CHAPTER 4

SOLUTIONS TO SUPPORT AND REHABILITATE OLDER ADULTS: SCOPING REVIEW

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ABSTRACT: Objective: The purpose of this review is to examine existing options for software and hybrid solutions designed to support and rehabilitate older adults. **Methods:** Scoping review based on Prisma Methodology and comparative analysis. The authors took articles from 6 major scientific databases: Association for Computing Machinery (ACM), IEEE Database, DBLP, Google Scholar, PubMed Database and SCOPUS, published in the last 6 years, from 2018 to 2023. For each article, a specific list of parameters was compiled to describe each of the solutions from a technical/software and functional perspective. **Results:** Final analysis of 38 articles with a target audience of older adults over age 50. During this analysis and comparison of the solutions presented, it was found that the most frequent research in the field of rehabilitation and support for older people is conducted in Western and Central Europe, China, North, as well as some South American countries, where the percentage of older people is quite high. It was also found that in the last two years there has been an increase in the activity of these studies compared to previous years. **Conclusions:** In general, the use of this kind of rehabilitation systems demonstrates a rather high degree of effectiveness, which contributes to an increasing spread in the medical field. Although such systems are still used primarily to maintain physical activity, they still have a high potential to become an instrument of socialization of the older generation in the modern information world.

KEYWORDS: frailty, serious games, elderly people, motion capture

INTRODUCTION

"Age is just a number", "No matter how old I am, I'm young at heart", "Yes, I'm old, but I'm happy". It's quite common to hear such expressions, isn't it? On the one hand it's the right approach, that life goes on despite numbers. But on the other hand, these phrases can be heard more and more often lately. Is this a problem? Is it worth worrying about this issue?

If you compare it with the global statistics on the age profile of the population, the 10% are elderly, which is quite standard, but if you analyze the timeline, according to The Organization for Economic Co-operation and Development (OECD), you can see the following: over the past 20 years, from 2000 to 2020, the percentage of older people increased from 6.87% to 9.33% (2.46%). At the same time, the time period from the 1980s to the 2000s shows an increase from 5.89% to 6.87% (0.98%). For a clearer picture, let us also take the period from 1960 to 1980. The elderly population increased from 4.98% in 1960 to 5.89% in 1980 (0.91%). This information suggests that over the past 20 years, the growth in the number of people over the age of 60 has increased by half, compared to the previous two time periods, where the difference was only 0.7%. [1-5]

At the moment, scientists and sociologists say that this statistic will be increased in the future. And this growth is possible in exponential progression, given the growth of the world's population and the increase in the level of medicine. Is that a problem?

According to the OECD, this trend is predominantly in countries with a high level of industrial and social development (European countries, North America, Australia, Japan, to a lesser extent China and Latin American countries). On the one hand, such an increase in the number of elderly people is somewhat frightening, because over time it can lead to a steep decline in the population in these regions. On the other hand, with the level of development of society that we have in these regions, the elderly are able to keep working long enough and maintain a normal climate for life. Despite this, this social group still needs additional support and care in varying degrees and directions. [6-10]

The most important area is the support of frailty people [11-14]. But the question remains: in what area is this support needed? Often, this category of people is mostly affected by physical problems of the musculoskeletal system, internal body systems and general condition due to their age [15, 16]. Due to physiological and age-related processes elderly people feel discomfort exactly in terms of physical condition. That's why assistance in this aspect is the most in-demand. For this purpose, there are all kinds of procedures and actions, starting with simple physical exercises and ending with serious modification and therapeutic equipment. There are several ways to help or support this plan. One of the main ones is the simplest physical exercise. In more complicated cases, various physical therapy and medication procedures may be used in addition. Undoubtedly, these techniques are extremely effective and allow to influence a wide range of problems, including an individual plan for each individual patient [17-19].

Nevertheless, the development of technology allows the introduction of new methods, which are not inferior and often more effective. One such area is Serious Games [20, 21]. In essence, these are computer platforms or individual games that sort of "disguise" physical exercise as some sort of interactive game activity. This method allows not only to make physical activity more meaningful, but also helps to improve the emotional background, allowing you to combine "pleasant with useful". Because of its simplicity of both development and use, the use of Serious Games allows for a fairly high level of performance [22, 23]. In addition, such methods allow older people to become more accustomed to and absorb modern global trends of general informatization. One of the most outstanding features is that almost any routine physical activity can be turned into a rather interesting interactive, and for any age category, not just the one for which the system or game was originally created.

Also, an important feature of this kind of solution is the ability to improve uninteractive interaction by means of the game. This includes both patient-doctor and patient-to-patient communication. If the first gives more and better control over the activities and results of the patient and allows for a more dynamic selection of individual programs for each, the second allows for a competitive aspect. Thanks to the second component, patients are more motivated to improve their outcome against others and allows for an increased sense of social feeling. Taken together, this is what makes tools like Serious Games quite effective as a means of help and support. [24, 25]

Given the variety of modern methods and tools for creating this kind of rehabilitation systems, one can already find quite a few examples of such applications, which are also divided into broadly and narrowly focused ones. Also, due to the different characteristics of technical and target parameters, the combination of functions and requirements, it makes sense to divide such systems into different areas, depending on the technological level, focus, target audience, topics, etc.

This article aims to explore those solutions that have been created and are aimed at a specific category and purpose of rehabilitation interventions, namely support for people with musculoskeletal problems. In this study, support systems will be analyzed, described and evaluated, both in the form of computer games and devices.

The article consists of five sections: Section 1 - Introduction; Section 2 – Materials and Methods, which describes the basic criteria and search procedures used for the analysis, demonstrates the materials themselves, as well as their characteristics and features; Section 3 - Results, which presents the results of analysis and comparison of selected articles; Section 4 - Discussion and Conclusions, which raises issues of the possibilities of application of the studied solutions, their comparison and conclusions about their effectiveness.

MATERIALS AND METHODS

In the scoping review presented in this article, the search criteria for the material of interest included several items: keywords searched for, libraries and databases of scientific articles, inclusion and exclusion criteria, article content, etc. Below we will describe all the main criteria and parameters for the selection of material.

A scoping review, which is a synthesis of knowledge, examines the scope, range and nature of the existing literature. Compared to a systematic review, a scoping review has two main differences:

Determining whether there is a well-developed topic, as scoping review review tends to focus on broader topics. Secondly, whether a detailed assessment of the quality of the literature needs to be carried out, whereas scoping review does not prioritize such tasks.

STATISTICAL ANALYSIS

Data extraction

To create the initial database, we investigated the results of the Web of Science portal. The results of found articles from Web of Science helped us to assess the situation of research trends in the direction of rehabilitation and frailty in general terms. Despite the rather extensive list of results, we still decided to investigate various more highly specialized databases.

To select articles for analysis, the main sources of digital resources were chosen 6 databases: ACM (Association for Computing Machinery), IEEE, DBLP Computer Science Bibliography, Google Scholar, PubMed, SCOPUS.

The following scientific terms were used to search for materials:

- (Frailty AND Rehabilitation) OR (Frailty AND Elderly) OR (Frailty AND Healthcare);
- (Games AND Elderly) OR (Games AND Healthcare) OR (Games AND Frailty);
- (Frailty AND Games) OR (Frailty AND Serious Games) OR (Serious Games AND Healthcare) OR (Frailty AND Rehabilitation AND Games).

During the analysis of the number of search results, it was found that only 4 databases have eligible materials. In this regard, the results from 4 databases will be used in the future: ACM, Scholar, PubMed and SCOPUS. The search in the online digital libraries was conducted in November 2021.

Inclusion and Exclusion criteria

Also, inclusion and exclusion criteria, which serve as limiters and filters of found articles, were introduced to select the materials we need for a more accurate sampling. The very form of these criteria is as follows:

Inclusion criteria: **Population**: Older adults aged 50 to 90 with different levels of frailty. **Intervention**: Digital solutions based on Serious Games, acting as support, and training assistants. Applications for mobile, personal computer and stationary systems mostly based on motion-capture technologies. **Publication source**: Journals with impact factor Q1/Q2.

Exclusion criteria: **Population**: People with very high physical dysfunctions, or with the presence of mental illness, or people younger than 50 years old. **Intervention**: Applications and tools aimed solely for entertainment and bearing no therapeutic function. Articles written in languages other than English. Also excluded are data that are in paid access. Articles published in conferences, books, or other sources other than high impact factor scientific journals. Also excluded are those sources that provide descriptions of systems or devices, but do not provide examples and descriptions of the systems themselves, which are used in this study. **Publication source**: Journals with impact factor Q3/Q4

Research questions

In the course of this study, a list of basic questions that need to be answered to understand the essence of each of the studies presented was compiled for a comprehensive analysis of the selected sources. All questions of interest were divided into two blocks: Main (MQ) and Additional (AQ) questions. Below, Table 1 shows the list of these questions.

Main block	**MQ1**	What is the main area of frailty?.
	MQ2	Type of a solution (simulator game, devise system)
	MQ3	Haptic feedback integration
	MQ4	Sensor's usage
	MQ5	Was integration of intelligent systems (AI, Neural Networks) used?
	MQ6	Specification of solution
	MQ7	Reusability of solution
	MQ8	Variability of solutions
	MQ9	Does the simulator allow the selection of different scenarios based on trainee's needs?
	MQ10	Characteristics of the target audience and its influence
Additional block	**AQ1**	*What is the level of interactivity of the system?*
	AQ2	*What immersion method is used (AR, VR, standard methods)?*
	AQ3	*What visualization methods used?*
	AQ4	*Solution portability*
	AQ5	*What platform types were used?*
	AQ6	*Which development kits were used for development?*
	AQ7	*Which metric was used for result evaluation?*
	AQ8	*Which evaluation method was used?*
	AQ9	*Was a statistical analysis performed?*
	AQ10	*Is current solution commercial?*
Statistical block	**SQ1**	What is the number or methods per platform?
	SQ2	What is the age scale of target audience for solutions?
	SQ3	How many solutions using motion capture?
	SQ4	Which used evaluation score system is most used?

Table 1. List of research questions.

The questions presented in the main block are aimed at improving the understanding of the fundamental aspects of each selected study. At the same time, an additional block clarifies various features on technical or functional grounds.

RESULTS

Flow Chart

In the end, after applying these criteria, a total of 360 articles were collected from database searches. Figure 1 below shows a diagram of the filtering and sampling of materials, before they were further examined.

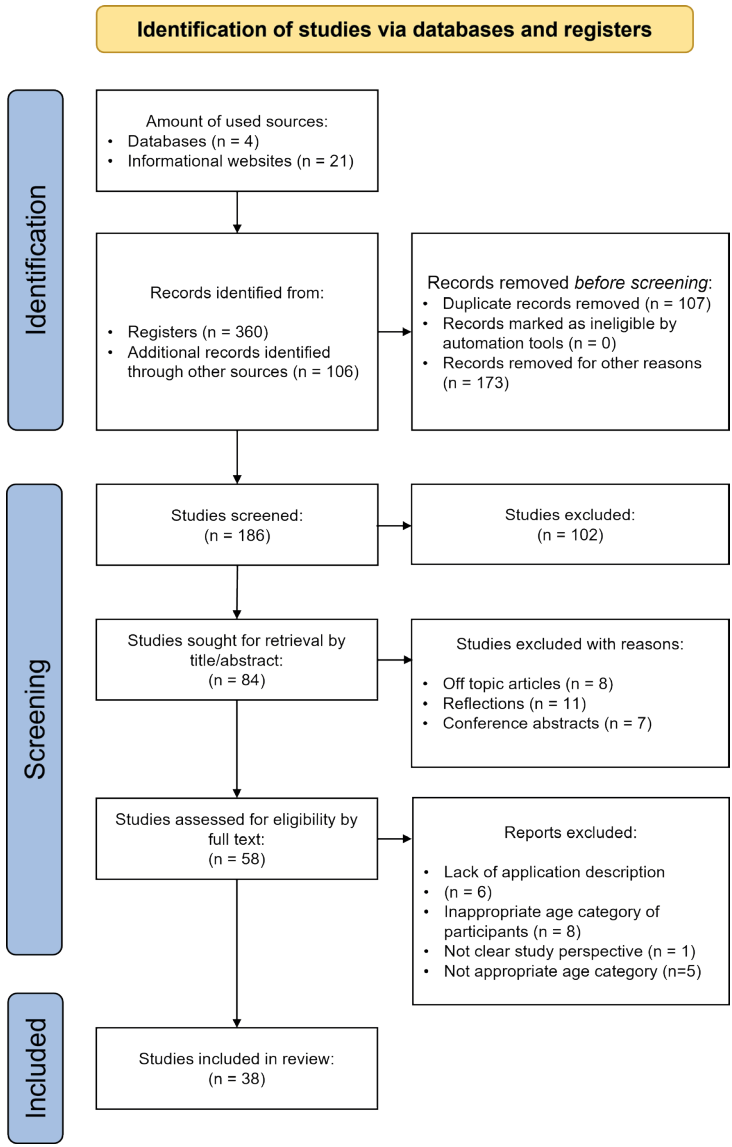

Figure 1 - Flow chart of articles selection process

Of all the originally selected articles, only 38 documents that meet the original search criteria remained for further research after several filtering steps.

Having carefully analyzed the selected studies, Table 2 was compiled, which shows a detailed description of the characteristics we are interested in. Having analyzed the data in this table, the following conclusions and analytical results are presented in Figure 2 and Figure 3 and Figure 4.

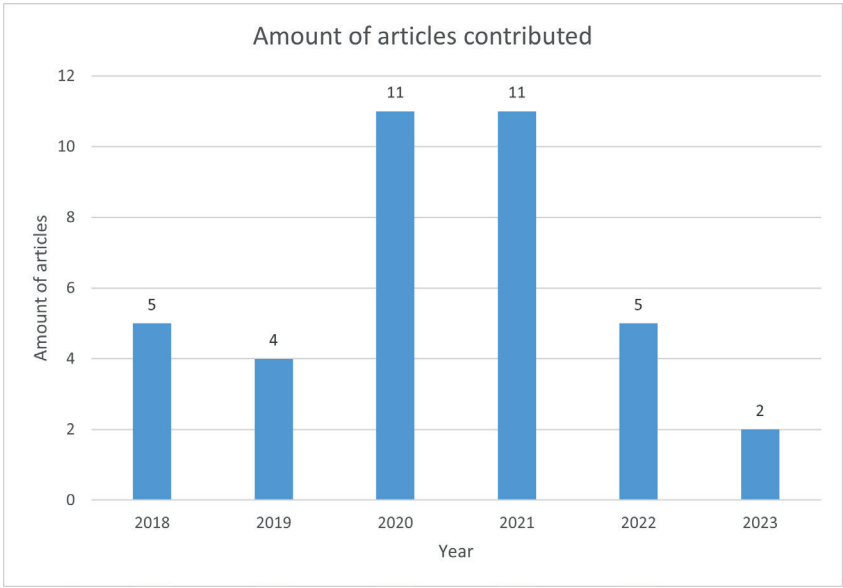

Figure 2 - Statistics of article distribution by year.

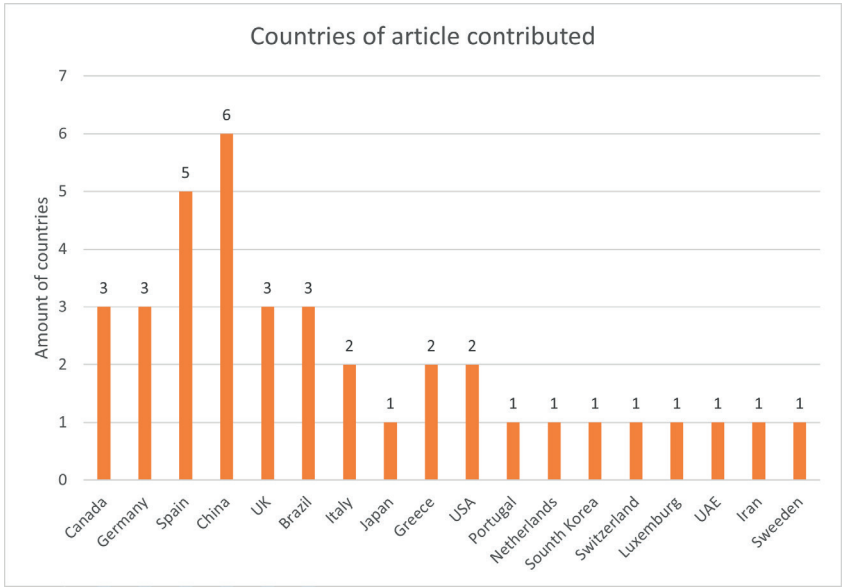

Figure 3 - Statistics of distribution of articles by country of publication.

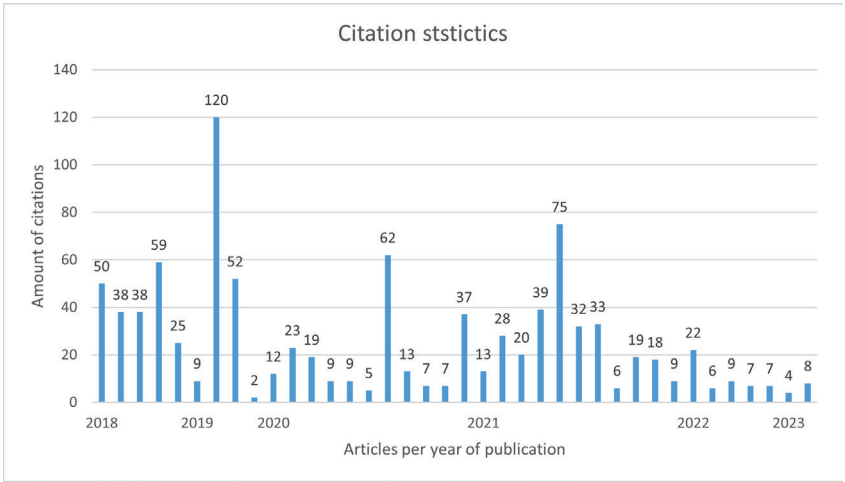

Figure 4 - Statistics of distribution of articles by number of citations.

Reference	Title of Selected Study	Results Description
Wu 2018 [26]	Understanding Older Users' Acceptance of Wearable Interfaces for Sensor-based Fall Risk Assessment	System implemented in this study achieved high user acceptance (Hypothesis H1), and participants consider the fall risk estimation useful and the accessibility is appreciated.
Graf 2020 [27]	Playing in Virtual Nature: Improving Mood of Elderly People Using VR Technology	Significant reduction of the elderly people's anxiety regarding the VR technology
Shahmoradi 2022 [28]	A Systematic Review on Serious Games in Attention Rehabilitation and Their Effects	A systematic review of solutions aimed at training and development of different program solutions in different settings and for different rehabilitation problems of the elderly.
Kondragunta 2019 [29]	Estimation of Gait Parameters from 3D Pose for Elderly Care	The necessary key joint for gait parameter estimation are selected and the projection of those key joints into a 3D environment is done. Some gait parameters that are useful to analyze the gait of a person are estimated
Brauner 2020 [30]	Serious Motion-Based Exercise Games for Older Adults: Evaluation of Usability, Performance, and Pain Mitigation	Study shows two games, that were evaluated as easy to use and fun to play. Both game interventions had a strong pain-mitigating effect in older adults
Gonzalez-Bernal 2021 [31]	Influence of the Use of Wii Games on Physical Frailty Components in Institutionalized Older Adults	A Wii Fit® console intervention for 8 weeks improved walking speed, static balance, and reduced falling risk and frailty levels in institutionalized older adults

Kwan 2021 [32]	Feasibility and Effects of Virtual Reality Motor-Cognitive Training in Community-Dwelling Older People With Cognitive Frailty: Pilot Randomized Controlled Trial	VR simultaneous motor-cognitive training is effective at enhancing the cognitive function of older people with cognitive frailty
Yu 2021 [33]	Randomized Controlled Trial on the Effects of a Combined Intervention of Computerized Cognitive Training Preceded by Physical Exercise for Improving Frailty Status and Cognitive Function in Older Adults	Improves frailty status and cognitive function of community-dwelling older adults,
Afyouni 2020 [34]	Adaptive Rehabilitation Bots in Serious Games	Feasibility and user experience measures were collected, and the results of experiments show that patients found our game-based adaptive solution engaging and effective, and most of them could achieve high accuracy in performing the personalized prescribed therapies.
Parke 2018 [35]	Age-related physical and psychological vulnerability as pathways to problem gambling in older adults	Study provides a significant novel contribution to understanding pathways that account for the development and maintenance of problem gambling in older adult pop
Chu 2021 [36]	Exergaming Platform for Older Adults Residing in Long-Term Care Homes: User-Centered Design, Development, and Usability Study	Study demonstrated that an exergaming platform could be co created with LTC home residents with multiple cognitive and physical impairments, who are a challenging group to engage in research
Oliviera 2021 [37]	Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit Plus™ for frail elderly: study protocol for a feasibility trial	The current study is designed to evaluate the feasibility, safety, acceptability, and functional outcomes of playing NWFP for frail older adults
Lunardini 2020 [38]	2D Virtual Reality-Based Exercise Improves Spatial Navigation in Institutionalized Non-robust Older Persons: A Preliminary Data Report of a Single-Blind, Randomized, and Controlled Study	Virtual reality-based exercise improves the spatial navigation of institutionalized non-robust older persons.
Tuena 2020 [39]	Validity and usability of a smart ball–driven serious game to monitor grip strength in independent elderlies	Game specifically designed to measure age-related muscle weakness while engaging elder users in a compelling activity.
Mugueta-Aguinaga 2019 [40]	Usability Issues of Clinical and Research Applications of Virtual Reality in Older People: A Systematic Review	-
Lin 2020 [41]	Development and Evaluation of a Computer Game Combining Physical and Cognitive Activities for the Elderly	This system simultaneously combines musical rhythm games with exercises for cognitive training, while the exercises are designed to correlatively combine movements with the concept of acupressure points.

Cuesta-Gómez 2020 [42]	Effects of virtual reality associated with serious games for upper limb rehabilitation inpatients with multiple sclerosis: randomized controlled trial	An experimental protocol using an LMC based Serious Games designed for UL rehabilitation showed improvements for unilateral gross manual dexterity, fine manual dexterity, and coordination in MS patients with high satisfaction and excellent compliance
Shimada 2019 [43]	Prevalence of Psychological Frailty in Japan: NCGG-SGS as a Japanese National Cohort Study	Defined psychological frailty as the co-presence of physical frailty and depressive mood
Zacharaki 2020 [44]	FrailSafe: An ICT Platform for Unobtrusive Sensing of Multi-Domain Frailty for Personalized Interventions	The system consists of an integrated platform that aims to early detect frailty in the older people through the use of ICT technologies equipped with artificial intelligence tools
Yu 2020 [45]	Older adults' perspective towards participation in a multicomponent frailty prevention program: a qualitative study	These findings highlighted several important factors for consideration in future design of frailty interventions regarding the needs of pre-frail and frail older adults, which could help to motivate and sustain their participation in community-based frailty prevention programs
Linn 2021 [46]	Digital Health Interventions among People Living with Frailty: A Scoping Review	-
Tegou 2018 [47]	A Low-Cost Indoor Activity Monitoring System for Detecting Frailty in Older Adults	The system is based on Bluetooth RSSI fingerprints using beacons
Randriambelonoro 2023 [48]	Gamified Physical Rehabilitation for Older Adults With Musculoskeletal Issues: Pilot Noninferiority Randomized Clinical Trial	A noninferiority related to the primary outcome (SPPB) was identified during the hospital stay, and no significant differences were found between the control and intervention groups for any of the secondary outcomes (IHGS, FIM, or steps), which demonstrates the potential of the serious game-based intervention to be as effective as the standard physical rehabilitation at the hospital.
Ruiz 2018 [49]	Validation of an automatically generated screening score for frailty: the care assessment need (CAN) score	Tool for detection of frailty and warrants further investigation regarding its applicability in primary care setting
Lau 2021 [50]	A framework and immersive serious game for mild cognitive impairment	A range of cognitive rehabilitation games have been proposed to supplement or replace traditional rehabilitative training by offering benefits such as improved engagement
Rahemi 2018 [51]	Toward Smart Footwear to Track Frailty Phenotypes—Using Propulsion Performance to Determine Frailty	This study demonstrates that a foot-worn sensor-derived gait measures during the propulsive phase of walking can be sensitive metrics in assessing frailty

Alhasan 2021 [52]	Application of Interactive Video Games as Rehabilitation Tools to Improve Postural Control and Risk of Falls in Prefrail Older Adults	In this study, objective postural control assessments were made using static posturography via traditional postural sway measurements
Han 2021 [53]	Mobile Augmented Reality Serious Game for Improving Old Adults' Working Memory	A mobile-based augmented reality system for regular cognitive function training is proposed to minimize declines in cognitive function among the elderly. Using the characteristics of markerless augmented reality technology that can support physical activities, the foregoing system was developed in the form of a serious game based on an understanding of physical aging
Pereira 2021 [54]	A Virtual Reality Serious Game for Hand Rehabilitation Therapy	The system was assessed by seven able-bodied participants using a semistructured interview targeting three evaluation categories: hardware usability, software usability and suggestions for improvement
Madureira 2020 [55]	My-AHA: Software Platform to Promote Active and Healthy Ageing	Software platform that comprises a software ecosystem designed to seamlessly integrate different health and active ageing solutions, targeting senior well-being
Gorregidor-Sanchez 2020 [56]	Effectiveness of Virtual Reality Systems to Improve the Activities of Daily Life in Older People	Use of VRSs is an innovative and feasible technique to support and improve the functional autonomy of community-dwelling older adults
Kosterink 2019 [57]	GOAL: An eHealth Application for Rewarding Healthy Behaviour. The First Experiences of Older Adults	Developed technology and assistive tools for the target population of less-technologically skilled older adults and those less motivated in achieving a healthy lifestyle, this is not necessarily the main target
Shapoval 2021 [58]	Biofeedback Applied to Interactive Serious Games to Monitor Frailty in an Elderly Population	The effectiveness of the gaming platform increases the patient's outcome from 30% to 50% depending on the level and activity, the value in this case does not show the specific rehabilitative potential of the system
Eun 2022 [59]	Artificial intelligence-based personalized serious game for enhancing the physical and cognitive abilities of the elderly	Study designed the exercise serious game Farming with Artificial Intelligence-(AI-) based personalized systems of difficulty level adjustment and relative scoring to motivate the user to keep playing the game with pleasure while applying a set of gratification and motivation technique.

Beltran-Alacreu 2022 [60]	A Serious Game for Performing Task-Oriented Cervical Exercises Among Older Adult Patients With Chronic Neck Pain: Development, Suitability, and Crossover Pilot Study	The serious game developed in this study showed good suitability for use in adults over 70 years of age with chronic neck pain. The game was a safe method for performing task-oriented cervical exercises, and patients reported very high levels of satisfaction and acceptance after the use of this technology
Liu 2023 [61]	Application of Immersive Virtual-Reality-Based Puzzle Games in Elderly Patients with Post-Stroke Cognitive Impairment: A Pilot Study	This pilot study suggests that IVR-based puzzle games are a promising approach to improve post-stroke cognitive function, especially executive cognitive function, and visual–spatial attention in older adults
Fu 2022 [62]	Conceptual Design of an Extended Reality Exercise Game for the Elderly	This research first analyzed the relevant literature and existing VR exercise games for the elderly to find characteristics and their particular needs
Rorato Souza 2022 [63]	A Serious Games and Game Elements Based Approach for Patient Telerehabilitation Contexts	Was developed to assist in conducting telerehabilitation sessions that involve a cycle ergometer as a device – a bedside bicycle used in rehabilitation sessions for patients with motor disorders

Table 2. Main reference table

Main investigation parameters

In addition to basic information about the articles selected for the study, it is also important to understand the specifics of the applications. For this purpose, it is necessary to further analyze the following parameters:

- Platform of use
- Principle of operation
- Form and type of use
- Need for additional tools and their number
- Variants of the information to be obtained

Due to this, it is possible to speak about the trend of research development in the direction of Serious Games for support and rehabilitation.

Main frailty area (MQ1)

In terms of functionality, all systems can be divided into two categories: evaluation [29, 41-43, 59] and training [32-34, 49, 58]. In the first case, the systems are aimed at detecting or monitoring [36, 47, 49, 58] the presence or absence of any problems, and if these problems exist, the system helps to analyze and understand the degree of frailty. The second case is designed directly to help train or prevent [26, 28] these very problems. Apart from the elements of collecting information about the training itself, this module does not carry in itself.

More generally, the presented solutions can be divided into monofunctional, for example [26, 28, 31, 38, 46], and multifunctional [30, 32, 41, 49], which include several tasks at once. The second type is more practical, at least in view of the fact that such systems can be used simultaneously for several purposes, which gives advantages. The author's system [58] is multifunctional, and along with, for example [41, 51, 52], it is able to perform all necessary measurements and calculations in the background, while the player will do game activities. In contrast to, for example [26, 35, 46, 50, 51], where the emphasis is on one thing only, often only training, or "here and now" data analysis without further recording and processing, multifunctional systems (including author's) give a wider toolbox in monitoring player/patient results. Of course, there are disadvantages of such systems in terms of reliability, because the strong overload of the presence of a variety of mechanics and algorithms increases the probability of failure and errors, however, modern computing resources can reduce them to a minimum.

If we analyze the main rehabilitation modalities presented in the above-mentioned studies, the 2 most important ones can be identified among the main ones, namely direct physical [29-31, 34-40, 47-49] and hybrid [28, 32, 33, 41, 42, 44-46], which include complex exercises and tasks that affect multiple aspects of the user's condition. The distribution statistics are shown in Figure 5.

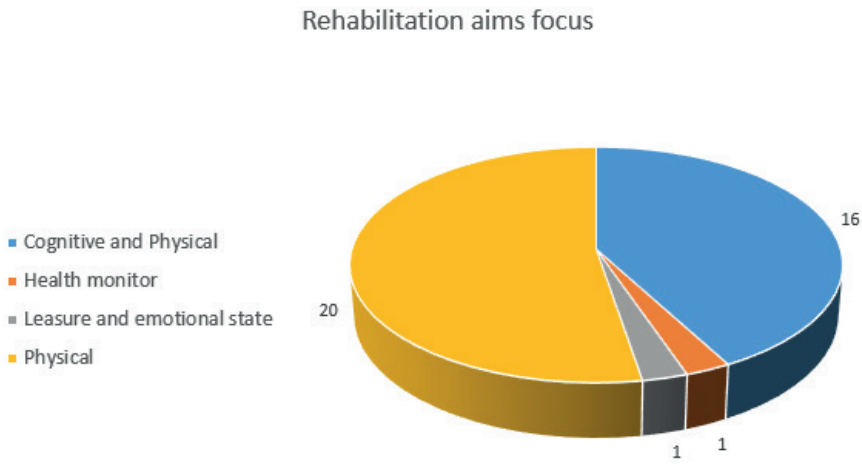

Figure 5 – Statistics on the distribution of the direction of rehabilitation impact.

Type of the solution (MQ2, AQ5)

The picture is also quite clear with regard to data sampling and estimation. Developers mainly resort to standardized measurement systems, or adapt them to their specific needs and goals. In this set of articles, all research is aimed at tracking and evaluating exactly the physical indicators, so the variability of measurement systems includes only the basic methods of assessment, or their modifications.

There are only a few types of such estimation parameters used in the articles we studied. These are either self-made estimation systems [42, 45, 48, 58] or algorithms for which a certain common parameter is introduced [28, 49, 52]. In their distribution, these two methods have approximately equal weight, but different specific estimation systems are less distributed, and give a more specific picture for their particular solution [34, 36, 50, 57]. As for the tests themselves, it is often a complex process of obtaining information about the player's movements, their evaluation and subsequent interpretation.

In fact, we get the following picture: if we take any system with self-made scale, for example [45, 48], in this case the result of the player is calculated based on the spatial characteristics X, Y of the key points of the body or the object. This method allows to compose quite accurately the temporal characteristic of the pattern of movements in the form of a signal. Author's system [58] uses the same method, so a custom scale was used to evaluate the results. At the same time, such solutions as [28, 52] measure and analyze by calculating kinetic characteristics, such as speed or acceleration of sensors or key points, which allows to bring the results of the system to already ready standardized scales of frailty

evaluation. And in this case, in contrast to the methods [45, 48, 58], both external sensors and software solutions can be used (then the speed and vector of change of their spatial parameters, rather than the general characteristic of the key points position, is calculated).

Considering the above, it is difficult to say which method is more efficient: in the case of [45, 48, 58] and similar ones, the advantage is simplicity and greater accessibility of use, in the absence of additional peripherals, and in the case of solutions similar to [28, 52], more accurate and standardized data extraction and evaluation. The disadvantage of each category is a more narrowly focused area of application (in case of [45, 48, 58]), because each solution introduces its own evaluation scale, which may cause difficulties in understanding the medical staff, while for [28, 52] the higher price (additional sensors) as well as possible difficulties in setting up and calibration of the system.

However, even so, the ratio of the presence or absence of additional means is roughly equally distributed among the different solutions. As can be seen from Figure 6, this parameter should be considered not from the fact of availability, but from the number of these additional devices or systems.

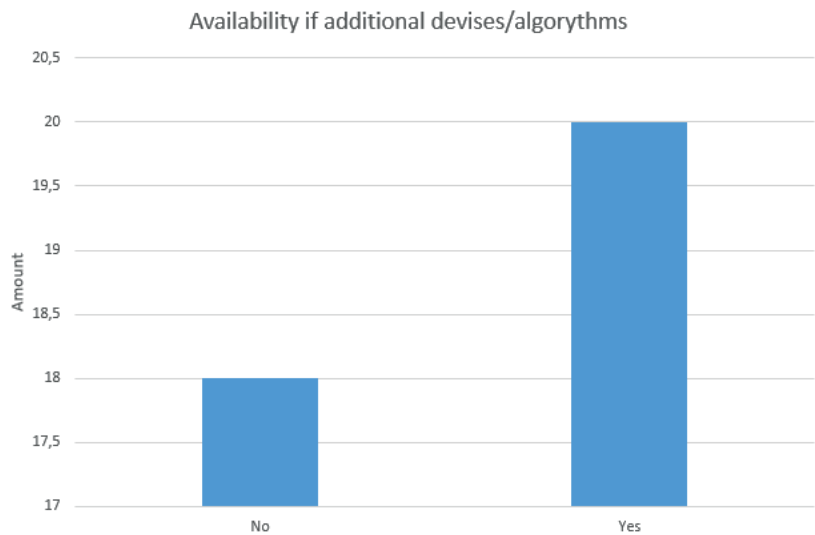

Figure 6 – Statistics on the distribution of the direction of rehabilitation impact.

Level of interactivity and haptic feedback integration (MQ3, MQ4, AQ1)

To be effective in using a particular solution, it is critical to understand whether a particular system has the additional means to provide not only tracking information about the player, but also to provide the player himself with additional value from the system/game. This is where the MQ3 (Haptic feedback integration) question is important to answer.

If we talk about feedback, then in this case we need to rely on what form this or that system has. In fact, all of them can be conditionally divided into 3 types: with low, medium and high degree of direct feedback. More specifically, mobile applications (in general cases) usually have a low degree [26, 47, 51, 55, 57]. The reason for this is to maximize accessibility and ease of use. The average degree of interaction is inherent in applications like computer games [30, 31, 34, 37-39, 42, 48, 50, 60]. In this case, this level can vary as necessary to ensure sufficient information exchange between the tutor, the client of the system, and the user directly. A high degree of interaction is characterized by systems with high interactivity, such as augmented reality systems [32] or virtual reality VR applications [27, 61], which provide maximum immersion in the process.

Separately, multiplatform solutions [29, 33, 35, 36, 41, 43, 44, 53, 59], in which it is quite difficult to distinguish a specific level and degree of interaction. Depending on the situation, they can have different degrees of interactivity with the same task inputs. The statistics of the distribution of the solutions presented above is demonstrated in Figure 7.

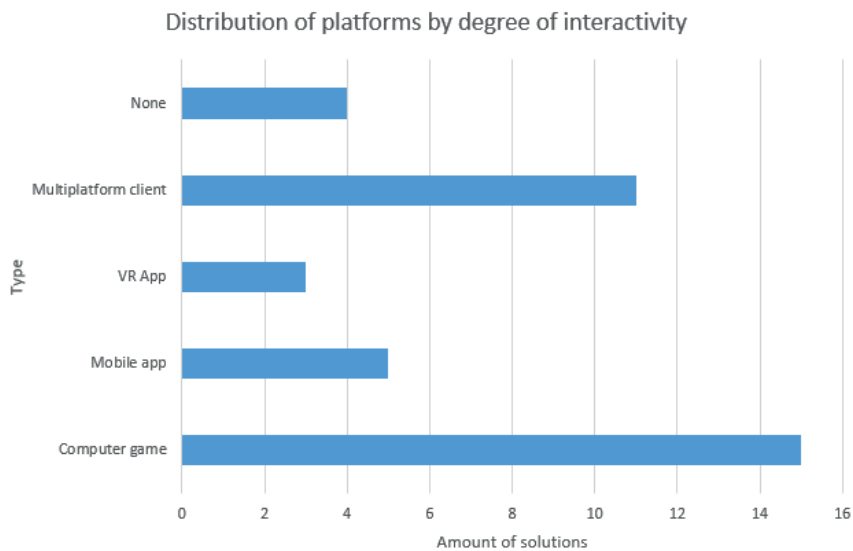

Figure 7 – Statistics on the distribution of the direction of rehabilitation impact.

Target audience (MQ10)

In order to analyze program solutions, it is also necessary to understand for which age group a particular system is designed. This is due to the fact that for different age intervals, even in the same population group, often external health factors are quite critical and can significantly affect the final results. Conventionally, we can distinguish 4 such groups: 51-60, 61-70, 71-80, 80+. Why this is the case will be described further on with examples.

In the first group, 51-60 years old, the state of users, if we take countries with a sufficient standard of living, in such an age there are less observed any chronic, acquired or age-related changes in the body, which can affect the parameters of users, relative to the other categories mentioned above. Thus, support and rehabilitation applications and systems do not require special customization and are easier to create.

In other groups, the higher the age indicator, the more it is necessary to consider before and during the development of such systems. Also, they are quite rare, because at more advanced ages the results of rehabilitation decrease, and it is more appropriate to start training and support in the segment of 50-55 years old. The same is confirmed by the results of analyzing the presented list of solutions, which are shown in Figure 8

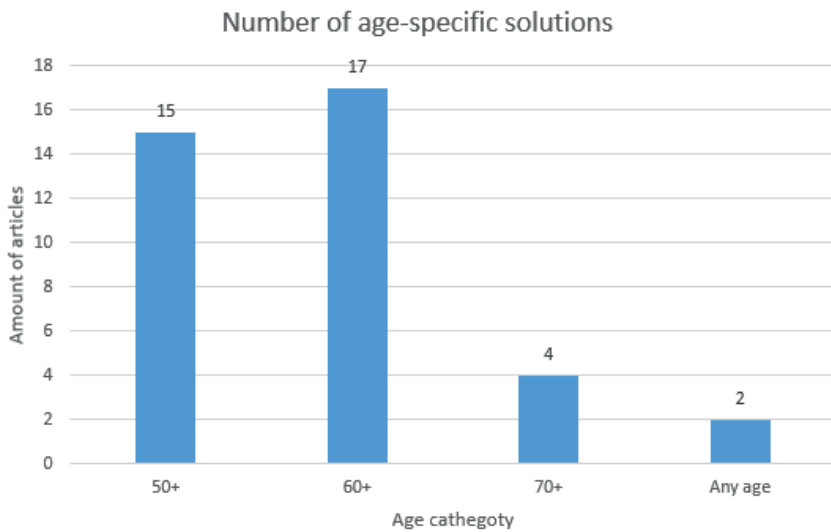

Figure 8 – Statistics on the distribution of studies in different age categories.

DISCUSSION

By analyzing and evaluating the articles about rehabilitation, there appears a possibility to draw a general conclusion about the situation in this area, as well as answer some of the questions that was proposed in the Introduction section. First of all, it is worth mentioning the general data that were obtained in the course of the study. As statistics show, the issue of support for the elderly has indeed become increasingly important in recent years, especially in developed countries. The number of studies in this direction is increasing every year, as well as the number of game-based applications and support tools.

This study has several purposes in itself. The first is to collect and evaluate information about those applications and platforms that are intended to support, highlighting their main

features and technical solutions. The second goal - on the basis of the data obtained, to assess the prospects for these or other technical solutions and compare them with a similar system author previously developed [58].

It should be mentioned that in parallel with this research there is a development of a game system, which is based on the technology of motion capture and is designed to support the physical condition of the elderly or patients with problems of the musculoskeletal system. All further discussions will be in the vein of discussing certain features and comparing them with our platform.

Next, the questions posed at the beginning of the study will be answered to help better understand the situation and draw a conclusion. It will be indicated at once that, in the following discussion, a few articles will be chosen from among those that have the highest quality score, or those that are most representative, as examples of certain situations or parameters.

Q3: What technical solutions were used for frailty studies?

If we talk about technological or software solutions that are used in such systems, the picture is quite complex. First of all, the availability of a solution will depend on the main task of the system and the functional requirements. In terms of such requirements, in this case, rehabilitation measures are considered. It is this initial program of rehabilitation measures that will ultimately determine how technically complex the system turns out to be.

In this article was mainly considered those technical solutions that are intended to be used in the case of physical problems. In this regard, we have almost 65% of the use cases of motion tracking systems [34, 45, 59]. The same 5% to 15% of the use of other hybrid [43, 44, 56] or intermediate [30, 39, 46, 58] systems for estimating body position in space.

When it comes to efficiency, it's hard to tell at a glance which technical solution shows the highest degree of efficiency. If we take as a basis solution with algorithms based on physical methods (hardware), then, for example, in systems [36, 43, 45, 48] these devices can be interpreted differently. These are "mats" based on strain-gauge or LED sensors [36], as well as miosensors with gyroscopes [43], VR and AR systems [45], stationary motion sensors [48] and many others. What they all have in common is the presence of an external periphery, which they actually are, acting as a "generator/collector" of incoming data. Compared to software solutions, these methods have an advantage in terms of accuracy and coverage of possible measurable parameters. On the other hand, they are somewhat inferior in terms of reliability, ease of use, price and energy efficiency.

Programmatic methods, on the other hand, have an equally complex structure and variability. They can be based on both conventional program algorithms [28, 34, 41, 52] and neural networks [48, 51]. The system we are developing also belongs to the second type [59]. The variability of software solutions allows us to solve different problems using a

minimum of resources. In the example of outhors system [59], all information comes through a conventional webcam, while the solution [51] also uses a camera, but with additional photosensors, which allow to increase the accuracy of the neural network, by simplifying the search for key points, which simplifies the neural network. In the case of system [59], the network itself has a more accurate method of training, and as a consequence, the principle of operation, which allows more accurate processing of the obtained image without the use of additional tools. In [48], for example, the algorithm processes several sensors at once. This allows to obtain more information, but the accuracy of processing will be lower, due to the large amount of data. These are direct examples, proving and demonstrating the variability of software methods, which is their undoubted advantage, along with the simplicity and cheapness of use by the end-user. Conventional software solutions are also quite effective, especially when combined with hardware components, or neural networks. These combinations make it possible to minimize the disadvantages inherent in each method separately.

What perspectives do all those solutions have?

To give an answer to this question, you must first determine for which direction the system with body tracking will be applied. If we talk about the sphere of entertainment and consider such systems as a means of leisure, there is little chance of viability. This is confirmed by the examples of games on the Kinect and Wii. They weren't bad entertainment services, especially for the times of 2010-2015. But now we see that they were extremely niche products and have extremely low popularity.

In addition, compared to other games or services, this direction does not give anything new or involving in the process. Even though modern body-tracking systems do not require any additional technical means besides a video camera, which is a fairly common gadget, in a normal situation such systems are perceived as "normal physical exercise disguised as a game".

If you look at such decisions from a medical point of view, the picture in this case is the opposite. In the process of rehabilitation, the patient will be forced to do the doctor's orders. Given that the processes of physical rehabilitation are rather monotonous and routine, a playful interpretation of these processes just saves the day. In fact, the player finds these actions more meaningful (notwithstanding his understanding of their necessity) and thus complies with the doctor's orders with greater enthusiasm, which has been confirmed by research. To a greater extent this applies to the sweet and old age category. Often patients in these age categories need additional motivation to perform rehabilitation measures (for various psychological and behavioral reasons). This is exactly where the methods of playful interpretation of routine activities are helpful. Nor should we forget the trends described in Section 1. Due to the increasing number of elderly people and the increasing research

interest in this area, the prospects for game-based rehabilitation systems in the medical field seem to be quite high at the moment.

During the analysis of the articles, one interesting fact was found, which relates to one of the additional unobvious tasks of the studied solutions. In parallel, we are developing a system [59] similar to those shown and described in this article. It is also aimed at supporting the elderly in terms of physical rehabilitation. In addition to a comparison with other similar solutions in terms of efficiency, technical design features and visuals, we were interested in another feature that is not obvious. Socialization Function. Due to the fact that this system, which is a computer game, can be used in terms of socialization of users, by introducing multiplayer. The idea is as follows.

In all of the solutions we studied, the result of any activity of the player is visible and used either only by him (in the vast majority of cases), or visible, for example, to a personal doctor. But what happens if the player sees the results of other participants? Confirming the data of the results of the system development and testing, authors asked themselves the question of socialization and its impact on the result. As it turned out, those test takers who saw other people's results tried to perform this or that task better, in terms of accuracy or speed. The mere fact that someone did the exercise better already spurred the player to take more responsibility for the task, which from the point of view of the process of adaptation and evaluation of performance is certainly a positive trend. It was also observed that such players were quicker to understand the task assigned to them, and therefore faster and better to cope with it. The same was true of the gameplay moments. Thus, the goals that the authors set during the development of their own platform contribute to one of the target programs of the United Nations, namely Goal 3 - Good Health and Well-Being.

LIMITATIONS

It is also worth saying that this study has certain limitations. The first is the methods of data selection and analysis. Considering that the presented article is aimed at studying the technical and conceptual side of the rehabilitation tools shown, the authors took into account the results of the direct work of these tools only indirectly. This is done in order to focus only on those technical and programmatic solutions that have positive effectiveness and results. The second limitation is the target audience. Although the type of apps under study is conceptually possible for use by any age group, the authors are most interested in research aimed specifically at supporting the elderly. This category was chosen because of the information presented in Section 1.

CONCLUSIONS

As a conclusion, it can be noted that game systems aimed at helping to support and rehabilitate patients with physical problems can become not only an additional and quite powerful tool in terms of medical effectiveness, but also an assistant in terms of socialization of such people. This is especially true for the elderly, because often their social activity is very low. Rehabilitation game systems can help not only improve the physical condition of this category of people, but also have a positive effect on the mental state, introducing an "adversarial" component to a seemingly routine process. This fact further confirms the necessity and prospects of continuing research in this direction.

The information obtained during this study will help to better understand the peculiarities of working with applications aimed at rehabilitation. In future work, the acquired knowledge will be useful during the development of our own platform, namely a better assessment of the player's capabilities, elaboration of functional tasks, a clearer focus on executive functions, better feedback.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest.

ABBREVIATIONS

SG – Serious Games.
VR – Virtual Reality.
AR – Additional Reality
AI – Artificial Intelligence.
CAN – Care Assessment Need
MQ – Main Question.
AQ – Additional Question.
OECD – The Organization for Economic Co-operation and Development.
ACM – Association for Computing Machinery.
IEEE – Institute of Electrical and Electronics Engineers.
DBLP – Databases and logic programming.

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