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Review

Can sensors be used to measure the Arm Curl Test results? a systematic review

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Abstract
There is growing interest in the automated measurement of physical fitness tests, such as the Arm Curl Test, to enable more objective and accurate assessments. This review aimed to systematically analyze the types of sensors and technological methods used for automated Arm Curl Test measurement and their benefits for different populations. The search consisted of the search related to the possibilities to measure the Arm Curl Test results with sensors in scientific databases, including PubMed Central, IEEE Explore, Elsevier, Springer, MDPI, ACM, and PMC, published from January 2010 to October 2022. The analysis included 30 studies from 15 nations with diverse populations analyzed. According to data extraction, the most prevalent sensors were chronometers, accelerometers, stadiometers, and dynamometers. In the investigations, statistical analysis predominated. The study shows how automated sensor technologies can objectively measure the Arm Curl Test. The detected sensors combined with statistical analysis techniques can enhance assessments. Applications for the Arm Curl Test may be improved even more with more research on cutting-edge sensors and algorithms. This evaluation offers insightful information about utilizing sensor-based automation to enhance Arm Curl Testing.

Keywords Arm Curl Test · IoT · Systematic review · Mobile devices · Telemedicine · Sensors

1 Introduction

The Arm Curl Test is a test for determining upper body strength and stamina [1, 2]. The Arm Curl Test is a quick test for measuring upper body strength and endurance that offers essential information about a person's physical fitness and health level [3, 4]. The test subject is seated in a chair and is holding a dumbbell in their dominant hand. The exercise begins with the arm fully extended, flexing the elbow to curl the weight up towards the shoulder, and then slowly and deliberately lowering it back down, consisting of one iteration [5]. The participant usually does as many repetitions as possible in 30 s while maintaining good technique and control [6]. The total number of completed repetitions determines the score [7, 8], where a higher number of curls suggests stronger and more resilient upper

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body muscles. The arm curl test, when administered properly, offers reliable and valid measurements of upper body strength, especially in older adults. Its psychometric properties and clinical validation make it a useful tool in both fitness and clinical settings.

People frequently utilize the arm curl test to evaluate physical fitness and monitor improvements over time [8]. It offers a functional measure of strength endurance corresponding to a person's capacity to carry out daily chores demanding strong arms and grips [9]. The test can be readily used in various contexts, including senior centers, gyms, clinics, and research projects, as it requires few equipment and is straightforward to conduct [10]. More accurate quantification of variables like curl frequency, velocity, and range of motion is made possible by automated measurement employing sensors [11–14], providing more insightful information. The Arm Curl Test is a helpful screening tool for assessing upper body function and tracking progress during exercise or rehabilitation, where, utilizing sensor technology, it is possible to improve assessment and enable remote management [15–17].

From the psychometric properties point of view, there are several aspects to be considered [18]. If an individual takes the test multiple times under the same conditions, their scores are usually fairly consistent, which is denoted as test-retest reliability [18]. The arm curl test generally shows good test-retest reliability when protocols are followed consistently [18]. Similarly, from an inter-rater reliability point of view, the scores are consistent when different testers are administering the test, which assumes proper training of testers [18]. From a validity point of view, the arm curl test is considered to have good construct validity for upper body strength, especially in older adults. Similarly, clinical validation involves studying how the arm curl test relates to real-world outcomes, like the ability of older adults to perform daily tasks.

This paper provides a systematic review of the studies using sensors to evaluate the Arm Curl Test across various demographics and settings. This would help in a consistent measurement of the test values and establishing a gold standard that would help in the clinical validation of how different people who have different test values perform in daily tasks. Recent studies have looked at integrating sensors to enable automated and more accurate measurement because manual administration of this test can be time-consuming and prone to human mistakes. A thorough literature search utilized the most reputable scientific sources to discover studies that used sensors to assess Arm Curl Test parameters. Thirty pertinent papers published from January 2010 to October 2022 were selected for inclusion after a stringent screening process. Data extraction was conducted to compile details on the sensors used, data processing techniques, medical partnerships, publication schedules, geographic locations, study populations, and health problems. The findings show that it is possible to acquire accurate Arm Curl Test readings utilizing a variety of sensors, including chronometers, accelerometers, and dynamometers, which can be analyzed with statistical and machine learning techniques. Automated evaluation can improve assessment across various age groups, illnesses, and research contexts.

2 Methodology

This systematic review is based on the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) methodological framework [19]. To discover and collect relevant papers, it used precise inclusion and exclusion criteria as well as well-defined search terms. The results are then filtered by removing duplicates, additional unconnected or incomplete articles, and papers that have been thoroughly screened. Then, a qualitative examination of hand-selected, top-notch publications is performed [20]. As a result, this study evaluates the most recent advancements in the literature about using wearable or mobile devices to administer the required test. The literature databases may be searched more efficiently using an artificial natural language processing (NLP) toolset [21]. The PRISMA flow is automated in other studies using a similar technology [22, 23].

2.1 Research questions

This systematic review was based on the following questions: (RQ1): What types of sensors can be employed to track and measure different approaches to the Arm Curl Test? (RQ2): Which technological methods can be integrated with the sensor data to measure the Arm Curl Test effectively? (RQ3): What are the benefits of automated measuring of the Arm Curl Test for different populations or conditions?

2.2 Inclusion criteria

For this study, several inclusion criteria were used, including (1) studies that measure the parameters of the Arm Curl Test with sensors; (2) studies that present various implementations of the Arm Curl Test; (3) studies that present the purpose clearly; (4) studies that clearly define the population; (5) studies that show the results; (6) studies presenting original research; (7) studies written in English.

2.3 Exclusion criteria

Also of the inclusion criteria, the articles are also excluded based on the following exclusion criteria: (1) studies that not used sensors or technological equipments for data acquisition; (2) studies that not detail the characteristics of the population; (3) studies that not define or use technological methods for the analysis of the data acquired; (4) studies that are surveys or literature reviews; (5) studies that are study protocols or interviews; (6) studies not related to the healthcare subject with technological equipments.

2.4 Search strategy

The research strategy followed a PRISMA methodology to identify and process the literature on Arm Curl Test published from January 2010 to October 2022. Through the NLP toolkit, the following electronic databases were explored automatically for articles selection: PubMed Central, IEEE Explore, Elsevier, Springer, MDPI, ACM, and PMC. The studies were analyzed to identify the various methods for automated measuring Arm Curl Test results. The research was performed on November 02, 2022.

The NLP framework input parameters are a collection of keywords used to identify potentially relevant articles and a set of properties that should be satisfied by the identified articles. The following research keywords were used: "arm curl test with wearables", OR "arm curl test with mobile devices", OR and "arm curl test". The program automatically eliminated all duplicates based on the DOI numbers. Additionally, the relevant papers were identified based on the keyword search and the inclusion criteria. For more detailed information about the features of the NLP toolkit, we refer the reader to the study by Zdravevski et al. [21].

Every identified study was independently evaluated by the authors, determining their suitability with the eligible criteria of the search. It is multidisciplinary research that includes researchers from healthcare, electrical enginnering, and computer sciences areas. Two authors are computer science students (T.M. and D.V.) that pefomed the analysis and data extraction related to the different studies found by the NLP framwork searched, performed by a researcher from North Macedonia (E.Z.). Additionally, the 2 students collaborated in the filtering of the non-related results. The work is validated and supervised by researchers from healthcare (C.A.), electrical engineering (P.J.C.), and computer science (I.M.P.) areas. The researcher from electrical engineering performed the validationg of the use sensor related to the use of Arm Curl Test. The computer science researcher performed the data validation in data analysis methods and results extracted by the different studies. The medical researcher performed the validation of the whole research and attested its usefulness and applicability in real applications. All the authors contributed to the manuscript elaboration.

2.5 Extraction of study characteristics

Several parameters were extracted from the various studies. The extracted properties from the different studies include the year of publication, location, the population of the study, purpose, methods used, sensors and equipment's used to collect the data, and the diseases associated with each study.

3 Results

Figure 1 shows the selection process, where it is identified 6240 records from the selected sources. Next, 1008 records were automatically discarded as duplicate records between databases. The NLP-framework used also excluded 82 papers as ineligible. To finalize the first selection, 4936 papers were excluded by title and abstract analysis. After analyzing each

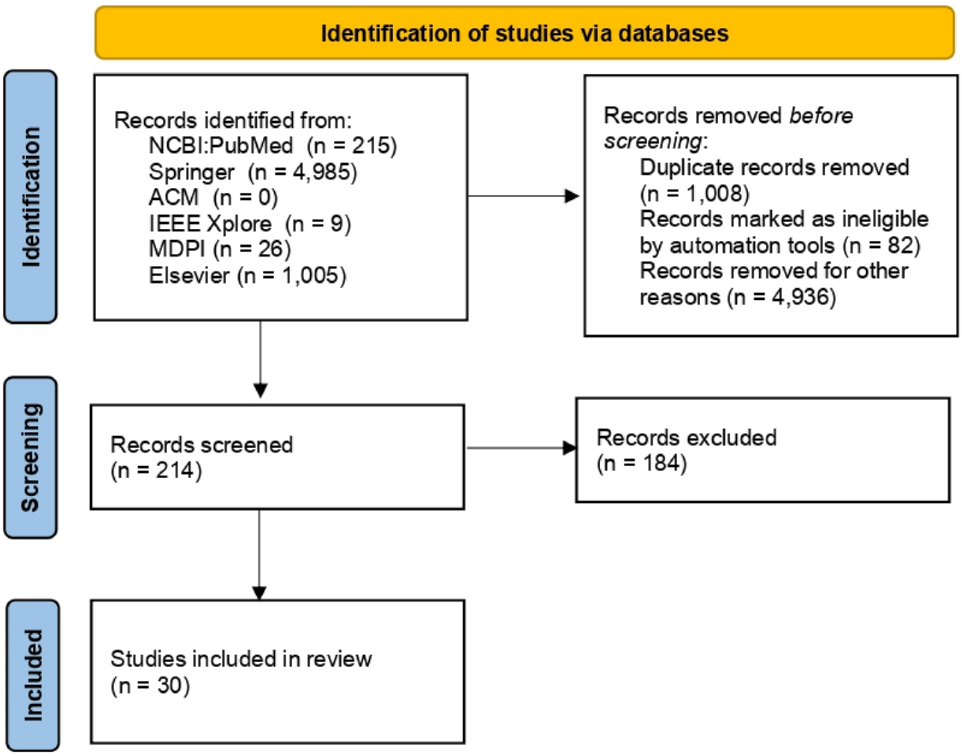

Fig. 1 Flow diagram of the selection of the papers

research article's title and abstract, the remaining 214 papers were manually analyzed, excluding 184 records that are not related to Arm Curl Test. Finally, the remaining 30 research articles were examined and included in the qualitative and quantitative syntheses.

The selected studies were examined to extract the relevant data. The query performed in this study retrieved papers published between January 2010 and October 2022. As reported in Table 1, five studies (16%) were published in 2022, eight studies (26%) in 2021, six studies (20%) in 2020, one study (3%) in 2019, two studies (6%) in 2018, three studies (10%) in 2017, one study (3%) in 2016, one study (3%) in 2015, one study (3%) in 2011, and one study (3%) in 2010. Regarding the location of the different studies, fourth studies (13%) were performed in the USA, three studies (10%) in Chile, one study (3%) in China, three studies (10%) in Australia, one study (3%) in Thailand, two studies (6%) in Korea, one studies (3%) in Turkey, one studies (3%) in Switzerland, two studies (6%) in Austria, two studies (6%) in Italy, one studies (3%) in Canada, one studies (3%) in Iran, one studies (3%) in Denmark, two studies (6%) in Spain, one studies (3%) in Finland, one studies (3%) in Poland, one studies (3%) in Taiwan, one studies (3%) in Brazil.

The diseases can be grouped into different categories, as presented in Table 2. The different studies can be grouped into Neurological and Cognitive Disorders (Sect. 3.1), Chronic Conditions and Cancers (Sect. 3.2), and diseases not defined (Sect. 3.3).

3.1 Neurological and cognitive disorders

In [29], the authors aimed to assess the feasibility and efficacy of couple-based interventions in improving the lifestyle behaviors of cancer survivors and their spouses. The study involved 69 individuals, where 37 men and 32 women, aged 76.0 ± 0.8 years, that used EEG sensors, chronometers, pedometers, accelerometers, and stadiometers. Data analysis methods included paired t-tests or Wilcoxon signed-rank tests. The study evaluated breast, prostate, and colorectal cancers and parameters such as physical activity, performance, weight status, body composition, and dietary intake. Results showed improved health behaviors and outcomes for cancer survivors and their partners in both couple-based and survivor-only intervention groups. The results reported 14.7 ± 0.5 repetitions for each 30 s.

A randomized control trial in Poland involved 31 community-dwelling older adults aged 68–85 who used manual wheelchairs as their primary mobility. The authors of [34] used sensors and equipment to evaluate various parameters, including a hand dynamometer, goniometer, box and block test, and peak flow meter. Medical collaboration was likely involved, as the study was conducted under the auspices of The International Association of Gerontology and Geriatrics.

Table 1 Study analysis

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Aschauer et al. [24]	2022	Austria	100 seniors	Examine the impact of resistance training and vitamin D supplementation on the physical performance of older persons with low vitamin D levels.	Accelerometer, Chronometer	Yes	Statistical	N/D	18.25 ±0.70 reps
Azamian Jazi et al. [25]	2022	Iran	28 elderly women	Analyze the cardiometabolic and adropin risk variables in obese elderly women.	Chronometer	Yes	Statistical	Inflammatory diseases, Cardiovascular disease, Chronic disease	16.14 ± 2.44 reps
Duncan et al. [26]	2022	Finland	13 males	Examine how a 12-week recreational football program affects older people's functional movement.	Bioelectrical impedance analysis, Handgrip dynamometer	No	Machine Learning	Pulmonary disease	Intervention group: 23.5 ± 3.9 reps (pre-train); 23.9 ± 4.2 reps (post-train) Control group: 14.2 ± 2.2 reps (pre-train); 15.3 ± 2.8 reps (post-train)
Kambic et al. [27]	2022	Australia	79 patients	Examine how resistance training affects patients with cardiovascular risk factors in terms of their physical performance and body composition.	Schiller ERR 911 ergometer, Ergo-spirometer, Stadiometer, Dynamometer, Chronometer	No	Statistical	Chronic disease	23 ± 6 reps
Valdés-Badilla al [28].	2022	Chile	470 older adults	Identify the relationship between morphological characteristics and physical fitness and health-related quality of life in older physically active persons.	Mechanical scale, stadiometer	Yes	Statistical	Cardiovascular disease	Female individuals: 22.51 ± 4.87 reps Male individuals: 23.33 ± 4.35 reps

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Benton et al. [29]	2021	USA	37 men and 32 women	Examine the relationship between aging and orthostatic hypotension in elderly people.	Multifrequency bioelectrical impedance analysis, Chronometer, Dynamometer	No	Statistical	Parkinson's disease	14.7 ± 0.5 reps
Boshnjakua et al. [30]	2021	USA	57 healthy adults and 61 older participants	Report the results of body composition assessments of younger and older Kosovan adults as well as test-retest reliability data from laboratory and field-based performance tests.	Stadiometer for height, Biodex dynamometer, Segmental multifrequency bioelectrical impedance analyser	No	Statistical	Chronic disease, Cardiovascular disease, Diabetes, Osteoporosis, Degenerative rheumatic problems	Healthy adults: 27.7 ± 6.6 reps Older adults: 14.7 ± 2.7 reps
Carmack et al. [31]	2021	USA	22 survivor-spouse couples	Examine the viability and effectiveness of couple-based interventions in improving the lifestyle choices of cancer survivors and their spouses in comparison to programs that target solely survivors.	EEG sensors, Chronometer, Pedometer, Accelerometer, stadiometer	No	Statistical	Breast Cancer, Prostate Cancer, Colorectal Cancer	17.6 ± 5.8 reps

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Ceballos-Laita et al. [32]	2021	Switzerland	32 women	Analyze the effects of therapeutic exercise and education in pain neurophysiology compared to therapeutic exercise alone on fatigue, sleep disturbances, and physical function in the short term and at three months of follow-up in women with fibromyalgia syndrome.	Visual Analogue Score, Jamar hydraulic dynamometer	Yes	Statistical	Fibromyalgia syndrome, Psychiatric disorder	10.44 ± 4.27 reps
Foccardi et al. [33]	2021	Italy	32 participants	Analyze the impact of daily text message recall on patients' ability to sustain healthy exercise routines after cardiac rehabilitation.	Chronometer	No	Statistical	N/D	Right arm: 15.8 ± 4.2 reps Left arm: 14.3 ± 3.0 reps
Huang [34]	2021	Taiwan	31 community-dwelling older adults	Examine how a 12-week Nordic walking training program affects older people who live in the community in terms of their spine position, physical function, and back pain.	Dynamometer, X-rays, Chronometer	No	Statistical	Parkinson's disease	Pre-train: 17.07 ± 3.67 s Post-train: 18.28 ± 3.74 s

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Se Jun Oh et al. [35]	2021	South Korea	80 subjects	Compare the long-term health advantages of land-based vs. water-based exercise for elderly persons in South Korea.	Chronometer	No	Statistical	N/D	23.77 ±4.68 reps
Waer et al. [36]	2021	Tunisia	19 healthy middle-aged women	Describe how caffeine use affects middle-aged and older persons' cognitive and physical performance.	Chronometer	No	Statistical	Chronic disease	23.3 ± 2.8 to 26.31 ± 2.3 reps
Wołoszyn et al. [37]	2021	Poland	5 older adults	Evaluate the impact of dance movement therapy on upper limb strength and functional performance in nursing house residents in wheelchairs compared to standard exercise programs and usual care.	Goniometer	No	Machine Learning	Cardiovascular disease, Systemic disease, Musculoskeletal disease	9.17 ± 6.68 reps
Ruangthai et al. [38]	2020	Thailand	14 male and 51 female	Comparing water- and land-based combined aerobic and resistance exercise programs for hypertensive older adults' cardiometabolic parameters, functional fitness, and quality-of-life.	Chronometer	No	Statistical	Cardiovascular disease, Hypertension	20.1 ± 4.32 reps

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Concha-Cisternas et al. [39]	2020	Chile	140 women	Find out how old women's physical fitness is affected by anthropometric and health indices.	Stadiometer	No	Statistical	Cardiovascular disease	21.0 ± 5.64 reps
Kazoglu et al. [40]	2020	Turkey	118 older adults	Examine how a person's level of physical fitness affects their home environment as they age.	Weighting machine	No	Statistical	Cardiovascular disease, Chronic disease	11.7 ± 4.0 reps
Lyu et al. [41]	2020	China	196 men and 360 women	Examine the connection between eating habits and physical condition among older Chinese people.	Wearable sensors	No	Statistical	Chronic disease	14.6 ± 3.5 reps
Posch et al. [42]	2020	Austria	40 females	Analyze the effects of a combined balance, strength, and jumping exercise intervention on static balance and functional mobility in older women with osteopenia when performed on a mini-trampoline.	Chronometer	No	Statistical	Osteopenia	Intervention group: 15.95 ± 2.93 reps (pre-train); 21.50 ± 3.62 reps (post-train) Control group: 16.80 ± 3.35 reps (pre-train); 17.40 ± 3.35 reps (post-train)
Villafaina et al. [43]	2020	Spain	36 women	Examine the physical performance and neurophysiological response of women with fibromyalgia and healthy controls while engaging in a motor-cognitive exercise.	EEG sensors	No	Statistical	Fibromyalgia	Woman with fibromyalgia: 17.00 ± 4.50 reps Healthy woman: 23.50 ± 5.50 reps

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Kim et al. [44]	2019	South Korea	23 older adults	Compare alterations in physical activity, fitness, and obstacles to physical exercise.	Chronometer	No	Statistical	Dementia	12.35 ± 7.89 reps (pre-train); 14.05 ± 6.80 reps (post-train)
Choi et al. [45]	2018	France	60 participants	Evaluate the effects of ground kayak paddling exercise on postural balance, muscle performance, and cognitive function in older persons with mild cognitive impairment.	Chronometer	No	Statistical	Mild cognitive impairment, Dementia, Alzheimer's disease, Spinal cord injury	Ground kayak paddling group: 18.13 ± 3.86 reps (pre-train); 23.70 ± 6.14 reps (post-train) Control group: 19.83 ± 4.49 reps (pre-train); 21.16 ± 6.52 reps (post-train)
Gilli et al. [46]	2018	Italy	86 sedentary older adults	Analyze the viability and efficacy of a semi-structured physical exercise intervention in enhancing older individuals' functional performance and physical fitness.	Pedometer, Chronometer	No	Statistical	Cardiovascular disease	PAAdv: 15.5 ± 3.0 reps (pre-train); 15.3 ± 2.8 reps (post-train) SSPA: 14.1 ± 2.5 reps (pre-train); 16.2 ± 2.8 (post-train)
Baillot et al. [47]	2017	Canada	25 participants	Evaluation of the distinction between responders and non-responders after epidural steroid injection	Accelerometer, Chronometer	No	Statistical	Cardiovascular disease	PreSET group: 19.6 ± 4.3 reps (pre-train); 24.8 ± 4.9 reps (post-train) Usual care group: 22.3 ± 4.1 reps (pre-train); 24.3 ± 6.1 reps (post-train)

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Bentes et al. [48]	2017	USA	40 post-menopausal women	Identify the relationships among muscular function, body composition, vitamin D status, and blood sugar in postmenopausal women with diabetes.	Stadiometer, Chronometer, Octopolar bioimpedance, Dynamometer	No	Statistical	Diabetes, Metabolic syndrome	Significant correlations between blood glucose arm curl test ($R = -0.367$ and $p = 0.020$),
Rojas et al. [49]	2017	Chile	116 subjects	Determine how various physical fitness characteristics affect the multidimensional assessment of quality of life in older persons.	Chronometer	No	Statistical	Chronic disease	Significant correlations between different parameters and arm curl test
Dutra et al. [50]	2016	Brazil	122 woman	The development of specialized vibration platforms allowed researchers to assess how low-intensity vibration affected osteopenic postmenopausal women's neuromuscular function and functional ability.	Dual-energy x-ray absorptiometry, Dynamometer, Vibration platforms, Chronometer	No	Statistical	Osteoporosis, Metabolic syndrome	Placebo group: 15.06 ± 2.28 reps (baseline); 18.50 ± 4.24 reps (12 months) Control group: 16.03 ± 3.84 reps (baseline); 17.42 ± 3.70 reps (12 months)
Aparicio et al. [51]	2015	Spain	487 woman	Find out if a series of physical fitness tests can distinguish between women who have fibromyalgia	Chronometer, tactile-electrode impedanciometer	No	Statistical	Fibromyalgia	Significant correlations between different parameters and arm curl test
Minges et al. [52]	2011	Australia	32 participants	Evaluate a community-based resistance training program's effectiveness.	Chronometer, X-ray DXA (Hologic Discovery Ci, Hologic Inc.)	Yes	Statistical	Chronic disease	17.7 ± 4.9 reps

Table 1 (continued)

Paper	Year	Location	Population	Purpose of study	Sensors used	Include medical collaboration	Type of methods	Diseases	Main results
Lohmann et al. [53]	2010	Denmark	127 patients	Examine whether physical testing and motivational interviewing may be used in primary care settings to encourage physical activity and enhance patient outcomes for those with diabetes.	Chronometer	No	Statistical	Diabetes	5.9 ± 0.30 reps

Table 2 Diseases categories

Neurological and cognitive disorders	Chronic conditions and cancers
Parkinson's disease	Pulmonary disease
Dementia	Chronic disease
Mild cognitive impairment	Cardiovascular disease
Alzheimer's disease	Breast Cancer
Spinal cord injury	Fibromyalgia
	Osteopenia
	Vascular diseases
	Diabetes
	Osteoporosis
	Degenerative rheumatic problems
	Prostate Cancer
	Colorectal Cancer
	Psychiatric disorder
	Systemic diseases
	Musculoskeletal diseases
	Hypertension
	Metabolic syndrome

Data analysis methods included descriptive statistics, chi-square test, one-way ANOVA, and Bonferroni post hoc procedures. The study found significant improvements in hand grip strength, manual dexterity, upper limb fitness, and overall functional performance among participants who underwent physical exercises with dance movement therapy. The individuals performed the arm curl test until exhausted, where the results reported 17.07 ± 3.67 s in pre-train, and 18.28 ± 3.74 s in post-train experiments.

In [44], the authors aimed to evaluate the effects of exercise and nutrition education programs on 23 older adults aged 83.5 ± 4.9 years old. The population included those with changes in exercise function and eating habits. Sensors like a chronometer were used to measure motor function and eating habits. Additional sensor-based assessments may have been employed, but information is not provided. Data analysis was performed using IBM SPSS Statistics software. The study primarily evaluated the effects of exercise and nutrition education programs on mild dementia patients, focusing on improvements in upper limb muscle strength, flexibility, endurance, and nutrition condition. The results showed significant positive changes after the program's implementation, reporting an evolution from 12.35 ± 7.89 repetitions in the pre-train, and 14.05 ± 6.80 repetitions in the post-train.

In [45], a study on 60 participants (11 males and 49 females) was comducted. The participants was distributed from two groups: Ground kayak paddling group, and Control group. The Ground kayak paddling group is composed by 6 males and 24 females aged 74.90 ± 5.10 years old. The Control group is composed by 5 males and 25 females aged 74.23 ± 4.38 years old. The study used a chronometer as the primary equipment. The study employed data analysis methods, including ANOVA tests, to assess the effects of treatment capsules on performance measures. The study focused to determine whether ground kayak paddling exercise can improve postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment. The results in the pre-train revealed 18.13 ± 3.86 repetitions for Ground kayak paddling group, and 19.83 ± 4.49 repetitions for the control group during 30 s. Finally, the results in the post-train revealed 23.70 ± 6.14 repetitions for Ground kayak paddling group, and 21.16 ± 6.52 repetitions for the control group during 30 s.

3.2 Chronic conditions and cancers

In [25], the authors aimed to evaluate the impact of 12 weeks of elastic band resistance training (EBRT) on adropin levels and cardiometabolic risk factors in overweight older women. The study involved 28 women aged 66 to 74 years randomly assigned to either the EBRT or control groups. Data analysis used ANOVA and Pearson correlation coefficient. The study examined serum levels of adropin, TNF-α, hs-CRP, insulin, glucose, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides. Results showed that EBRT significantly increased serum adropin levels, improved physical function, and decreased insulin resistance, inflammation, and body fat percentage in overweight older women. The results reported 16.14 ± 2.44 repetitions for each 30 s.

In [26], the study aimed to assess the impact of a 12-week recreational football intervention on functional movement in older adults. Thirteen males aged 60–80 years underwent the intervention, while another group of 13 males was used as a control. Data was collected using sensors such as bioelectrical impedance analysis, handgrip dynamometer,

and chronometer. The study did not mention collaboration with medical professionals or institutions. Data analysis was performed using repeated-measures ANOVA. The study found significant improvements in functional movement performance and suggested positive effects on body fatness in older adults who underwent the intervention. The intervention group reported 23.5 ± 3.9 repetitions during pre-train, and 23.9 ± 4.2 repetitions during post-train for 30 s, and the control group reported 14.2 ± 2.2 repetitions during pre-train, and 15.3 ± 2.8 repetitions during post-train for 30 s.

In [27], the authors analyzed the effects of combined resistance and aerobic training on physical performance and body composition in patients with coronary arteriosclerosis (CAD) enrolled in phase II cardiac rehabilitation in Australia. The study included 59 participants aged 61–62 years, divided into three groups: aerobic training (AT), low load resistance training (LL-RT), and high load resistance training (HL-RT). Sensors were used to measure various aspects of physical performance, with medical collaboration from nurses and physiotherapists. The results showed that both high-load and low-load resistance training and aerobic training led to similar improvements in physical performance, surpassing those achieved through aerobic exercise alone. The results reported 23 ± 6 repetitions between groups for 30 s.

The authors of [28] used mechanical scales and stadiometers to gather data on morphological variables, physical fitness, and health-related quality of life in physically active older individuals. The study involved 470 participants (421 females and 49 males) aged 63–64 years old. Data analysis methods examined relationships between age, overweight, waist circumference, and poor performance in physical fitness tests, revealing a decrease in health-related quality of life in physically active older people. The results reported 22.51 ± 4.87 repetitions in female individuals, and 23.33 ± 4.35 repetitions in male individuals for 30 s.

The study [30] was conducted with 57 healthy adults (18–35 years old) and 61 older participants (60 + years old) using semi-structured physical activity (SSPA) and physical activity advice (PAAdv) groups. The study used sensors and chronometers to monitor physical activity levels, with other types of sensors possibly employed. The study did not mention any medical collaboration or specific data analysis methods. The results showed that SSPA effectively promoted physical fitness and functional performance in older adults, especially at higher levels (> 500 MET min/week). The results reported 27.7 ± 6.6 repetitions with healthy adults, and 14.7 ± 2.7 repetitions with older adults for 30 s.

The study [31] aimed to assess the effects of ground kayak paddling (GKP) exercise on 22 older adults (10 males and 12 females) with mild cognitive impairment, specifically those aged 74–77 years. The study used a chronometer for time measurements and did not mention other sensors or medical collaboration. Data analysis methods included repeated-measures ANOVA to analyze time, group, and interaction effects. The study primarily evaluated the effects of GKP exercise on postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment. The study reported positive results, indicating significant improvements in postural balance, muscle performance, and cognitive function after the intervention. The results reported 13.2 ± 3.4 repetitions during 30 s at the baseline, and 17.6 ± 5.8 repetitions during 30 s after 6 months.

In [32], the study analyzed data from medical records and wearable devices on 32 woman aged 52–63 years old. Sensors like heart rate, accelerometers, glucose, temperature, and blood pressure were used for specific evaluations. Medical collaboration was crucial, involving healthcare professionals, researchers, and technology experts. Data analysis methods included statistical analysis, machine learning algorithms, and pattern recognition techniques. The study evaluated various diseases and conditions, including cardiovascular disorders, diabetes, and sleep disorders, assessing their impact on overall health. Results showed significant correlations between sensor data and disease progression, enabling a better understanding and management of these health conditions. The results reported 10.44 ± 4.27 repetitions during 30 s.

In [36], the study included 19 healthy middle-aged women aged 52 ± 3 years old, focusing on various health conditions. Data collection involved sensors like heart rate monitors, accelerometers, sleep trackers, blood pressure monitors, and glucose meters. With the collaboration of medical professionals, the research used various data analysis methods, including statistical analysis and machine learning algorithms. Key variables like heart rate variability, physical activity levels, sleep quality, and blood glucose levels were evaluated. The results provided valuable insights into the relationships between lifestyle factors, physiological indicators, and disease outcomes, enabling the development of personalized healthcare interventions. The results reported between 23.3 ± 2.8 and 26.31 ± 2.3 repetitions for 30 s, depending on the level of caffeine consumption.

The authors of [37] aimed to explore the relationship between physical activity and cardiovascular health using data from electronic health records and wearable devices. It included 5 older adults with chronic conditions, using sensors like heart rate monitors, accelerometers, and GPS trackers were used to collect physiological and movement data. Collaborative approaches were employed, involving medical professionals, researchers, and technology experts to ensure data accuracy and reliability. Data analysis methods, such as statistical modeling and machine learning algorithms, were employed to extract meaningful insights. The study found a positive correlation between physical activity and

cardiovascular health, emphasizing the importance of regular exercise in disease prevention and management. The results reported 9.17 ± 6.68 repetitions for 30 s.

The authors of [38] analysed 14 male and 51 female individuals to investigate the effects of water- and land-based combined exercise training programs on hypertensive older adults aged over 60 years. Data extraction was conducted using chronometers, blood pressure monitoring, and electrocardiogram measurements. Medical collaboration was involved, with a physician examining participants' general health status and resting electrocardiogram. Data analysis methods, such as statistical tests and comparisons, were used to assess various parameters, including blood pressure, cardiometabolic variables, functional fitness, and quality of life. Results showed significant improvements in blood pressure, antioxidant activity, oxidative stress, inflammation, muscle strength, aerobic endurance, and quality of life perception. The results reported 20.1 ± 4.32 repetitions for 30 s.

In [39], the authors examined the impact of anthropometric and health indices on the physical fitness of older women in Chile. The Senior Fitness Test assessed 140 women aged 70 ± 5 years, revealing that physical activity levels significantly impact aerobic endurance. Factors like high plasma total cholesterol, supra iliac fold thickness, and increased BMI and LDL-c were linked to lower physical fitness performance. The study also found that c-HDL positively correlated with performance in all tests evaluated in the Senior Fitness Test. These findings suggest that certain anthropometric and health indices can modify the physical fitness of older people and potentially contribute to chronic non-communicable diseases and physical fitness loss. The results reported 21.0 ± 5.64 repetitions for 30 s.

The authors of [40] gathered sensor data from various devices to analyse physical fit of 118 older persons aged between 65 and 76 years old. A weighting machine served as the primary sensor, measuring body weight and enabling BMI calculation. Various sensors measured several metrics, including aerobic capacity, balance, and agility. These sensors allowed for a thorough assessment of many facets of physical fitness in the study group and offered insightful information on the participants' overall level of physical fitness. The results reported 11.7 ± 4.0 repetitions in 59 Nursing Home Residents, and 11.5 ± 4.3 repetitions in 59 Community-Dwelling Older Adults for 30 s.

The authors of [41] found that dietary patterns and physical fitness were linked among older Chinese individuals aged 60–93 years old. The sample analysed was composed by 556 residents (196 men, and 360 women) with three dietary patterns were identified: Western, Vegetarian, and Modern. Men in the fourth quartile of Western were less likely to be classified in the high-level group, while those in the fourth quartile of Vegetarian and Modern patterns were ranked in the high-level group. The study emphasized the importance of adhering to Vegetarian and Modern patterns for maintaining good physical fitness. However, limitations, such as small sample size, uneven distribution, and residual confounding, should be considered when generalizing the results to the broader Chinese elderly population. The results reported 14.6 ± 3.5 repetitions for 30 s in the whole sample.

In [42], the study aimed to assess the effectiveness of a mini-trampoline training program for 40 older women with osteopenia aged 67–72 years, distributed equally in the control and intervention groups. The study used a chronometer to measure time-based parameters, and no other sensors were mentioned. Osteopenia was the main condition evaluated, characterized by muscle mass loss and impaired motor control. The individuals were evaluated in two stages: pre-train, and post-train. The results in the pre-train revealed 15.95 ± 2.93 repetitions for intervention group, and 16.80 ± 3.35 repetitions for the control group during 30 s. Finally, the results in the post-train revealed 21.50 ± 3.62 repetitions for intervention group, and 17.40 ± 3.35 repetitions for the control group during 30 s. Results showed significant improvements in gait speed, static balance, lower limb muscular strength, and fear of falling among participants. However, no significant changes were observed in bone mineral density.

The authors of [43] involved 17 woman with fibromyalgia aged = 51.88 ± 7.30 years, and 19 healthy woman aged 50.95 ± 6.83 years old, who were non-smokers and able to stand up and ambulate independently or with assistive devices. The study used multifrequency bioelectrical impedance analysis to evaluate older adults' muscle loss and orthostatic hypotension. Data analysis was conducted using SPSS version 25, focusing on parameters such as hydration, systolic and diastolic blood pressure, total body water, fluid volume, and strength measures. Results showed that age-related muscle loss was associated with decreased hydration, unstable postural systolic blood pressure, and increased risk of orthostatic hypotension, potentially leading to falls. The results reported 17.00 ± 4.50 repetitions for woman with fibromyalgia, and 23.50 ± 5.50 repetitions for healthy woman for 30 s.

In [46], the study aimed to effects of a semi-structured physical activity (SSPA) intervention including aerobic as well as strength and flexibility exercise in comparison to generic physical activity advice (PAAdv) in healthy older adults. The study was composed by 86 sedentary older adults, where 56 individual (44 females and 12 males) constituted the SSPA group aged 70.1 ± 10.1 years old, and 30 individuals (23 females and 7 males) constituted the PAAdv group aged 72.3 ± 5.2 years old. EEG sensors and chronometers were used to record their activity during the dual-task performance. The

data was analysed with SPSS Statistical Software using ANOVA and statistical tests. The results in the pre-train revealed 15.5 ± 3.0 repetitions for PAAdv group, and 14.1 ± 2.5 repetitions for the SSPA group during 30 s. Finally, the results in the post-train revealed 15.3 ± 2.8 repetitions for PAAdv group, and 16.2 ± 2.8 repetitions for the SSPA group during 30 s.

In [47], the study analyzed data on physical activity, fitness, barriers to physical activity, and quality of life in 25 individuals who underwent bariatric surgery. The participants were distributed in a pre-surgical exercise training (PreSET) group (13 individuals) aged 44.5 ± 8.8 yeas old, and a Usual care group (12 individuals) aged 41.1 ± 10.3 years old. The study used an accelerometer sensor to assess participants' physical activity levels. Medical collaboration was conducted through individual counseling sessions with a dietitian and physical activity specialist and group educational sessions on physical activity, nutrition, and weight management. The data analysis methods used in the study are not specified in the text. The PreSET group showed higher physical activity levels one year after surgery than the usual care group. No significant differences were observed in physical fitness measures, barriers to physical activity, or weight-related quality of life. The results in the pre-train revealed 19.6 ± 4.3 repetitions for PreSET group, and 22.3 ± 4.1 repetitions for the Usual care group during 30 s. Finally, the results in the post-train revealed 24.8 ± 4.9 repetitions for PAAdv group, and 24.3 ± 6.1 repetitions for the Usual care group during 30 s.

A study involving 40 postmenopausal women between 62 and 69 years (62.48 ± 7.67) with Type II Diabetes found positive associations between muscle function, age, lean body mass, and resting metabolic rate [48]. Negative correlations were found between relative strength, weight, body mass index, fat mass, and visceral fat area. Fasting glucose negatively correlated with relative strength, arm curl test, and hip flexion range of motion. No significant correlations were found with serum vitamin D. The study suggests that resistance training may benefit individuals with Type II Diabetes and that serum glucose concentration may be associated with decreased muscle strength and function in older individuals. The results reported a significant correlation between the different parameters analysed.

The authors of [49] examined data extraction from sensors used to evaluate various diseases and conditions in the population. The study involved 116 subjects (47 men and 69 women) from multiple countries and a diverse sample of 72.34 ± 5.8 years old, including healthy individuals and those with chronic illnesses. Sensors included wearable, implantable, and non-invasive devices and electroencephalography and electromyography (EMG) for brain activity and muscle movement. Medical collaboration between specialties was involved, and data analysis methods included machine learning and statistical analysis. The diseases evaluated included cardiovascular disease, diabetes, and respiratory illness, with parameters such as heart, blood, and respiratory rates. The results demonstrated the potential of sensor technology in healthcare, offering valuable insights into the health of individuals and populations.

In [50], the study aimed to gather information on the effects of a 12-week Nordic walking training program on older adults aged 61–67. The participants in ths study are 112 (62 in Placebo group, and 60 in Control group), where the Placebo group is aged 63.2 ± 9.8 years old, and the Control group is aged 62.9 ± 7.9 years old. Data collection involved sensors like dynamometers, X-rays, and chronometers. Additional sensors or equipment were used for specific measurements. The study evaluated parameters related to spinal posture, physical function, back pain, and the strength and endurance of back extensor muscles. Results showed that the Nordic walking training program did not significantly improve spinal posture or back extensor strength and endurance, but showed significant improvements in specific measures of physical function. The results in the Placebo group reported 15.06 ± 2.28 repetitions in the baseline, and 18.50 ± 4.24 repetitions in 12 months. Finally, the results in the Control group reported 16.03 ± 3.84 repetitions in the baseline, and 17.42 ± 3.70 repetitions in 12 months.

The authors of [51] aimed to evaluate the effectiveness of physical fitness tests in identifying fibromyalgia in women. A sample of 487 women with fybromialgia, aged 51.9 ± 8.3 years old, and 250 control group, aged 49.3 ± 9.9 years old, was analyzed. The arm curl test assessed physical fitness, while the revised fibromyalgia impact questionnaire assessed severity and symptoms. Results showed that patients with fibromyalgia performed worse in all fitness tests. Arm curl scores below 20 repetitions were associated with increased odds of fibromyalgia in women aged 35–44 years. The handgrip strength test had the highest odds of fibromyalgia in women aged 55–65 years.

In [52], the study collected waist circumference measurements, body strength, and agility measurements from 32 participants aged between 60 and 89 years old with diabetes. Participants participated in a community-based resistance training program using a chronometer and X-ray DXA sensor for bone density measurement. Medical practitioners approved the study and conducted baseline assessments. Data analysis methods included pooled time series regression, adjusting for age and sex. Results showed significant reductions in waist circumference, strength improvements, and enhanced physical function among participants, reporting the performance of 17.7 ± 4.9 repetitions during 30 s.

In [53], the authors aimed to evaluate the feasibility and effectiveness of fitness consultations in routine care for patients with Type II Diabetes. The study involved 127 patients (73 males, and 53 females) aged 49–59 years old,

using a chronometer to measure physical tests and assess health parameters. Medical collaboration between general practitioners and researchers in primary care units was involved. Data analysis used mixed models to assess the development and changes in various outcome variables. Results showed improvements in VO2max, muscle strength, and HDL-cholesterol levels, indicating the potential benefits of incorporating fitness consultations into diabetes programs in primary care settings. The results reported 5.9 ± 0.30 repetitions during 30 s.

3.3 Diseases not defined

The authors of [24] analyzed data from 100 individuals (33 female and 67 male) aged 67 to 74.8 years old from various demographic backgrounds and age groups using various sensors, including heart rate monitors, accelerometers, and temperature sensors. Collaboration with medical professionals and institutions was crucial for accuracy and reliability. Data analysis methods included statistical analyses, machine learning algorithms, and pattern recognition techniques. The study evaluated various diseases and conditions, including cardiovascular health, sleep disorders, and physical activity levels. The results provided valuable insights into the relationships between sensor data and health outcomes, contributing to advancements in medical understanding and personalized healthcare. The results reported 18.25 ± 0.70 repetitions between groups during 30 s.

In [33], a study analyzed the impact of text messaging on maintaining physical activity levels after cardiac rehabilitation. The study involved 32 patients aged 61–71 years who completed a phase 2 cardiac rehabilitation program and had a mobile phone. A chronometer was used to measure exercise tolerance, and other sensors were not explicitly mentioned. The research was conducted in collaboration with the Cittadella Hospital Rehabilitation Cardiology Unit. Data analysis methods, including statistical analyses, assessed the intervention's effectiveness. Results showed that daily text message reminders significantly improved adhering to physical activity, leading to increased moderate recreational activity, reduced sedentary behavior, improved exercise tolerance, and motivation to continue after cardiac rehabilitation. Regarding the number of repetitions, the participants reported 15.8 ± 4.2 repetitions with the right arm, and 14.3 ± 3.0 repetitions with the left arm.

The authors of [35] compared water-based and land-based exercise among older adults in South Korea, focusing on the durability and effects of these activities on physical fitness and quality of life. The study included 80 older adults aged 65 and above living in the local community. The sensors used in the study included a chronometer for measuring time-related parameters. It demonstrated sustained beneficial effects of water-based exercise on physical activity, quality of life, falls efficacy, and various aspects of physical fitness among older adults in South Korea. The results reported 23.77 ± 4.68 repetitions for 30 s.

4 Discussion

4.1 Interpretation of the results

Regarding the countries of the studies selected according to our inclusion criteria, presented in Fig. 2, the higher ratio of four studies (13.3%) was performed in Italy, three studies for each country (10.0%) were conducted in Austria and the United States of America, two studies for each country (nearly 6.7%) were conducted in Chile, Australia, South Korea, and Spain, and the remaining countries only refer to one study.

Considering the sensors used in the various studies presented in Figs. 3 and 39.6% considered chronometer, 15.1% applied the dynamometer, 11.3% used the stadiometer, 5.7% for each X-rays and accelerometer sensors, and 3.8% for each pedometer, impedanciometer, and EEG sensors. In addition, other residual sensors were used, including biosensors, wearable sensors, ergometers, weighing machines, ergo-spirometer, and goniometers.

Regarding the diseases studied in the various papers presented in Figs. 4 and 17.8% each considered both cardiovascular disease and chronic disease, 6.7% each was applied to both diabetes and fibromyalgia, 4.4% each used were used in dementia, osteoporosis, Parkinson's disease, and vascular diseases. Based on the remaining 15 studies, their conditions were residual.

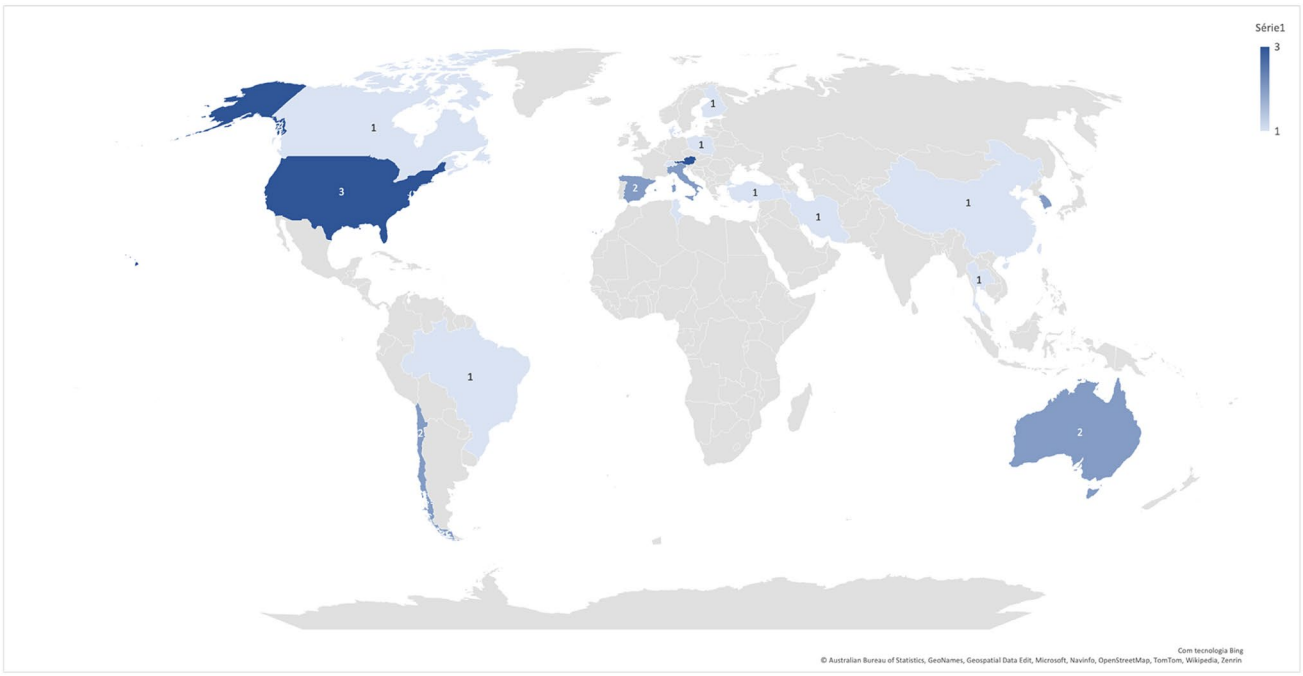

Fig. 2 Relation between the number of studies and countries

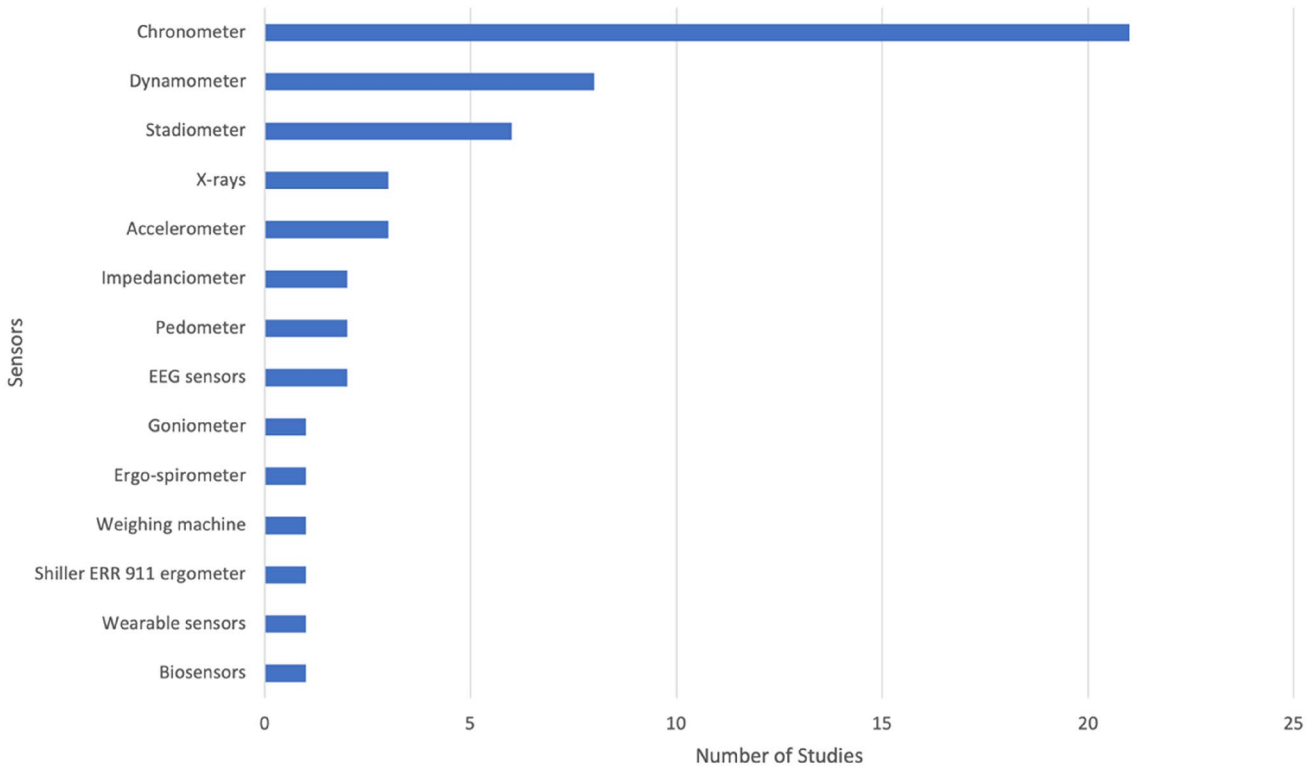

Fig. 3 Relation between sensors and the number of studies

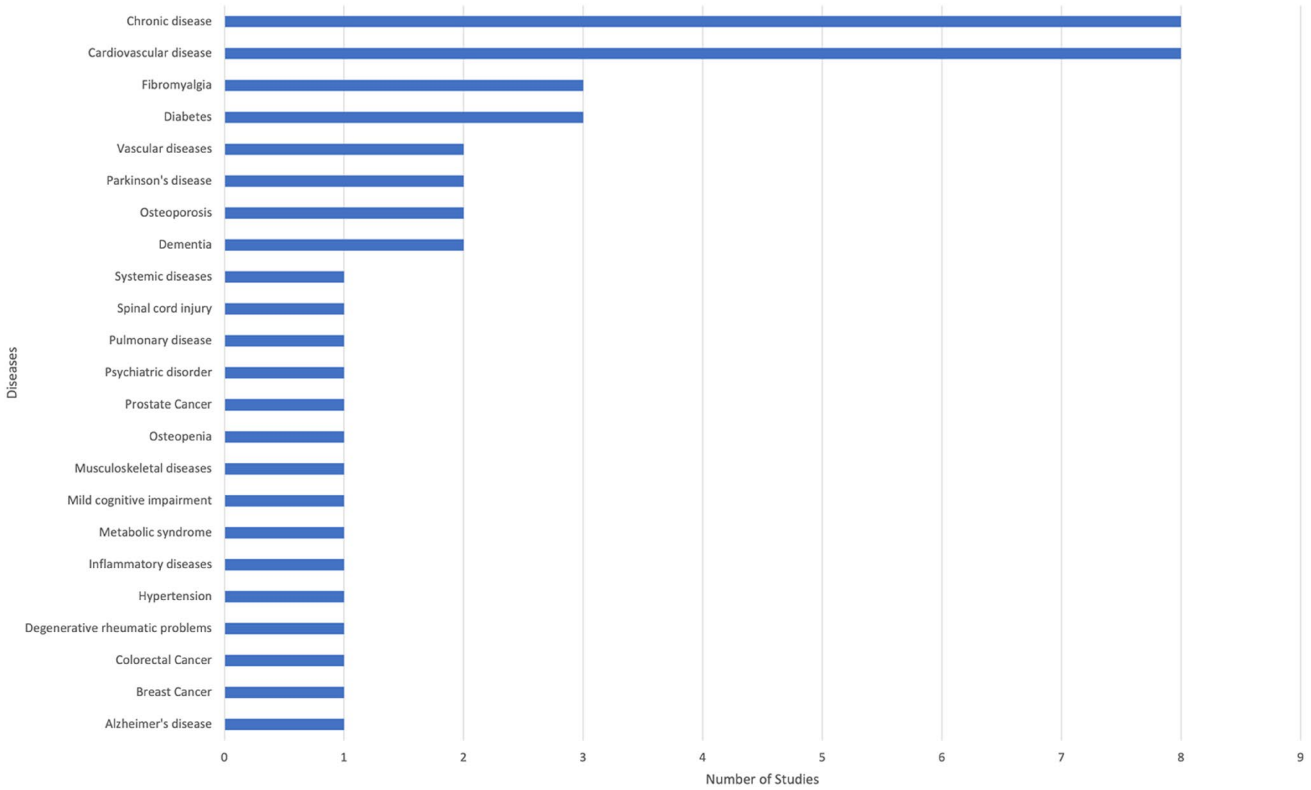

Fig. 4 Relation between diseases and the number of studies

4.2 Comparison of the analyzed studies

Figure 5 presents the confusion matrix between diseases and the methods used in the studies, where it is possible to observe that the most used sensor is the chronometer to perform measurements in cardiovascular and chronic diseases. Stadiometer is also used for cardiovascular disease assessment.

Table 3 summarizes the strengths and drawbacks of each research for comparison. Varied modules or systems are displayed concerning the outcomes and advantages of the investigations, although the diverse authors are considering numerous aims. As a result, a new approach or system based on recent research is encouraged.

Based on the analysis of Table 3, we propose using inertial, time, and force sensors to handle the measurement of the results of the Arm Curl Test, providing reliable insights for the evolution of different diseases with precision. The research also proved that some kinds of involuntary movements can be detected, but it still needs to be explored.

4.3 Limitations

The systematic review compares various studies on the use of sensors in measuring the Arm Curl Test, high-lighting both their strengths and drawbacks. While the review showcases the varied approaches and systems used in these studies, it also emphasizes that the diverse objectives considered by different authors necessitate the devel-opment of new approaches or systems based on recent research.

The different authors reveal several limitations that may impact their findings' reliability, applicability, and generalizability. These include non-probabilistic sampling and cross-sectional design, small sample sizes, lack of control groups and blindness in trials, specificity of populations and interventions, methodological shortcomings, data collection and analysis limitations, long-term effects and follow-up periods, and external factors affecting study design. Non-probabilistic sampling and cross-sectional designs limit external representativeness, while small sample sizes and specific geographical areas limit generalizability. The absence of control groups and blindness in trials also

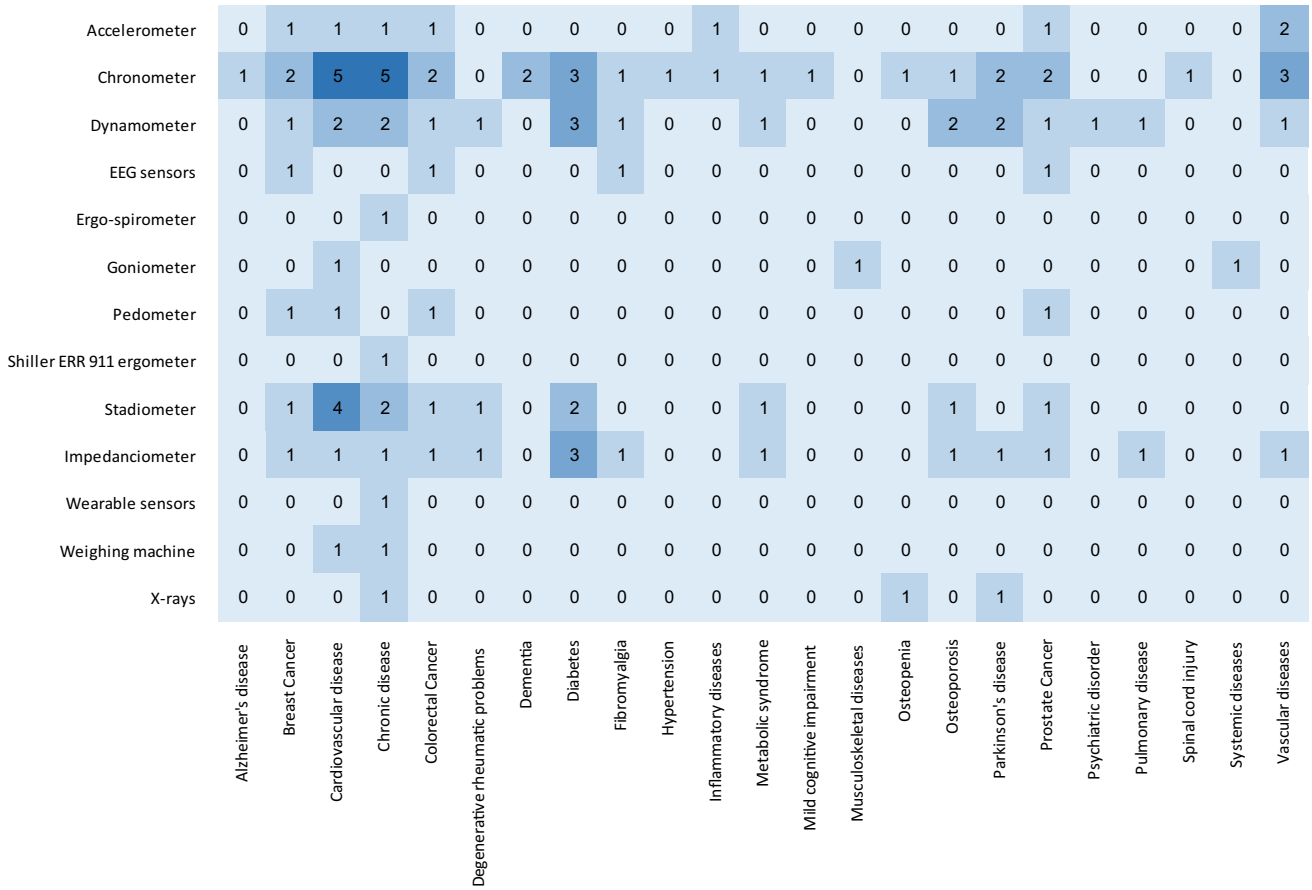

Fig. 5 Confusion matrix between diseases and the methods used in the studies

introduce bias. The specificity of populations and interventions also limits applicability. Methodological shortcomings include a lack of randomized controlled designs and insufficient power analysis. Data collection methods, such as self-reported physical activity measures and analytical approaches, also have limitations. Short follow-up periods and lack of assessment also limit long-term effects and follow-up periods. External factors like the COVID-19 pandemic may affect study design and participant recruitment. Overall, these limitations suggest the need for more extensive, more diverse, and methodologically rigorous studies to understand better the effects of interventions on physical fitness and health outcomes.

This review was only performed in seven scientific databases, and some unpublished work may exist, and the years of studies published for the review can be extended. This systematic review suggests a need for innovation and adaptation in this field, as the existing methods may have limitations or may not fully address the variety of research goals in the area. The research in this field can be an opportunity to create new solutions to improve medical and sports monitoring.

4.4 Final remarks

This systematic review proved that developing an automatic solution for measuring the results of physical ability during the performance of the Arm Curl Test is possible. We aim to develop an integrated system for remote monitoring and prescription of treatments. Sports practitioners perform the arm curl movement, which can help diagnose and monitor different physical diseases. Various sensors are embedded in the users' equipment and can measure and communicate the results to health professionals.

The main findings from the 30 studies identified by this review are as follows. Regarding RQ1, "What types of sensors can be employed to track and measure different approaches to the Arm Curl Test?", the revealed sensors in the literature are more related to motion and inertial sensors, including accelerometer, chronometer, and force platforms. These sensors may help to measure the time, the performed force that is an important factor of the Arm Curl Test, and the acceleration

Table 3 Study's benefits and drawbacks

Study	Results and benefits	Limitations
Concha-Cisternas et al. [39]	Regular dancing can enhance this population's quality of life and aid in maintaining physical function. It assessed the impact of dance programs on the physical function of healthy older persons in randomized control trials.	N/A
Bentes et al. [48]	The physical fitness of elderly women is related to both anthropometric and health indices. This fact implies encouraging actions that support the improvement of physical capacities for the benefit of greater autonomy and functional independence in old age, while also encouraging adequate control and management of the anthropometric and health indices related to the decline in physical fitness.	Although data on physical activity levels were gathered using validated instruments, they could not represent the actual conditions of the participants due to the selection of individuals from a non-probabilistic sampling, which may limit the external representativeness of the study. Since the study is cross-sectional, causation in connections cannot be established.
Rojas et al. [49]	Improved knowledge of the relationships between blood sugar, vitamin D status, muscle function, and body composition in postmenopausal women with type 2 diabetes. Identifying possible risk factors for muscle loss and deterioration in this population may help create focused therapies to enhance muscle function and stop functional decline.	The data was gathered at a single moment in time because the study's methodology is cross-sectional. The constrains of the capacity to determine the direction of the relationships we find and to establish causation between the variables.
Lyu et al. [41]	Designing effective policies and programs to enhance the quality of life for older individuals can be done using the study's findings. Healthcare professionals can create tailored interventions to increase the physical fitness of older persons and, in turn, improve their health-related quality of life by identifying the physical fitness characteristics that are associated with greater health-related quality of life.	The results might not apply to different populations or environments. The SF-12v2 questionnaire was the only one utilized in the study to measure the quality of life in terms of health. The health-related quality of life may have been evaluated using other questionnaires or techniques.
Kambic et al. [27]	The older study participants' physical fitness benefited from the vegetarian and modern patterns, like other diets that have been suggested to be healthy. Examples of such diets include the Mediterranean diet, the Nordic diet, and other healthful diets with a high intake of fish and shellfish, fruit, vegetables, nuts, legumes, whole grains and cereal products, dairy, and a limited intake of red meat and meat products as its commonalities.	The current study's sample size was modest (particularly for men). It was difficult to employ additional age categories because of the tiny size, although age has a significant role in an older person's physical health. All participants were from Shandong Province. Therefore, the results might not represent all Chinese seniors well due to the uneven distribution of urban and rural samples.
Ruangthai et al. [38]	Compared to aerobic exercise alone, the study indicated that combining aerobic exercise with either high-load or low-load resistance training led to comparable increases in physical performance.	The study's relatively small sample size of middle-aged cardiovascular disease patients may restrict the findings' applicability to other populations. Furthermore, the lack of a control group in the study may make it more difficult to draw firm conclusions about the efficacy of the various exercise regimens. Additionally, the kinesiologist who evaluated the results was not blinded in the trial, which could have influenced the findings.
Se Jun Oh et al. [35]	Greater benefits in the cardiometabolic are brought on by aerobic exercise. Muscular strength and improved body composition are the main results of resistance exercise. Therefore, combined exercise can activate the neuromuscular systems.	Despite improvements in arterial stiffness, no statistically significant difference existed between the water-based aerobic training group and the control group who did not exercise, despite multiple reports, how profiles and body fat work is still unknown.
Kazoglu et al. [40]	Due to the buoyancy of the water, there is less strain on the joints and less weight on the body. Movements that are regulated, supervised, or supported using weights or flotation aids. Improved physical fitness, including increased strength, flexibility, and balance.	Since the study was only done in one place, older adults may not be represented in different areas or nations. The findings may not be as generalizable as they may be due to the study's relatively small sample size.

Table 3 (continued)

Study	Results and benefits	Limitations
Ceballos-Laita et al. [32]	The study provides insight into how physically fit older persons who reside in nursing homes and in the community are. The study emphasizes how crucial it is to consider older individuals' living situations when assessing their degree of physical fitness.	Due to a scarcity of space in both houses and nursing homes, applications were made. It would also be more useful to compare the results if the older people's physical activity levels had been assessed.
Posch et al. [42]	The most recent clinical guidelines for treating fibromyalgia syndrome suggest combining therapeutic exercise with patient education. Patients with fibromyalgia syndrome may have improved physical function if pain neurophysiology education is combined with therapeutic exercise. There isn't enough data to determine how therapeutic exercise (aerobic exercise and strengthening) and pain neurophysiology education affect fibromyalgia patients' levels of exhaustion, sleep problems, and physical function.	Because the sample size was determined only by the primary variable, extrapolating the data may be challenging and may affect the outcomes. Because fibromyalgia syndrome affects women more than males, only women were included in the study, making it impossible to apply the findings to men.
Foccardi et al. [33]	The study found that a training intervention program significantly improved gait speed, static balance, lower limb muscular strength, and fear of falling. Using exercises that can be easily replicated in health centers or at home, this multidisciplinary approach was considered an effective tool for enhancing balance, strength, gait performance, and fear of falling. The program's simplicity and high reliability make it an effective tool for improving physical function and quality of life.	The earlier study lacked an a priori power analysis. Despite attempting to reach out to potential participants via various communication methods, a total sample size of 40 females was nonetheless obtained.
Baillot et al. [47]	These greater levels of physical activity and the research intervention's associated good effects on submaximal labor capacity may positively impact everyday activities. According to earlier studies, there haven't been any major modifications.	Future research is required to confirm these results over the long term. It should also explore the effectiveness of sending patients a more tailored SMS message to boost their motivation and exercise adherence. The small sample size may have hampered the study's conclusions, but the findings may show how useful text messaging is for routine medical treatment.
Kim et al. [44]	The study demonstrates improvements in quality of life, self-efficacy, physical activity level, and self-consciousness about engaging in physical activity.	Because of the small sample size and potential underrepresentation of the obese population, it was difficult to identify significant differences between groups on some outcomes. Additionally, the high percentage of individuals who were eliminated because they were unable to attend regular exercise sessions restricts the applicability of our findings and the intervention's potential efficacy.
Aschauer et al. [24]	Nutrition education has led to an improvement in nutritional condition recovery. The study offers fundamental empirical data for patients with mild dementia undergoing exercise and nutritional instruction. After the fitness and nutrition instruction program, there was an improvement in the arm curl test. According to the study, persons with moderate dementia may benefit from regular exercise and knowledge about diet.	Physical composition and conditions, such as weight loss, significantly impact the nutrition and cognitive abilities of older adults with dementia. Regular physical activity and nutrition education for mild dementia patients resulted in increased upper limb muscle strength, flexibility, and endurance. However, this also increased nutrition conditions, which are associated with malnutrition. Although the study did not analyze factors affecting cognitive function, physical function, and nutrition, significant results were observed before and after the program. It is crucial to provide exercise and basic empirical data on dietary life nutrition education for mild dementia patients.
Azamian Jazi et al. [25]	The possibility of increasing muscle strength and stamina in elderly people with low vitamin D levels by resistance training and vitamin D administration. According to the study, both types of vitamin D treatment significantly improved the individuals' health, with the higher-dose supplementing technique having marginally more favorable results.	The findings may not be generalizable due to the study's relatively small sample size of 60 older persons with low vitamin D levels. The study's lengthy intervention period, which lasted 12 weeks, may have affected the outcomes.

Table 3 (continued)

Study	Results and benefits	Limitations
Minges et al. [52]	The training intervention program mentioned in the document helps older women with osteopenia improve their balance, strength, gait performance, and fear of falling. The exercises utilized in the program were simple to repeat in any health and sports facility or at home, and it was extremely effective in enhancing gait speed and static balance.	The study's interpretation is limited by the absence of a randomized controlled study design, which is challenging in community-based programs. This makes it difficult to determine the intervention's true effect. Additionally, the real-life community environment increases the risk of missing data points due to instructors adhering to Lift for Life requirements. Assessments at different time points may also affect measurement precision.
Valdés-Badilla al [28].	The study's strengths include the validated SF-36 questionnaire for assessing older people in Chile, providing reliable information for health professionals. The morphological and physical fitness assessments are simple, making them suitable for older people's physical activity programs. Additionally, these activities are low-cost, making them suitable for large population groups like community health centers or neighborhood associations.	Assessments of neurophysiological mechanisms for flexor-extensor muscle activation in physical fit measurements are limited by sample selection, low male participation, and geographical context, limiting extrapolation to other realities. The study's intention is non-probabilistic, limiting the analysis to association and limiting results to older people.
Lohmann et al. [53]	Despite a high level of comorbidity, the trial indicated that the intervention was safe and well-tolerated, with a dropout rate of 19.6%. Overall, the research points to using physical examinations and motivational interviewing in primary care settings as viable and efficient means of enhancing physical activity and health outcomes in type 2 diabetes patients.	The lack of a control group makes it difficult to tell whether reported improvements in outcomes were brought about by the intervention or by other factors like type 2 diabetes normal progression or participants' growing accustomed to physical testing.
Aparicio et al. [51]	The fitness tests effectively discriminated between fibromyalgia presence and absence in the entire sample and age-specific groups. The AUC ranged from 0.741 to 0.893 for the whole sample, while age-specific analyses showed a 0.793 to 0.910 AUC for women aged 35–44, 0.726 to 0.901 for women aged 45–54, and 0.708 to 0.846 for women aged 55–65.	The study was limited to women due to the small male sample size and insufficient statistical analysis tests for significant effects. Future research should replicate the analysis in larger samples of men with fibromyalgia. Additionally, physical fitness levels differ between groups, making it impossible to merge them.
Waer et al. [36]	Improved cognitive and functional abilities in middle-aged women. Improved functional mobility, cardiovascular endurance, and muscle endurance in women in their middle years.	Only 19 healthy middle-aged women who matched certain inclusion criteria made up the study's modest sample size. The findings might not apply to all middle-aged women as a result. Additionally, the study did not look at the long-term effects or potential negative consequences of caffeine consumption; it simply looked at the immediate effects of caffeine consumption on functional and cognitive performance.
Choi et al. [45]	The study concludes that older persons with mild cognitive impairment benefit physically and mentally from ground kayak paddling (GKP) activity. The study finds that GKP exercise can enhance postural balance, muscle performance, and cognitive function in older persons with mild cognitive impairment.	Most of the individuals in the study were female (80%), and every subject lived in the same neighborhood, which is one of its drawbacks. The Montreal Cognitive Assessment was used to diagnose mild cognitive impairment. As a result, generalizing about older populations with modest cognitive impairment is challenging.
Carmack et al. [31]	Potential advantages of a diet and exercise program based on a pair for cancer patients and their partners. The study shows that interventions benefit cancer survivors and their spouses, with improvements in health-related behaviors and outcomes seen in both the CB and SO groups of survivors.	Because the major objective of the study was to determine whether the lifestyle intervention was feasible, one of its drawbacks was the lack of statistical power to identify differences between groups in outcome measures. Another noteworthy weakness of the study was the presence of numerous secondary outcomes, multiple testing, and potentially false significant differences.

Table 3 (continued)

Study	Results and benefits	Limitations
Benton et al. [29]	The study provides a better knowledge of the connection between muscle loss and orthostatic hypotension, which also sheds light on the potential contribution of muscle loss to the emergence of orthostatic hypotension in older persons. This can aid medical providers in better understanding the illness and creating prevention and treatment plans that are more successful.	The fact that there were only 69 participants in the study may limit how broadly the results may be applied. The use of medications, which might impact orthostatic hypotension in older persons, was not properly controlled for in this investigation.
Villafaina et al. [43]	Women with FM showed no neurophysiological differences between ST and DT. Alpha and beta frequency bands between the healthy and FM groups also showed between-group variations, with lower values of beta and alpha in the FM group.	Since there were only female volunteers, conclusions cannot be extended to FM-affected men. Only larger differences may be significant due to the relatively limited sample size. As a result, findings cannot be generalized, and more research in this area is required.
Gilli et al. [46]	Age-related functional performance and fitness increases have been linked to supervised, center-based exercise programs.	The study excluded a control group due to ethical concerns. Instead, a novel approach was compared to a classic one. Self-reported methods were used to assess physical activity, which may be imprecise for determining the amount and intensity.
Boshnjakua et al. [30]	Younger participants performed significantly better in various tests, including body fat percentage, SMM, ASMM, and self-perceived health. Improvements were observed in CST, PT flexion, AvgP flexion, AvgP extension, SMM, and SMI. These improvements were observed from the test to retest, indicating a significant improvement in overall health.	With a sample size of 61 per group, a 95% one-sided confidence limit with an ICC of 0.80 ensures a lower limit of 0.65 with an 80% assurance probability.
Duncan et al. [26]	Lower body physical endurance, agility, body fatness, and cardiovascular disease all offer advantages.	The study had a small sample size, and more research was needed to understand additional possible effects of participating in an exercise intervention.
Wołoszyn et al. [37]	In contrast to conventional physical activities, DMT has the potential to become a universal activity that can be modified for age and physical constraints, and they can help improve social relationships and mental health. According to the study's findings, DMT significantly impacts the development of upper extremity fitness and overall functional performance.	The study included only seniors using manual wheelchairs, excluding those using electronic wheelchairs. The intervention's homogeneity was limited due to the large number of NHs involved. To counteract this, physiotherapists received multiple trainings and were interchanged between NHs. The authors did not assess long-term effects after 36 weeks, and future studies should schedule sampling points at 6- and 12-month marks.
Huang [34]	According to the study, a 12-week Nordic walking training regimen may enhance balance and upper and lower body strength. The study examined older persons' back pain, physical function, and spinal posture as well, adding to the body of knowledge on how Nordic walking affects these outcomes.	The single-group pretest-posttest study design, which prevented comparison with unassisted walking, is one of the study's shortcomings. The COVID-19 pandemic, which impacted participant willingness to join group fitness programs, was being studied at the time.
Dutra et al. [50]	The decrease in falls, physical harm, and fractures in this high-risk population may be attributed to the improvements in balance, flexibility, and mobility in this study.	One of the study's most significant drawbacks is the absence of a dummy placebo group, which makes it impossible to totally rule out the placebo effect in the treated group.

of the movement. Some of these sensors are embedded in wearable devices that combine all measurements into one piece of equipment. In the minority, other sensors, such as medical and specific platforms, are used.

Concerning RQ2, "Which technological methods can be integrated with the sensor data to measure the Arm Curl Test effectively?", the most used methods are statistical and mathematical methods for the different conversions between measurement units. However, some studies use machine learning to predict health status and movements.

Finally, based on the RQ3, "What are the benefits of automated measuring of the Arm Curl Test for different populations or conditions?", we verified that using sensors can make the measurements more precise. Some involuntary movements can be detected and cannot be seen with the visualization. As Arm Curl Test is a cardio fitness exercise, it revealed the importance of monitoring cardiovascular, physical, and chronic diseases in older adults.

Even though there are multiple systematic reviews related to physiological tests, this is the first comprehensive study focusing on the Arm Curl Test. One study that focuses on grip and arm curl strength is [18], which is not a review study, but rather shows the results from the clinical examination of a few related tests.

5 Conclusions

The sensors and methods used to measure the outcomes of the Arm Curl Test have been thoroughly reviewed in this article. The fact that 30 papers in all were deemed pertinent for the inclusion criteria indicates how appealing a study area this is. In line with this, mobile devices and sensors make the Arm Curl Test performance measurement possible. Additionally, customized mobile applications may allow users to evaluate the test results and detect or measure involuntary movements.

This evaluation highlighted the most popular sensors, current research trends, and techniques that produce the best predictive and analytical performance for continuous Arm Curl Test application measurements. The data presented in this review can be used to create automated systems for measuring the results of the Arm Curl Test. Creating a system for this purpose is urgently needed since aged people's force must be quantified to improve their quality of life.

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Declarations

Conflict of interest This authors declare no conflicts of interest.

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