and death [5]. The physiology and pathology of ageing ultimately result in dependency on others, which in developed countries translates into dependency on social care and healthcare systems.

It is the legal duty of the state to provide safety to its citizens and, in the case of the elderly, there is an urgent need to organize care and healthcare solutions that can meet their needs while financing the functioning of such a system of solutions, at least at a basic level [6]. The rapidly digitizing world needs an information technology-based approach, and the state needs to regulate such solutions and oversee their safety from the point of view of data security [7]. For a number of decades, the financing of care and healthcare for dependent citizens has increasingly stretched the state and medical insurance budgets now, with the highest costs resulting from providing care and healthcare to citizens in the last years of their lives, especially in hospitals [8]. The COVID-19 pandemic exposed and exacerbated the existing chronic healthcare system deficiencies, including the difficult to compensate medical staff shortages [9]. Most comorbidities currently observed in the elderly are lifestyle-dependent and thus potentially modifiable, but there is very limited compliance in the vast majority of the society with preventive public health actions, including vaccinations [10], even among those who are considered as the most informed and motivated, such as medical professionals [9]. Great effort is made by the state and health authorities together with particular healthcare workers to improve the compliance of the public with public health programs and to create new ones aimed at maintaining the ability of the care and healthcare system to deliver services with limited budgets and staffing [11]. Most unfortunately, the conventional approach to securing care and medical services to the elderly by simply increasing the amount of money and delegated workforce reached its inevitable end with the financial crises and demographic changes, which limited the financial and human resources. Avoiding collapse in the social and health security of the elderly requires introducing an alter-

native approach – and the only one within reach is the wider adoption of modern information-technology based solutions.

Material and methods

A literature review was been carried out in order to identify the characteristics of modern technology-based tools for providing care and healthcare to community-dwelling people sixty years old and older.

Results

Home-based care is preferred over institutional care, including in nursing homes, by about 90% of the elderly, and it fits mainly into one of four categories: daily care, medical care, emergency care, and emotional care [12]. Home-based care, diagnostics, and monitoring limit the financial and organizational pressure on the healthcare system as a whole and on the medical staff members in particular [13]. In this context, it is tempting to improve home-based care further by limiting its need for human input through leveraging the growing potential of modern information technologies, such as the Internet of Things (IoT); this is composed of objects linked to the Internet that are intended to operate and exchange data autonomously, without the need for human interference [14], "to interconnect, detect, identify and process data between objects or services in order to fulfill a common objective" [15]. This approach is in sharp in contrast to the traditional model of the Internet of Computers (IoC) operated by humans [16]. As access to the Internet is virtually ubiquitous in developed countries thanks to numerous data transmission technologies, both wire-dependent and wireless, the limiting factor for IoT based solutions becomes end user acceptance and digital competence, which are often limited in case of the elderly [17]. The traditional data transmission limitations of bandwidth, delay, and energy pose much smaller and more surmountable obstacles [18]. This demands urgent innovations capable of breaking through the reluctance of the elderly to accept and use new technologies, both stationary products used at home and wearable devices (wearables) for when on the move [19], and finding workarounds to constraints in the form of additional cost, inconveniences, social constraints, or privacy issues by utilizing existing standard equipment, such as in the analysis of Wi-Fi signal equivalents for the movement of people [20] or even smart TV usage [21]. Passive technologies working in the background, such as the analysis of sound patterns in rooms [22], radio frequency identification (RFID) [23], floor vibration detectors [24], thermal and air quality sensors [25, 26], are to be preferred to active monitoring, like video surveillance, which are often considered too intrusive [20]. The best results are achieved when several sensing technologies are combined into a single integrated system [23]. Taking into account the limited financial and human resources of the healthcare system, there is growing demand for affordable specialized solutions, often referred to as the Internet of Medical Things (IoMT) [13] or Internet of Healthcare Things (IoHT) [27]. This is defined as "all medical devices and applications that connect to health information systems through online computer networks" with a stress on the reliability of the solution and the ability to process large amounts of data in real time [13] using biomedical sensors (which are well tolerated by users), computation using low-power processors, and secure wireless communication [28]. The huge aggregated stream of IoT data contains a lot of sensitive personal information that needs to be properly protected against interception by unauthorized third parties [29]. In healthcare, IoT devices serve three main purposes: increasing patient morale, enabling diagnosis, and monitoring; these are often intertwined and can thus be fulfilled together [30].

Indoor and outdoor living environments are at present mainly designed to meet the needs of individuals who are fully fit and whose physical and mental functions are not impaired in any significant way. Such environments thus turn out to be unsuitable for the people living with disabilities, and some locations become either unavailable to them or available only with assistance, which is difficult to organize and finance [3]. The trend towards a universal design that promotes solutions that allow access and accessibility to all people [3] may not be associated with any additional cost if the solution is provided anew based on identified needs and habits; however, it typically generates significant costs when it involves modifying existing, functional solutions; it is thus often avoided. Nevertheless, in an increasing number of cases, the total cost of adjustments may be lower than the expenses that result from the long-lasting or permanent loss of access to certain activities by numerous people, or from the need to provide human assistance, which may be scarce and expensive. The main obstacle to universal design projects is correctly identifying genuine needs and habits, and not simply relying on what has been stated. This can be achieved by introducing the widespread use of targeted surveillance solutions, including the sensors on the IoT [3], often utilized as organized wireless sensors networks (WSNs) [31], which integrate all available external sources of data, including geographic information systems (GIS) [32]. The idea of universal design as applied most often to common use spaces translates to indoor solutions closely resembling a smart home that recognizes the daily activities of residents and reacts accordingly [33]. Even without further modifications this can significantly improve the quality of life of the elderly [34] despite the often low level of their digital competences [35]. Ambient assisted living (AAL) goes further and aims at optimizing the environment for people living with disabilities, including the elderly, to provide the needed assistance and reduce challenges [36] by utilizing systems that vary widely in terms of technical advancement and implementation cost [1], including the newest applications of artificial intelligence and robotic technology [37]. The common denominator for information technology-based solutions addressing the needs of the elderly is to provide them with the means to easily maintain existing connections while making new ones with the world and people outside their homes, in order to avoid dependence, alienation, and loneliness, which are detrimental to quality of life and physical and mental health [38]. A good example of this may be the use of currently available commercial speech recognition software as a means to provide elderly people – especially those suffering from neurology or musculoskeletal disorders – with a channel of active communication with the smart home, AAL, and medical emergency signaling systems [39], as well as to execute commands, adjust settings, or modify connected mobile device applications on the fly [40].

To date, most motor-skeletal system rehabilitation procedures are carried out under the direct supervision of specialized medical staff at rehabilitation offices or centers. This leads to bottlenecks in the system, mainly on account of the limited availability of qualified medical staff. Modern rehabilitation monitoring systems using body sensors linked to programmed devices with graphical interfaces can allow patients to practice predefined sets of function-improving exercises independently, and sometimes even at home, in a manner that is safe. This can be evaluated and supervised remotely, without the need for scarce medical staff to be constantly present with the patient, and without the requirement for the patient to be transported back and forth, which is expensive and may be difficult to organize [41]. Commercial voice assistants, such as Apple Siri, Google Assistant, and Amazon Alexa can be in used connection with integrated IoT-based systems that monitor physical activity to actively prevent sedentary lifestyles [42] and overweight or obesity [14] in the elderly, sometimes by using the gamification of physical exercise [43].

Mobility impairments often lead to wheelchair use in the elderly, both indoors and outdoors. This is associated with multiple risks, including the wheelchair becoming stuck or the user

falling out of the wheelchair, which require urgent external intervention. Anticipation of such risks often stops elderly people from engaging in activities that would otherwise be available to them and which might improve their quality of life. Such limitations may be overcome using smart wheelchairs propelled by electric motors and equipped with a microcontroller IoT device that allows for intervention by remote external support services in the case of emergency. Such intervention could take the form of audiovisual communication with the wheelchair user, determining the location of the wheelchair, using video to orient the wheelchair in the surroundings, or even taking temporarily remote control of the wheelchair's movements [14].

Circulatory system diseases are among the most common in the old age in developed countries, and the ability to effectively monitor their status and to detect and intervene rapidly in the case of exacerbation is crucial for the survival and well-being of such patients – including those suffering from chronic heart failure. Remote cardiology solutions based on IoT devices and teleassistance allow optimal control of the disease in a proactive way, avoiding crises before they occur rather than reacting to them afterwards, while at the same time reducing the need for unnecessary direct contact with medical staff, including primary care physicians, as well as offices visits and hospitalizations, thus sparing the healthcare system its limited finances and scarce human resources [44].

Chronic metabolic diseases demand the accurate monitoring of crucial parameters, such as glucose levels in the case of patients living with diabetes, which is one of the greatest growing healthcare system challenges in the world. Acute complications of improper control of diabetes are life-threatening, chronic inadequate treatment results are often irreversible and very costly to treat, and compliance with the treatment regimen is often unsatisfactory among the elderly; remote diabetology solutions are thus emerging, utilizing medical IoT devices consisting of sensors that provide continuous measurement and transmission of glucose levels, as well as recording, in order to enable any required acute medical intervention or modification of regular treatment plan [36].

Monitoring the growing number of elderly people living with physical and particularly mental disabilities is becoming an increasing organizational and financial burden for both healthcare institutions and independent caregivers. This burden can however be lessened to a significant extent through implementing remote monitoring solutions that combine the potential of IoMT sensors with nonmedical devices like smartphones and wearables [26], such as smartwatches and smartbands [45]. These are sometimes interconnected into an integrated body area network (BAN) [46] that can measure physical and physiological parameters [47], and which often involve software for human activity recognition (HAR) [27] and activities of daily life (ADL) and fall detection systems (FDS). These use artificial intelligence (AI) and deep learning [48] that allow highly accurate recognition of the type of activity being engaged in, whether typical everyday activities or emergencies [27]. These may be recognized through abrupt changes in parameters or behavior, compared to identified pattern of daily routine norm [49]. Falls, which are among the most common situations requiring immediate external assistance in the elderly [27,50], are correctly identified in up to 99% of cases by the most advanced systems [27, 51]. An alternative available approach is direct prediction or prevention of the most common falls through remote monitoring of movement coherency [52] and of unattended bed exit or room exit attempts using wearable sensors [53].

Lack of compliance with treatment regimens is common among the community-dwelling elderly, and often leads to the therapy being ineffective or having serious side-effects. There is thus great demand for in-home remotely monitored drug management stations that allow control over the time and dosage of drug dispensation, eliminating or limiting the direct engagement of caregivers [54].

Conclusion

The problem of providing care and healthcare to the increasing number of disabled elderly within the constraints of the available budget and with scarce qualified staff can be resolved only through the broad application of solutions based on information technology (IT), which benefit from the dynamic growth of the Internet-of-Things, including the Internet-of-Medical-Things (IoMT) and Artificial Intelligence (AI). This will allow longer home-based care, which is not only preferred by the elderly to institutionalized care or hospitalization, but is also the cheapest of available solutions.

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