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Feasibility of high intensity exercise training in people with dementia and Mild Cognitive Impairment: a systematic review

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Abstract

Background The number of people with dementia is around 50 million worldwide and this number is expected to grow in the coming decades. To date, scientific evidence suggests that physical activity is an encouraging aid in slowing down the progression of dementia and has positive effects on many aspects: metabolic, independence in activities of daily living (ADLs), cognitive and muscle strength. However, few studies analyze the feasibility and the effects of high-intensity exercise programs in people with dementia. The aim is to synthesize evidence on the feasibility of high-intensity exercise training (HIET) in people with dementia and/or Mild Cognitive Impairment (MCI) and to evaluate its effects on cognition, physical performance, ADLs, neuropsychiatric symptoms and quality of life.

Methods Clinical trials and RCTs published up to March 2025 were selected through searches in PubMed, Scopus and Google Scholar, using MeSH terms related to dementia and high-intensity physical exercise. Studies involving people with dementia and/or MCI undergoing high-intensity aerobic and/or strength training were included. Methodological quality was assessed using the PEDro scale, and risk of bias was evaluated with the Cochrane RoB 2 tool.

Results 21 studies met inclusion criteria, including participants with dementia and/or MCI. Feasibility was generally supported and the dropout rate was 13% with high adherence to the programs. Regarding effectiveness, HIET showed cognitive improvements in some studies, while others reported no significant effects. Physical performance, such as walking speed and balance, improved, but there were no significant changes in activities of daily living or quality of life.

Conclusions The results of the literature analyzed show that HIET can be proposed to this population, furthermore it benefits on many parameters of interest. It can be concluded that HIET could be taken into consideration for training people with dementia and/or MCI.

Keywords High intensity, Exercise, Dementia

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Introduction

The number of people with dementia worldwide is about 50 million and this number is expected to grow in the coming decades, reaching 150 million by 2050 [1, 2]. The World Health Organization defines dementia as a syndrome involving cognitive decline, which is usually chronic and progressive in nature. Dementia consists in impairments at several higher cortical functions, such as memory, thinking, understanding, calculation, learning, language and judgment [3]. This condition should be considered as a syndrome, with multiple possible causes, rather than a specific disease and over the time leads to severe cognitive degeneration, together with the worsening of physical functions and loss of independence [4, 5]. Cognitive decline in individuals with dementia is frequently accompanied by physical and functional impairments [3]. According to the ICD-11, dementia is characterized by a marked decline in two or more cognitive domains representing a deterioration from previous functioning and sufficiently severe to interfere with independence in ADLs, with possible associated neurobehavioural changes [6]. Gait disturbances are also common in this population, leading to an increased risk of falls, reduced mobility, and a higher likelihood of hospitalization [7]. Additionally, a decline in cardiorespiratory fitness is frequently observed in people with dementia and has been associated with greater disease severity, accelerated progression and brain atrophy [8]. Growing evidence supports the role of PA as a non-pharmacological intervention that may help slow symptom progression and enhance physical function in individuals with dementia [9].

The beneficial effects of PA on physical parameters—such as strength, balance, mobility, and fatigue resistance—as well as on cognitive function and the ability to perform ADLs, have been well-documented in individuals with dementia [10]. The ACSM emphasizes the importance of regular PA in this population and provides guidelines for exercise prescription accordingly [11].

While the majority of studies have focused on low- to moderate-intensity exercise interventions [12], fewer have explored the impact of high-intensity exercise. HIET represents a relatively recent approach within clinical populations and is gaining attention for its potential benefits. In healthy older adults, HIET has been shown to improve both muscular strength and aerobic capacity. Additionally, HIET has demonstrated superior effects on muscle hypertrophy, including increases in muscle mass and CSA, compared to lower-intensity training protocols [13, 14]. In terms of cardiovascular health, evidence suggests that HIET may confer greater improvements than low- or moderate-intensity aerobic exercise [15].

Despite the potential benefits of HIET, several barriers may limit its feasibility in individuals with dementia [16]. High-intensity activities can pose notable risks for this population due to the motor impairments commonly associated with the condition, which increase the likelihood of falls and injuries. Furthermore, individuals with advanced cognitive or physical impairments may require substantial assistance during exercise sessions, limiting their capacity to participate independently [16].

Accurately determining appropriate exercise intensity in this group can be particularly challenging, given the variability in physical capacity, fluctuating health status and the high prevalence of comorbidities such as depression, heart failure and osteoporosis [1, 2, 16]. These factors may elevate the risk of adverse events during high-intensity interventions. Additionally, cognitive impairments often hinder the ability to follow complex instructions or adhere to exercise protocols, further complicating the implementation and safety of HIET in this population [7]. In this review, studies including individuals with a diagnosis of dementia as well as those enrolling participants with MCI were considered, given that MCI is frequently included in exercise trials [12, 17] and represents a clinically relevant condition along the cognitive impairment continuum [17]. The rationale for this review is based on evidence suggesting that HIET can induce greater physiological adaptations and improvements in physical performance compared with lower-intensity exercise when appropriately prescribed and supervised in other adult and clinical populations [13–15]. However, its feasibility and safety in people with dementia and/or MCI remain unclear, highlighting the need for a systematic evaluation.

Accordingly, this systematic review aims to synthesize the available evidence on the feasibility of HIET in people with dementia and/or MCI and to evaluate its effects on cognition, physical performance, ADLs, neuropsychiatric symptoms and quality of life, with the hypothesis that appropriately prescribed and supervised HIET may be feasible and associated with favorable effects across these clinically relevant domains.

Methods

Eligibility criteria

An article was included if it met the following inclusion criteria: type of population, type of intervention and outcomes. The target population was people with dementia, this included people with AD, MCI, dementia caused by Parkinson's Disease and Lewy bodies. The other inclusion term was the type of training, which should consist of high-intensity aerobic or strength training or combined aerobic and strength

training. Referring to the ACSM exercise guidelines [11], vigorous activity corresponds to exercise carried out at 60–89% of HRR or 77–95% of HRmax; for strength activity instead, it is defined as vigorous activity at 70–84% of the 1RM. The last inclusion criteria were physical performance, cognition, metabolic functioning and psychological symptoms. All these aspects had to be measured with validated measurement tests. For these reasons, studies that did not meet the requirement for population type, exercise intervention and measured variables were excluded.

Information sources

Conforming to PRISMA guidelines [18] and to identify studies of interest to this review, electronic databases were autonomously searched by the researchers from 1995 until February 2023. Another update of research was made from February 2023 until March 2025. The following electronic databases were selected: PubMed, Scopus and Google Scholar.

Search strategy

The search was conducted on MeSH terms which included the area of dementia and/or MCI and high intensity strength and/or aerobic exercise. Table 1 lists the keywords and search terms of the articles. Boolean operators (AND, OR, NOT) were used to combine search terms with related keywords. If the search terms were incomplete, an additional search was run using the modified search terms.

The search was created by associating the search terms related to pathology with those related to the type of physical exercise. Therefore, the search string was the following: ((dementia) OR (Alzheimer's Disease)) OR (Mild Cognitive Impairment) AND ((high intensity training) OR (high intensity physical training) OR (high intensity physical exercise) OR (high intensity exercise) OR (maximal strength training)).

Duplicate records were removed prior to screening. Searches were limited to articles published in English and to original clinical studies, including clinical trials and randomized controlled trials. Reviews, systematic reviews, and book chapters were excluded. No restrictions were applied based on geographic location, race, or sex of the study population. Only studies conducted in humans were considered. Articles published up to March 2025 were included.

Table 1 List of keywords and synonyms generated as search terms

Condition	Physical activity intervention
Dementia	High intensity training
Alzheimer's disease	High intensity physical training
Mild Cognitive Impairment	High intensity physical exercise
	High intensity exercise
	Maximal strenght training

Selection and data collection process

Titles and abstracts identified through the database searches were independently screened by two authors (C.B. and A.P.) to assess potential eligibility. Studies that clearly did not meet the inclusion criteria were excluded at this stage. Any disagreements during the title and abstract screening phase were resolved through discussion and when consensus could not be reached, a third researcher (M.V.) was consulted. Subsequently, in the full-text review phase, two authors (C.B. and A.P.) independently evaluated the full-text articles of potentially eligible studies. In this phase, disagreements were resolved after discussion with a third researcher (M.V.). The screening process was conducted manually using Rayyan software (Rayyan Systems Inc., Qatar), and no automation tools were used. In the second phase, data extraction was performed independently by the same two reviewers. The variables collected for which data were sought were: article title, year of publication, geographical setting, total sample size, type of dementia and/or MCI, pharmacological therapy (if reported), inclusion criteria, mean age and MMSE of the experimental and control groups, type of activity performed by both groups, measurements and tests used, program duration, main results (both positive and negative), dropout rate and reasons for dropout in the experimental group, and study conclusions. A positive result did not necessarily indicate statistical significance; in such cases, this was explicitly noted. Gaps in knowledge emerging from the studies were also recorded. The coding of the articles was done using Microsoft Excel.

Quality of paper

The methodological quality of the included studies was evaluated using the PEDro scale [19, 20]. The PEDro scale consists of 11 items, of which 10 contribute to the final score (the first item, which assesses external validity through specification of eligibility criteria, is not included in the total score). Each of the 10 scored items contributes one point, resulting in a total score ranging from 0 to 10. Higher scores indicate better methodological quality and internal validity. The items assess whether the study: (1) specified eligibility criteria; (2) subjects randomly allocated to groups; (3) concealed allocation; (4) ensured baseline comparability of groups; (5) blinded all subjects; (6) blinded therapists administering the intervention; (7) blinded assessors measuring key outcomes; (8) obtained outcome measures from more than 85% of initially allocated participants; (9) analyzed data using intention-to-treat or ensured compliance with allocation; (10) reported between-group statistical comparisons for

at least one key outcome; and (11) provided both point estimates and measures of variability for at least one key outcome. In line with commonly accepted thresholds in the literature [21], studies with a PEDro score of 9–10 were considered to have excellent methodological quality, those scoring 6–8 were rated as good quality, scores of 4–5 indicated fair quality and scores below 4 were considered to reflect poor methodological quality. No automation tools were used in this process.

Study risk of bias assessment

The risk of bias of the included studies was assessed using the RoB 2 [22]. RoB 2 is a domain-based evaluation tool that considers five key domains of bias: 1) bias arising from the randomization process, 2) bias due to deviations from intended intervention, 3) bias due to missing outcome data, 4) bias in measurement of the outcome, and 5) bias in selection of the reported result. Each domain is judged as "low risk of bias," "some concerns," or "high risk of bias," and an overall risk of bias judgment is derived accordingly for each outcome. Two reviewers independently assessed each study using the RoB 2 tool. Discrepancies were resolved through discussion and consensus. No automation tools were used in the assessment process.

Effect measures

For each included study, the effect measures used to report outcomes were extracted as presented by the original authors. Continuous outcomes (e.g., cognitive and physical performance scores) were generally expressed as mean values with standard deviations or mean differences between intervention and control groups. When available, studies also reported percentage changes from baseline and corresponding p-values for statistical significance. Dichotomous outcomes (e.g., dropout rates, presence of adverse events) were described using proportions or percentages. As this review did not perform a quantitative synthesis (meta-analysis), the results were narratively summarized, emphasizing direction and magnitude of effects rather than pooled estimates.

Synthesis methods

All studies that met the inclusion criteria were grouped and analyzed according to the main domains of interest: feasibility, cognitive, psychological and neuropsychiatric outcomes, ADLs, physical performance and quality of life. During the selection phase, studies were assessed for eligibility and subsequently organized into descriptive tables summarizing intervention type, participant characteristics, outcome measures and key findings.

Data were extracted exactly as reported in the original publications; no statistical conversions, transformations, or imputations were performed. Results were presented narratively and, when available, accompanied by the effect estimates provided by the authors (e.g., mean differences, percentage changes, or p-values).

Given the heterogeneity in study design, intervention type and outcome measures, no quantitative synthesis or meta-analysis was conducted. Instead, a descriptive comparison across studies was used to highlight consistent trends and discrepancies. The synthesis emphasized direction and magnitude of effects rather than pooled effect sizes. Exploration of statistical heterogeneity or subgroup analysis was not applicable to this review.

Reporting bias assessment and certainty of evidence

No formal statistical assessment of reporting bias (e.g., funnel plot analysis) was conducted, as no meta-analysis was performed. However, potential reporting bias was considered qualitatively during the review process by examining whether all pre-specified outcomes were reported in the included studies and by assessing selective outcome reporting within the risk of bias evaluation (RoB 2 tool). Any missing or selectively reported results were described narratively where identified.

A formal assessment of the certainty of evidence (e.g., using the GRADE approach) was not performed, as no quantitative synthesis was conducted. However, the overall confidence in the body of evidence for each outcome was qualitatively appraised based on study quality (PEDro scores), risk of bias (RoB 2 results), and consistency of findings across studies.

Results

Study selection

A comprehensive search was conducted across three databases—PubMed, Scopus, and ScienceDirect—yielding a total of 1312 results. By applying filters related to the type of publication (specifically clinical trials and randomized controlled trials) and restricting the selection to human studies, 241 articles were initially selected. A further analysis based on predefined inclusion and exclusion criteria and after removing duplicates, led to the selection of 24 studies considered eligible for full-text review. Additionally, two more relevant articles were identified through reference list screening. Five studies were excluded as they only reported the description of the intervention protocol without presenting results or conclusions. As illustrated in the PRISMA flow diagram (Fig. 1), a total of 21 articles met the inclusion criteria and were included in this review.

Study and subjects' characteristics

The total subjects included in the sample were 2560 and located internationally [UK 5% (494 subjects, 1 paper), Netherlands 5% (91 subjects, 1 paper), Australia 18% (309 subjects, 4 papers), Italy 5% (39 subjects, 1 paper),

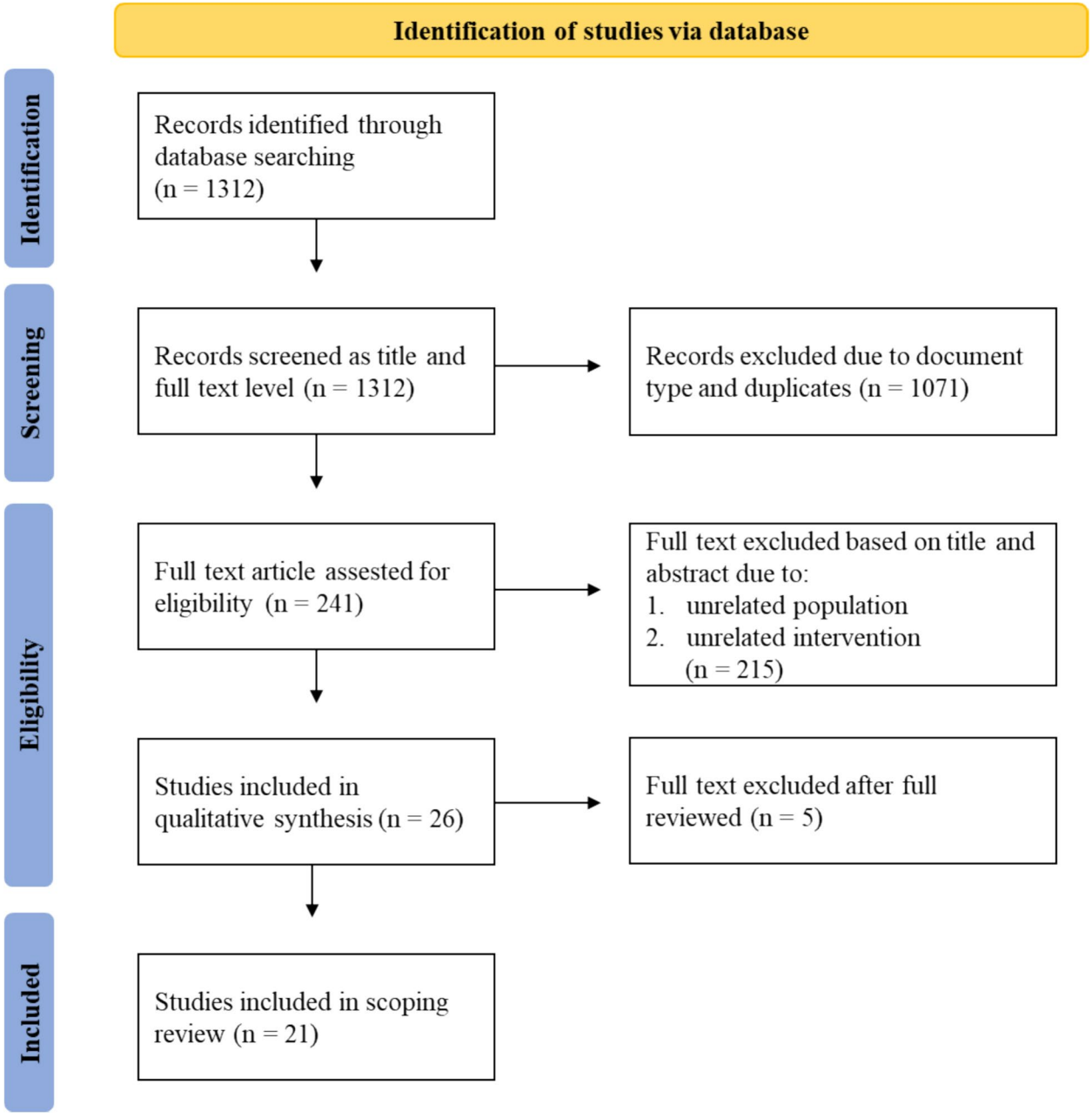

Fig. 1 Prisma flow chart of the studies analysed

Germany 5% (61 subjects, 1 paper), Sweden 18% (754 subjects, 4 papers), Norway 9% (170 subjects, 1 papers), USA 5% (33 subjects, 1 paper), Denmark 27% (577 subjects, 6 papers), Lebanon 5% (68 subjects, 1 paper)]. Sixteen studies [5, 16, 23–37] investigated the elderly population with dementia or Alzheimer's disease, 4 articles [31, 36, 38, 39] studied people with MCI, and 1 article [30] studied people with dementia caused by Parkinson's disease and Lewy bodies. The mean age of the subjects was 75.8 ± 6.8 years. The year of publication ranged from 2009 to 2025. The studies object of this review had as objective the analysis of the effects of HIET, be it aerobic, strength or a combination of the two, on physical and/or cognitive aspects.

Most studies, 15 in total [16, 23–26, 28–34, 40, 41], had as inclusion criteria the confirmed diagnosis of dementia, a MMSE score > 10 according to the classification by Folstein et al. [42] and stable pharmacological therapy for dementia for at least 3 months. Other widely used inclusion criteria were the ability to perform the TUG with or without assistance, the absence of unstable medical conditions and having contact with at least one caregiver.

As regards the pharmacological therapy taken by users, 10 studies [23, 25, 27, 31, 33, 34, 38, 39, 43, 44] did not

declare the drugs used by the subjects, while other 9 studies [16, 24, 26, 28, 29, 32, 33, 35] reported the classes of drugs taken (mainly benzodiazepines, antipsychotics, anticoagulants, neuroleptics, analgesics, diuretics, beta-blockers, dementia drugs). One study [30] reported the names of specific dementia medications that subjects were taking.

Quality of studies

The methodological quality of the included randomized controlled trials was assessed using the PEDro scale. Of the 21 included studies, 1 study [33] scored 4 points, indicating poor methodological quality; 4 studies [29, 30, 34, 38] scored 5 points; 5 studies [23–25, 40, 43] scored 6 points; 6 studies [26, 28, 30, 31, 35, 39] scored 7 points; and 5 studies [5, 16, 28, 32, 44] scored 8 points. Detailed PEDro scores for each study are presented in Table 2.

Risk of bias in studies

The risk of bias for each included randomized controlled trial was assessed using the RoB 2 tool. Figure 2 presents a traffic light plot summarizing risk of bias judgments across the five RoB 2 domains for each individual study. Among the 21 included studies, 3 studies [25, 26, 31] were judged to be at low overall risk of bias, 10 studies [5, 24, 28, 29, 32, 33, 35, 36, 39, 40] were considered to have some concerns (moderate risk), and 8 studies [16, 23, 30, 31, 33, 34, 38] were rated as being at high risk of bias. The domains most frequently rated as having a high risk or some concerns were "bias due to deviations from intended interventions" and "bias in selection of the reported result." In contrast, "bias arising from the randomization process" and "bias due to missing outcome data" were most often judged as low risk across studies.

Table 2 Quality of studies score via PEDro Scale**.** Summary of methodological quality based on the PEDro scale. The table shows the PEDro score for each included study (out of 10), with higher scores indicating greater methodological rigor

Study	PeDRO Score
Lamb et al. (2018) [23]	8/10
Sanders et al. (2020) [24]	6/10
Broadhouse et al. (2020) [44]	5/10
Fiatarone Singh et al. (2014) [25]	7/10
Pedrinolla et al. (2020) [5]	6/10
Schwenk et al. (2014) [26]	6/10
Inskip et al. (2022) [27]	5/10
Mavros et al. (2017) [45]	7/10
Littbrand et al. (2009) [28]	8/10
Hoffmann et al. (2017) [39]	7/10
Van der Kleij et al. (2017) [46]	6/10
Sobol et al. (2018) [30]	7/10
Baker et al. (2010) [43]	6/10
Sondell et al. (2018) [32]	5/10
Sobol et al. (2016) [31]	7/10
Telenius et al., (2015) [33]	8/10
Conradsson et al. (2010) [38]	8/10
Toots et al. (2016) [34]	8/10
Frederiksen et al. (2019) [36]	5/10
Frederiksen et al. (2014) [35]	4/10
Abbas et al. (2023) [47]	7/10

Characteristics of the interventions

Duration

The mean duration of the experimental protocols was 17 ± 5.2 weeks. Most studies proposed an intervention length of 3 to 4 months, 6 studies [23, 24, 31, 39, 43] instead proposed 6 months of training and only one study [30] proposed an 8-week intervention. More specifically regarding training frequency, 3 studies [16, 31, 45] proposed a training protocol of 2 times a week, 7 studies [5, 29, 31, 32, 38, 39, 47] of 2/3 times a week (for a total of 5 sessions in two weeks), 10 studies [23, 24, 28, 30, 33–35, 40, 48] of 3 times per week, and one study [36] of 4 sessions per week.

Training protocols

All the studies proposed HIET protocols involving aerobic, strength, or a combination of the two. Therefore, regarding the protocol of the experimental group, 4 studies [16, 23, 35, 49] analyzed combined aerobic and strength training, 6 [30, 33, 34, 37, 40, 43] analyzed only aerobic training, 2 [38, 39] analyzed strength training combined with cognitive training, and 9 [5, 25, 26, 29, 30, 32, 38, 39, 47] analyzed the effects of strength training alone. As regards the studies that analyzed aerobic activity only, 4 studies [33, 34, 40, 43] proposed interval training, while the other 3 [30, 33, 34, 37, 40, 43] proposed continuous activity on a cardio equipment (treadmill, cycle ergometer, arm ergometer). 70% of HRmax or 60% of heart rate reserve was chosen as the starting point for high intensity. The mean aerobic exercise intensity was 79.5% of HRmax (range 70%–89%). Regarding strength activity the average intensity was 81% 1RM (range 70%–92%). More specifically regarding the type of activity proposed, to conduct the aerobic activity, exercise was done with a cycle ergometer, arm ergometer, cross trainer, treadmill and, in a single case, walking in the open air. As regards strength activity, isotonic machines were used, such as leg press, chest press, lat-machine, leg extension, leg curl, etc. In relation to free body activities and functional exercises, weight bearing exercises and exercises with overloads that reproduce the activities of everyday life have generally been chosen (for example: trunk twisting, climbing steps, chairs stand, etc.).

Control groups performed the following activities: 6 articles [16, 26, 28, 34, 40] reported the usual assistance of the subjects, others 6 [5, 23, 31, 32, 47, 50] the performance of sitting/recreational activities, 4 studies [25, 31,

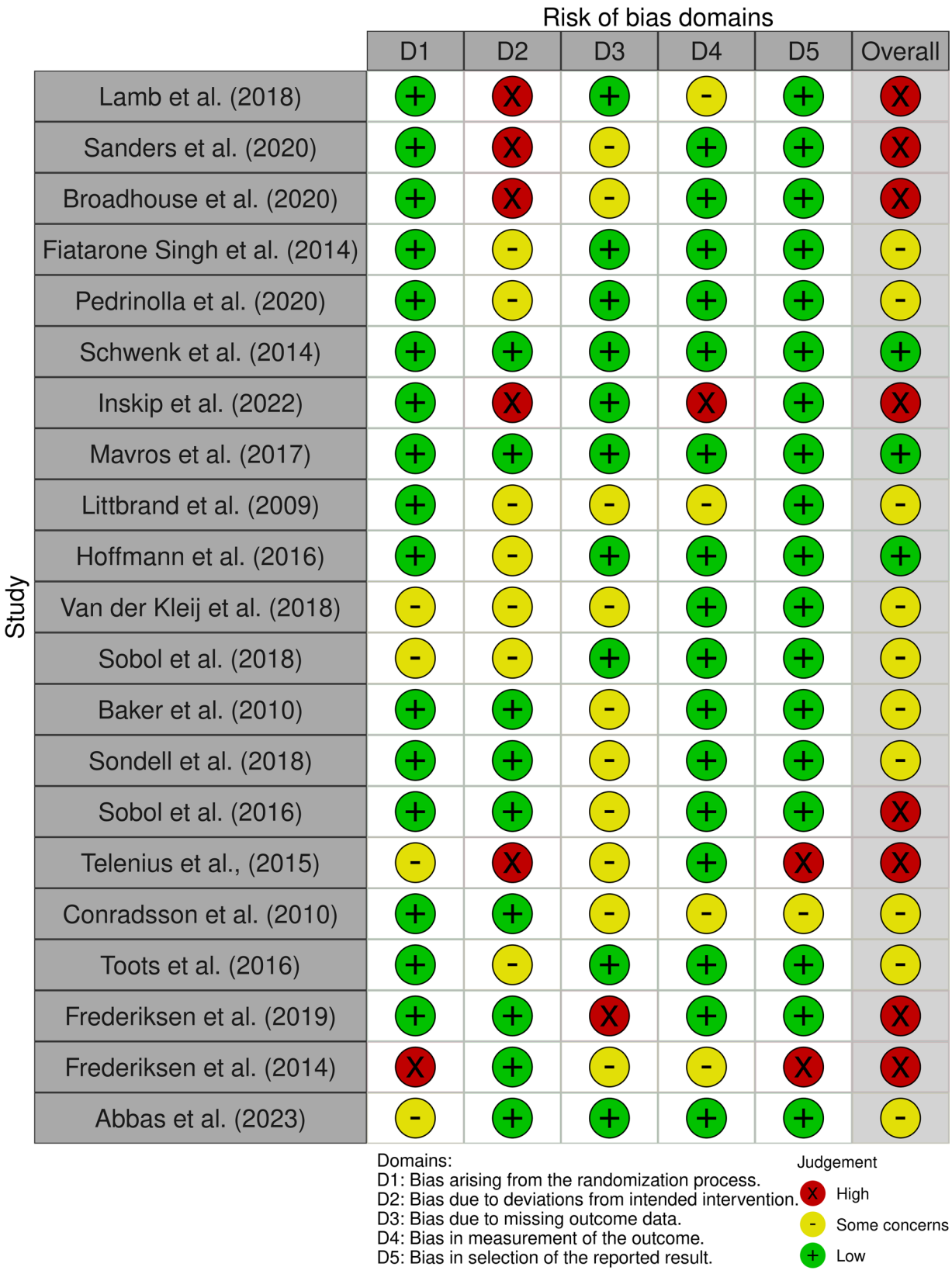

Fig. 2 Risk of bias assessment via Rob2 tool**.** Graphical representation of the risk of bias for each included study, assessed across five domains using the RoB 2.0 tool. Judgments are color-coded: green (low risk), yellow (some concerns) and red (high risk). The final column shows the overall risk of bias for each study

38, 39] reported placebo physical and cognitive activity, 2 studies reported stretching and mobility, and 1 study [24] reported regular cognitive therapy. In two studies the control group was not included. One study [35] reported that the control group performed separately the physical activity components proposed in combination with the intervention group.

Assessments and endpoints

In this section, the assessment and the related results of the areas of interest investigated will be described point by point.

Feasibility

The main research question of this review concerns the feasibility of HIET in people with dementia and/or MCI. The feasibility was based on several aspects. The inclusion/exclusion criteria and the comorbidities of the subjects, the dropout rate, the reasons for abandoning the program and the percentages of screened individuals included in the studies, as well as the adherence/session attendance to the program were analyzed. Furthermore, to determine the feasibility and applicability of the exercise, the execution of a CPET before starting the exercise program was also taken into consideration.

Overall, all studies proposed inclusion/exclusion criteria for exercise programs. Regarding dropout rate, all studies reported dropout rate. Regarding the analysis of comorbidities, 11 studies [5, 16, 24, 28, 31, 32, 34, 36, 40, 47] listed the concomitant pathologies to dementia and/or MCI of the subjects included in the program.

About CPET in the phases of subject evaluations, 5 studies [27, 28, 33, 36, 38] have included CPET among the evaluation tests.

The most reported exclusion criteria were: MMSE < 10 points in 9 studies [5, 16, 23, 24, 28, 31, 34, 38, 47], unstable or acute concomitant pathologies in 10 studies [16, 25, 26, 31, 32, 35, 39, 43, 51], chronological age < 55 years in 8 [26–28, 30–32, 38, 39] studies, inability to getting up from a chair in 6 studies [5, 26, 29, 32, 34, 47] and changes in pharmacological therapy in the last 3 months in 6 studies [27, 28, 31, 33, 35, 46].

The comorbidities of people with dementia and/or MCI involved in the studies were analyzed. About comorbidities analysis, what emerged was that individuals with joint disorders (arthritis, muscle pain, limited range of motion), mental diseases (depression, delusions, apoplexy) and organic/metabolic diseases (diabetes, cardiovascular diseases, lung diseases, oncological diseases) were included. However, individuals with these conditions were included only if these conditions were in a chronic phase and stable. Individuals with these conditions were excluded if they were not stable or had recent acute events.

Analyzing the dropout rate, all 21 studies analyzed reported subject dropouts; specifically, the dropout rate ranged from 0 to 28%, with an average of 12.8 ± 8.1% dropouts. Overall, when analyzing the causes of dropout in detail, 3 [16, 23, 34] studies mentioned withdrawal of study consent, 10 studies [23, 25, 26, 28, 30, 31, 33, 36, 39] reported participant health deterioration/disease development during the treatment period, 2 studies [31, 34] reported participant transfer at other facilities/returning home, 4 studies [25, 36, 39, 52] reported subjects' lack of motivation and refusal to participate in the protocol, while 9 studies [16, 23, 25, 31–33, 35, 47, 53] cited the death of the subjects among the reasons of drop the trial. However, 2 studies [34, 38] did not report the causes of dropouts. In general, all studies have specified that the causes of the dropout of the participants were not directly due to exercise, only one study reports that it cannot exclude the direct causality between exercise and death of a participant.

With regard to adherence to the exercise intervention, 17 [16, 23–25, 28, 30–35, 39, 47, 48, 51, 53] out of 21 studies (81%) explicitly reported quantitative adherence data. Adherence was described using different metrics, including session attendance, percentage of sessions completed, mean number of sessions attended, or predefined attendance thresholds. Specifically, the mean reported adherence as the percentage of sessions attended, with values ranging from approximately 54% to 100% of scheduled sessions. 7 studies [31–33, 37, 47, 51, 54] (33%) documented attendance rates ≥ 70%, and 5 studies [24, 25, 28, 34, 35] (24%) reported adherence values exceeding 85–90%.

When examining the relationship between screened, randomized and completed participants, approximately 40% of people who were screened initially were then randomized into groups. Among these subjects, 84% then finished the experimental trial.

Also, performing CPET in the initial evaluation phase was considered. Only 5 studies [27, 28, 33, 36, 38] proposed the CPET. About the use of CPET before starting training, it is very important to underline that none of the studies has performed it as a screening test, but only to evaluate the maximum oxygen consumption.

Exercise intensity prescription varied across the included studies. As mentioned earlier, baseline CPET test was performed in five studies; however, only two of these trials used the results of maximal testing to directly prescribe exercise intensity. In the remaining studies, CPET, when performed, was used exclusively as an outcome measure rather than as a prerequisite for participation or for intensity prescription. Overall, the majority of studies regulated exercise intensity using alternative and pragmatic approaches. Specifically, exercise intensity was prescribed and monitored through heart rate–based

targets in 9 studies [23, 24, 26–28, 30, 33, 34, 36], perceived exertion scales in 5 studies [16, 23, 24, 28, 30], repetition maximum–based resistance training in 11 studies [5, 24, 25, 30–32, 35, 38, 47, 50]. These methods were often used in combination and allowed for individualized adjustment of exercise intensity throughout the intervention period. All feasibility parameters are listed in Table 3.

Cognitive function, psychological and neuropsychiatric aspects

In many studies, one of the main focuses was the analysis of cognitive aspects. Regarding the tests to evaluate the cognitive component, 16 studies [16, 23, 26, 28, 30–35, 38–40, 50] included, in their measures, the ADAS-Cog and/or the NPI and/or the MMSE. Other main validated neuropsychological scales used were: Cornell Depression Scale in 1 study [31], and SDMT in 6 studies [26, 28, 30, 33, 36, 39]. Instead, for the care burden assessment, 6 studies [16, 26, 28–31] included the ZBI and/or NPI in their measures.

From a cognitive point of view, most studies reported significant improvements: 6 studies [16, 30, 31, 36, 39] that analyzed cognitive aspects reported positive changes in global cognitive function, 4 studies [26, 31, 39, 52] reported changes in non-cognitive symptoms related to dementia, and 2 studies [30, 36] reported greater motivation and perception of self-efficacy to participate in activities; 4 studies [23, 33, 35, 40], on the other hand, showed that the intervention with high-intensity activity did not have significant cognitive effects.

Independence and activities of daily living

Regarding activities of daily living, 8 studies [5, 16, 26, 29, 31, 33, 34, 47] included assessment of ADLs and/or BADL and/or the IADLs and/or the FIM and/or the BI.

Overall, the articles analyzed have shown that HIET exercise does not lead to benefits in the activities of daily living. Only 1 [31] studies that analyzed ADLs reported an increase in the BI, while the others reported no significant changes [5, 16, 26, 29, 33, 34, 47].

Table 3 List of feasibility parameters

Feasibility parameters
Inclusion/exclusion criteria
Admitted comorbidities
Dropout rate
Dropout cause
Adherence/attendance to the HIET
% screened subject included in the HIET
CPET performance

Physical performance

With regard to physical performance tests, the most used were the 6MWT which was reported in 3 [16, 23, 24] studies, 3 studies [25, 31, 38] referred maximal strength tests to the various muscle groups, 4 studies [23, 28, 34, 35] used TUG, 8 studies [28, 30, 31, 33, 34, 38, 40, 43] used VO_2peak/VO_2max, 7 studies [29–33, 35, 47] used tandem test/BBS/static balance and 3 studies [23, 30, 33] reported Short Physical Performance Battery (SPPB).

The main aspects that significantly improved in the physical performance part were walking speed and other parameters related to pace, strength, cardiorespiratory fitness and balance. More specifically, 2 studies [16, 24] that analyzed physical parameters reported an increase in 6MWT, 3 studies [30, 31, 33] of gait speed, 4 studies [30, 31, 33] of maximal strength to various muscle groups, 6 studies [28, 31, 34, 40, 43] of VO_2peak/VO_2max and 3 studies [31, 35, 47] of BBS.

Quality of life

About the quality-of-life analysis, there were 4 studies [16, 26, 30, 31] of the present review that also included this aspect in their measures. In 1 of these studies [31], the QUALID scale was used. The other 3 studies [16, 30, 48] respectively used the QoL-AD scale, DEMQoL and EuroQol five-dimension scale.

As far as the quality-of-life parameter is concerned, no significant improvements were reported.

Discussion

To our knowledge, this is the first review to specifically address the feasibility and effects of HIET in the dementia and/or MCI population. Previous reviews and meta-analyses have primarily focused on the impact of low-to moderate intensity exercise in these groups, without examining the feasibility or outcomes of HIET [12, 34].

The purpose of this review was twofold: first, to analyze the feasibility of HIET in individuals with dementia and/or MCI, and second, to evaluate its effects on these populations. We hypothesized that HIET would be feasible for these individuals and would lead to improvements in cognitive function, physical performance, ADLs, and quality of life. To test this hypothesis, 21 articles were analyzed (Table 4).

Feasibility was assessed by examining inclusion and exclusion criteria, participants' comorbidities, dropout rates and reasons, adherence to HIET, the proportion of participants who completed HIET programs and the completion of CPET prior to program initiation. Regarding exercise effects, the review focused on cognitive/neuropsychiatric and psychological functions, physical performance, quality of life and ADLs. The findings indicate that HIET may be a feasible intervention for people

Table 4 Summary of the characteristics, interventions and outcomes of included studies

				AGE (mean ± SD)		Intervention				
Author	**Sample**	**Type of population**	**Inclusion criteria**	**IG**	**CG**	**IG**	**CG**	**Program frequency and duration**	**Measurements**	**Results**
Lamb et al. (2018) [23]	494	People with dementia	Clinically confirmed diagnosis of mild to moderate dementia, MMSE > 10, ability to sit on a chair and walk 10 feet (3.05 m) without assistance, living in community	76.9 (± 7.9)	78.4 (± 7.6)	Aerobic training: 5 min warm up, 25 min moderate to hard cycling. Strenght training: moderate to hard arm training	Usual care	4 months (2 t/w)	ADAS-cog BADL NPI EQ-5D QoL-AD ZBI 6MWT	Cognition: Worsened in the exercise group at 12 months (ADAS-cog mean diff − 1.4 [95% CI: − 2.6 to − 0.2], p = .03) Quality of life: No significant differences in EQ-5D or QoL-AD (e.g., QoL-AD proxy diff 0.02 [95% CI: − 1.0 to 1.0], p = .96) Physical fitness: 6MWT improved in the exercise group (+ 18.1 m [95% CI: 11.6 to 24.6], p < .001)
Sanders et al. (2020) [24]	91	People with dementia	Confirmed dementia diagnosis, age ≥ 65 years, able to complete the Timed Up & Go with or without assistance, MMSE score > 10	81.7 (± 7.16)	82.1 (± 7.51)	Combined aerobic and strength Training program. In the LI phase,the target RPE was 9–11 and target HR was 57–63 HRmax. Aerobic training: HI phase: interval training with alternating 4-min peak performance at 83–89%HRmax and 3-min active rest 71–77%HRmax. Strenght training: in LI phase the target RPE was 9–11. In the HI phase, the RPE was 13–16	Flexibility exercises and recreational activities	72 sessions, 6 months (3 t/w)	6MWT SPPB 6MWS FICSIT-4 TUG MMSE TMTA STROOP DSFW DSBW VMSFW VMSBW Fluency	Gait speed: Improved significantly in the exercise group after 24 weeks (+ 0.05 m/s, d = 0.41, p < 0.001), but declined at follow-up Other physical functions: No significant between-group differences (e.g., SPPB: p > 0.05; leg strength: d = 0.07) Cognition: No significant effects on any cognitive test (e.g., MMSE: d = − 0.04, p > 0.05) Exercise intensity: High-intensity phase did not lead to additional cognitive benefits (LI vs. HI: d ≈ − 0.03 to − 0.04) Moderators: ApoE4 carriership did not significantly moderate physical or cognitive outcomes (p > 0.05)

Table 4 (continued)

Author	Sample	Type of population	Inclusion criteria	AGE (mean ± SD)		Intervention		Program frequency and duration	Measurements	Results
				IG	CG	IG	CG			
Broadhouse et al. (2020) [44]	100	MCI	People with diagnosis of MCI, non demented, not depressed anch aged ^{3} 55, with a MMSE score of 24–28, and a Clinical Dementia Rating Score ≤ 0.5, CDR < 1.0, no ustable medical condition	69.5 (± 6.6)		Progressive Resistance Training (PRT) at 80% peak capacity, 3 × 8, 5/6 exercises + cognitive training	3 groups: 1) PRT + Sham Computerized Cognitive training; 2) CCT + Sham PRT; 3) sham PRT + sham CCT	26 weeks (2/3 t/w)	ADAS-cog COWAT WAIS-III VO_2peak MMSE	Global cognition: Improved in the resistance training group (PRT + SHAM) compared to the control group (SHAM + SHAM) after 18 months ($p = 0.028$, Cohen's d = −0.36 for ADASCog; $p = 0.046$, Cohen's d = 0.32 for executive function) Hippocampal atrophy: Reduced in the PRT group compared to the control group. Functional connectivity: Increased between the hippocampus and posterior cingulate cortex in the resistance exercise groups ($p = 0.018$)
Fiatarone Singh et al. (2014) [25]	100	MCI	People with diagnosis of MCI, non demented, not depressed anch aged ^{3} 55,with a MMSE score of 24–28, and a Clinical Dementia Rating Score ≤ 0.5, CDR < 1.0, no ustable medical condition	70.1 (± 6.7)		Strenght training at 80% peak capacity, 3 × 8, 5/6 exercises + cognitive training	3 groups: 1) PRT + Sham Computerized Cognitive training; 2) CCT + Sham PRT; 3) sham PRT + sham CCT	6 months (2/3 t/w)	ADAS-Cog BAYER-ADL WAIS-III COWAT SDMT BVRT WMS-III	Global Cognitive Function: PRT improved ADAS-Cog at 6 months (−0.33, 95% CI: −0.73, 0.06; $p < .05$) and maintained benefits at 18 months ($p = .08$), with more participants reaching normal scores compared to control (48% vs 27%, p < .03, OR = 3.50, 95% CI: 1.18, 10.48) Executive Function: PRT improved the Executive Domain at 18 months (p < .02), with greater benefits than Combined Training (z-score change 0.42, 95% CI: 0.22, 0.63 vs 0.11, 95% CI: −0.60, 0.28; $p = .02$) Memory: CT attenuated memory decline at 6 months ($p < .02$), while PRT improved visuoconstructional memory (BVRT, $p = .04$) but worsened delayed memory at 6 months ($p < .03$)
Pedrinolla et al. (2020) [5]	39	People with AD	Age between 65 and 90 years; clinical diagnosis of probable AD dementia, POMA score > 19, MMSE > 10, have not modifications of medications during the last 3 months, history of mental and physical pathologies	79 (± 8)		Endurance exercises divided into 15 min of cycling, 15 min of walking, and 15 min of arm cranking at 70% of maximal heart rate. Resistance exercise was performed with 3 sets of 12 reps at 85% of 1 RM	Regular cognitive therapy	72 sessions, 6 months (3 t/w)	FMD PLM VEGF 6MWT PPT	Vascular function: FMD increased by + 3.725% in EX group ($p \leq .001$); between-group diff. + 5.296%, $p < .001$ Peripheral blood flow: PLM Δpeak improved by + 99.056 ml/min ($p = .004$); AUC + 37.359 ml/min ($p = .037$) Biomarkers: VEGF increased by + 8.825 pg/ml in EX group (p = .004); between-group diff. + 10.728 pg/ml ($p = .011$) Physical function: 6MWT increased by + 70.5 m ($p = .002$), PPT + 2.5 points ($p = .023$); both significant vs control

Table 4 (continued)

Author	Sample	Type of population	Inclusion criteria	AGE (mean ± SD)		Intervention		Program frequency and duration	Measurements	Results
				IG	CG	IG	CG			
Schwenk et al. (2014) [26]	61	People with dementia	Confirmed dementia diagnosis, age > 65; ability to walk 10 me without walking aid; no uncontrolled or terminal neurologic, cardiovascular, metabolic, or psychiatric disorder	80.4 (± 7.1)	82.3 (± 7.9)	Resistance training was a submaximal intensity (70–80% of 1-RM)	Motor placebo group	3 months (2 t/w)	Gait Performance: Gait speed, Cadence Stride length Stride time Double support Step width Step time variability Walk-Ratio	Gait speed: improved in the intervention group (+ 18.3 cm/sec, $p < 0.001$, 95% CI: 9.85–26.80) Cadence: increased in the intervention group (+ 11.16 steps/min, $p = 0.002$, 95% CI: 4.37–17.94) Stride length: improved in the intervention group (+ 7.88 cm, $p = 0.008$, 95% CI: 2.14–13.61) Double support: reduced in the intervention group (−2.89%, $p = 0.001$, 95% CI: −4.53 to −1.25) No improvement: step width, step time variability, and Walk-Ratio ($p > 0.42$)
Inskip et al. (2022) [27]	9 (only 6 completed the protocol)	Parkinson's disease dementia and Lewy Body dementia	Diagnosis of LBD, age over 55, ambulatory with/without assistance, ability to follow rudimentary instructions,to tolerate functional testing, to travel to gym facility and complete sessions	74		Training sessions were divided into four sections: static balance, dynamic balance, functional practice, and progressive resistive exercise (2 sets 6 reps from 70% 1RM to 80% 1 RM)	–––	8 weeks (3 t/w)	MDS-UPDRS FIM MMSE PD-CRS SPPB DEMQoL GDS-15	Functional Independence: MDS-UPDRS significantly improved (−8 points, 95% CI: −17.5, −2; $p = 0.027$) Physical Function: Improvements in sit-to-stand, total balance time, and maximum strength ($p = 0.043$) Cognition: MMSE (+ 4.5 points, 95% CI: 1.5, 7.5; $p = 0.027$), PD-CRS (+ 8 points, 95% CI: 4, 17.5; $p = 0.027$)
Mavros et al. (2017) [45]	100	MCI	People with diagnosis of MCI, non demented, not depressed anch aged ^{3} 55, with a MMSE score of 24–28, and a Clinical Dementia Rating Score ≤ 0.5, CDR < 1.0, no ustable medical condition	70.1 (± 6.7)		Strenght training from 80% 1RM to 92% 1RM and cognitive training (computer-based multimodal and multidomain exercises targeting memory, executive function, attention, and speed of information processing)	3 groups: 1) PRT + Sham Computerized Cognitive training; 2) CCT + Sham PRT; 3) sham PRT + sham CCT	6 months (2/3 t/w)	(ADAS-Cog) Logical Memory I (Immediate) Logical Memory II (Delayed) BVRT WAIS-III Similarities WAIS-III Matrices COWAT Category fluency Symbol Digit Modalities Test Peak Strength VO2peak test	Memory Domain: No significant improvement (Baseline: 0.10 ± 0.65, 6 months: 0.03 ± 0.67, $p = 0.88$) Executive Function: Improvement noted (Baseline: −0.09 ± 0.65, 6 months: −0.17 ± 0.66, $p = 0.02$) Global Cognition: Significant improvement with PRT (direct effect: b = −0.37, 95% CI: −1.51 to 0.78) Strength Gains: Increased significantly (lower body strength: SMD = 0.94, 95% CI: 0.69–1.20) Aerobic Capacity (VO2peak): Improved (absolute change: 1.8 mL/kg/min, 95% CI: 0.6–3.0, $p = 0.003$)

Table 4 (continued)

				AGE (mean ± SD)		Intervention				
Author	**Sample**	**Type of population**	**Inclusion criteria**	**IG**	**CG**	**IG**	**CG**	**Program frequency and duration**	**Measurements**	**Results**
Littbrand et al. (2009) [28]	191	Old people and people with dementia (52.4%)	Age 65 and older, dependent on assistance in one or more personal ADLs, ability to stand up from a chair, MMSE score of 10 or more	85.3 (±6.1)	84.2 (±6.8)	Strength exercises performed at 8- to 12-repetition maximum	activities while sitting (watching a film, reading, singing, and conversation)	13 weeks (2/3 t/w)	Barthel Index	Overall ADL Performance: No significant group differences; exercise group prevented decline in dementia patients (mean difference: 1.1, $p=0.03$) Indoor Mobility: Less deterioration in exercise group at 3 months (3.5% vs. 16%, $p=0.01$) and 6 months (7.7% vs. 19.8%, $p=0.03$) Short-Term Effects in Dementia: Significant improvement at 3 months ($p=0.03$), but not maintained at 6 months ($p=0.18$) Long-Term Effects: No overall ADL improvement
Hoffmann et al. (2016) [39]	200	People with AD	Mini Mental State Examination (MMSE) score > 19, age between 50–90 years, a caregiver with regular contact, to be on a stable dose for at least three months before inclusion	69.8 (±7.4)	71.3 (±7.3)	Aerobic exercise of moderate-to-high intensity (70–80% of maximal HR)	Treatment as usual	16 weeks (3 t/w)	SDMT ADAS-Cog Stroop MMSE HAMD-17 NPI-12 ADCS-ADL EQ-5D	Cognition: No significant improvement in SDMT ($\Delta=+2.5$, 95% CI −1.1 to 6.1, $p=0.179$); per protocol analysis showed improvement ($\Delta=+4.2$, 95% CI 0.5 to 7.9, $p=0.028$) Neuropsychiatric Symptoms: NPI-12 improved in the exercise group ($\Delta=-3.5$, 95% CI −5.8 to −1.3, $p=0.002$) Depression: No significant change Quality of Life: No significant change ADL: No significant change
Van der Kleij et al. (2018) [46]	51	People with AD	Clinical diagnosis of probable AD, MMSE score of > 19, age 50–90 years, stable dose of anti-dementia or mood stabilizing medication, not have controindication to physical activity, not have severe psychiatric disease or alcohol abuse within last 2 years	68 (± 7)	69 (± 7)	Moderate-to-high intensity aerobic exercise (70–80% HRR)	Care as usual	16 weeks (3 t/w)	MMSE VO2 peak CBF (Whole brain, ACC, PCC, SPG, Precuneus)	Cognition: No significant change Cardiorespiratory Fitness: VO2 peak increased in the exercise group (+ 3 mL/min/kg, $p<0.01$), stable in controls Cerebral Blood Flow: No significant difference in CBF change between groups Frontal & Precuneus Regions: No significant CBF change

Table 4 (continued)

				AGE (mean ± SD)		Intervention				
Author	**Sample**	**Type of population**	**Inclusion criteria**	**IG**	**CG**	**IG**	**CG**	**Program frequency and duration**	**Measurements**	**Results**
Sobol et al. (2018) [30]	55	People with AD	Age 50–90 years; a score of 20 or above on the MMSE, to have contact more than once monthly to a caregiver; to not have unstable cardiac disease, musculoskeletal problems, joint problems and neurological diseases that cointroindicate aerobic training	69.2 (±6.9)	68.9 (±7.2)	Moderate-to-high intensity aerobic exercise (70–80% maximal HR). 3 × 10 min of exercise plus the pauses, in total 34–40 min	Care as usual	16 weeks (3 t/w)	Vo2peak, SDMT, NPI	Cardiorespiratory Fitness: VO2peak increased by 13% in the intervention group, with a between-group difference of 3.92 ml/kg/min (95% CI: 6.34–1.51, $p = 0.003$) Cognitive Function: SDMT changes correlated positively with VO2peak (Rho = 0.36, $p = 0.010$) Neuropsychiatric Symptoms: NPI score improvements correlated negatively with VO2peak (Rho = –0.41, $p = 0.042$)
Baker et al. (2010) [43]	33	MCI	Unstable cardiac disease, significant cerebrovascular disease, musculoskeletal impairment, or presence of other medical conditions with significant psychiatric, neurologic, or metabolic sequela	67.9 (±8.5)	72.6 (±8.7)	Aerobic training at 75% to 85% of heart rate reserve	Stretching training	6 months (4 t/w)	SDMT Trails B Stroop Verbal Fluency Task Switching Story Recall List Learning Delayed-Match-To-Sample VO2peak BMI DEXA IMGD FPI HDL IGF-I	Cardiorespiratory Fitness: VO2peak increased 11% in the aerobic group and decreased 7% in controls ($F = 17.93$, $p = 0.003$) Executive Function: Significant improvement in SDMT, Stroop, Trails B, and Verbal Fluency for aerobic exercise, especially in women ($F = 3.05$, $p = 0.04$) Glucose Metabolism: Increased insulin sensitivity in women only ($F = 7.49$, $p = 0.01$) Hormonal Changes: Cortisol decreased in women but increased in men ($F = 6.00$, $p = 0.02$); IGF-I increased in men only ($p = 0.02$) Amyloid Biomarkers: Aβ42 decreased 6% in aerobic group but increased 24% in controls ($p = 0.13$, not significant)

Table 4 (continued)

Author	Sample	Type of population	Inclusion criteria	AGE (mean ± SD)		Intervention		Program frequency and duration	Measurements	Results
				IG	CG	IG	CG			
Sondell et al. (2018) [32]	186	People with dementia	Diagnosis of dementia, age > 65 years, dependency in personal ADLs, to stand up from a chair with armrests with help from no more than one person, a Mini-Mental State Examination (MMSE) score > 10	84.4 (± 6.2)	85.9 (± 7.8)	High-Intensity Functional Exercises performed at 8–12 repetition maximum (RM)	Seated social group activity	40 sessions, 4 months (2/3 t/w)	MMSE Barthel ADL Index BBS Gait Speed NPI GDS-15 MNA, Likert Scale for motivation, self reported good health, perceived loneliness	Motivation During Sessions: High or very high in 61.0% (exercise) vs. 62.6% (social activity) sessions; no significant difference between groups Motivation Over Time: Increased in the exercise group (OR 1.01, 95% CI 1.01–1.02) and decreased in the social activity group (OR 0.98, 95% CI 0.97–0.99) Motivation to Attend Sessions: Lower in the exercise group (OR 0.71, 95% CI 0.63–0.80) but increased over time Comparison of Motivation (Before vs. During Sessions): Motivation during sessions was significantly higher than motivation to attend (OR 2.39, 95% CI 2.38–2.40 for exercise)
Sobol et al. (2016) [31]	200	People with AD	Diagnosis of AD, MMSE score > 20, age between 50–90 years, a caregiver who was willing to participate in the study, stable medication therapy, for at least 3 months before inclusion, not have co-morbidity that prevented exercising	69.8 (± 7.4)	71.3 (± 7.3)	Moderate-to-high–intensity aerobic exercise in 3 periods of 10 min at an intensity of 70%–80% of maximal HR	Care as usual	16 weeks (3 t/w)	VO_2max TUG STS 400-m walk 10-m walk SDMT NPI	Cardiorespiratory fitness: VO_2max increased significantly in the intervention group by 4.0 ml/kg/min [95% CI: 2.3–5.8], $P < .0001$ Exercise self-efficacy: Improved by 1.7 points [95% CI: 0.5–2.8], $P = .004$ Single-task physical performance: Significant improvements in TUG, 400-m walk, and 10-m walk in per-protocol analysis (e.g., TUG: − 0.47 s [95% CI: − 0.83 to − 0.12], $P = .009$) Dual-task performance: Improvement in 10-m walk with cognitive tasks (e.g., counting backwards: − 0.09 m/s [95% CI: − 0.17 to − 0.00], $P = .038$) for adherent participants
Wiken Telenius et al., (2015)	170	People with dementia	Being above 55 years of age, having dementia of mild or moderate degree, to be to stand up alone or by the help of one person, to be able to walk six meters, not to be medically unstable, psychotic or having severe communication problems	86.9 (± 7)	86.4 (± 7.8)	The intensity of strengthening exercises was 12 repetitions maximum (RM). The balance exercises intended to be "highly challenging"	Leisure activities	12 weeks (2 t/w)	BBS CST NWS BI MMSE NPI (including agitation, affective, apathy subscales) QUALID Cornell	Balance: BBS score improved by 2.9 points in the exercise group vs. 1.2 in control ($p = 0.02$; 95% CI: 0.24–4.48) Strength: CST improved by 1.2 points in adherent exercisers vs. 0.4 in others ($p = 0.03$; 95% CI: 0.07–1.65) ADL: Slight BI increase in intervention group (+ 0.1) vs. decline in control (− 0.7), trend toward significance ($p = 0.085$) Neuropsychiatric symptoms: Apathy reduced significantly in exercise group (− 0.2 points; $p = 0.048$; 95% CI: − 0.60 to − 0.01)

Table 4 (continued)

Author	Sample	Type of population	Inclusion criteria	AGE (mean ± SD)		Intervention		Program frequency and duration	Measurements	Results
				IG	CG	IG	CG			
Conradsson et al. (2010) [38]	191	Old people and people with dementia (52%)	Aged 65 years and over, dependent on assistance in one or more ADL, able to rise from a chair with armrests with help from no more than one person; a MMSE score of 10 or more	85.3 (±6.1)	84.2 (±6.8)	Strength exercises were performed at eight–12 repetition maximum (RM)	Activities performed while sitting	29 sessions, 3 months (2/3 t/w)	GDS-15 PGCMS MMSE MNA BBS ADL (Barthel Index)	Psychological well-being: In participants with dementia, PGCMS improved significantly at 3 months (between-group diff. 1.12 [95% CI: 0.09–2.16], p =.03)
Toots et al. (2016) [34]	186	People with dementia	Aged 65 years and over, dependent on assistance in one or more ADL, able to rise from a chair with armrests with help from no more than one person; a MMSE score of 10 or more	84.4 (±6.2)	85.9 (±7.8)	Strength exercises were performed at eight–12 repetition maximum (RM)	Activities performed while sitting (conversed, sang, listened to music or readings)	40 sessions, 4 months (2/3 t/w)	FIM BI BBS	Balance: Significant improvement at 4 months in exercise group vs. control (BBS: 4.2 [95% CI: 1.8–6.6], p <.001); no difference at 7 months Subgroup – non-AD dementia: Significant positive effects on FIM, BI, and BBS at 4 and/or 7 months (e.g., FIM at 7 months: 7.3 [95% CI: 1.1–13.5], p =.02)
Frederiksen et al. (2019) [36]	62	People with AD	Between 50 and 90 years of age, a MMSE score of more than 19, at least three months of stable doses if dementia medication	68.7 (±7.6)	70.4 (±7.4)	10-min warm-up including balance training followed by three 8-min bouts of aerobic exercise (70–80% HRR) interspersed by two-min breaks	Care as usual	16 weeks (3 t/w)	MMSE ADCS-ADL PASE VO_2max TUG STS 400-m walk 10-m walk SUVR (11C-PiB-PET)	Amyloid pathology: No significant difference in SUVR change between groups (Intervention: Δ = +0.02, p =.46; Control: Δ = –0.03, p =.68) Aerobic capacity: VO_2max improved in the exercise group (+2.3 mL/kg/min, p <.01) Walking endurance: 400-m walk time improved in intervention group (–17.0 s, p <.01)

Table 4 (continued)

Author	Sample	Type of population	Inclusion criteria	AGE (mean ± SD)		Intervention		Program frequency and duration	Measurements	Results
				IG	CG	IG	CG			
Frederiksen et al. (2014) [35]	9	People with AD	Diagnosis of dementia, age between 65 and 80 years, pharmaceutical treatment to be stable for at least 3 months, a contactable informant able to assist the patient and positive amyloid PET, to not have severe physical or psychiatric illness	71.9 (± 5.4)		10-min warm-up including balance training followed by three 8-min bouts of aerobic exercise (70–80% HRR) interspersed by two-min breaks	---	14 weeks (3 t/w)	MMSE SDMT GDS-15 ADCS-ADL QoL-AD VO_2peak SPPB 30-s CST Handgrip Isometric Quad Strength Leg Extension Power	Cognition: SDMT decreased significantly at 120 s (− 4.4 points, p = .03); MMSE unchanged (p = .3) Depression: GDS-15 improved (− 1.0 point, p = .04) Quality of Life: Proxy-rated QoL worsened (− 3.4 points, p = .002); patient-rated unchanged Physical function: Leg power improved in right leg (+ 0.12 W/kg, p = .03); VO_2peak trend (+ 0.7 mL/kg/min, p = .07)
Abbas et al. (2023) [47]	68	People with dementia	Age > 65 years, pharmaceutical treatment to be stable for at least 3 months, diagnosis od dementia, acceptable hearing or visual acuity, able to rise from a chair and walk for 6 m	78.4 (± 6.21)	81.55 (± 7.42)	25 min of MCE training + 25 min of HIFE	2 groups: 1) 50 min of HIFE. 2) 50 min MCE	12 weeks (3 t/w)	MMSE BBS TUG	BBS improved significantly in all groups after 12 weeks (e.g., MoEx: + 7.1 points, p = .001) Mobility: TUG improved significantly only in the MoEx group (− 1.73 s, p = .001); no changes in Mo or Ex

Abbreviations: *ADAS-Cog* Alzheimer's Disease Assessment Scale – Cognitive Subscale, *BADL* Basic Activities of Daily Living, *NPI* Neuropsychiatric Inventory, *EQ-5D* EuroQol 5 Dimensions Questionnaire, *QoL-AD* Quality of Life in Alzheimer's Disease, *ZBI* Zarit Burden Interview, *6MWT* 6-Minute Walk Test, *SPPB* Short Physical Performance Battery, *6MWS* 6-Minute Walk Speed, *FICSIT-4* Frailty and Injuries: Cooperative Studies of Intervention Techniques – Balance Test, *TUG* Timed Up and Go, *MMSE* Mini-Mental State Examination, *TMTA* Trail Making Test Part A, *STROOP* Stroop Color and Word Test, *DSFW* Dual-Task Speed Forward Walking, *DSBW* Dual-Task Speed Backward Walking, *VMSFW* Verbal-Motor Speed Forward Walking, *VMSBW* Verbal-Motor Speed Backward Walking, *Fluency* Verbal Fluency Test, *COWAT* Controlled Oral Word Association Test, *WAIS-III* Wechsler Adult Intelligence Scale – Third Edition, *VO_2peak* Peak Oxygen Uptake, *BAYER-ADL* Bayer Activities of Daily Living Scale, *SDMT* Symbol Digit Modalities Test, *BVRT* Benton Visual Retention Test, *WMS-III* Wechsler Memory Scale – Third Edition, *FMD* Flow-Mediated Dilation, *PLM* Passive Leg Movement, *VEGF* Vascular Endothelial Growth Factor, *MDS-UPDRS* Movement Disorder Society – Unified Parkinson's Disease Rating Scale, *FIM* Functional Independence Measure, *PD-CRS* Parkinson's Disease – Cognitive Rating Scale, *Logical Memory I/II* Logical Memory Subtests (Immediate/Delayed) – from Wechsler Memory Scale, *Peak Strength* Peak Muscle Strength, *Barthel Index (BI)* Barthel Index for Activities of Daily Living, *BBS* Berg Balance Scale, *CST* Chair Stand Test, *NWS* Normal Walking Speed, *Cornell Scale* Cornell Scale for Depression in Dementia, *QUALID* Quality of Life in Late-Stage Dementia, *HAMD-17* Hamilton Depression Rating Scale – 17 items, *ADCS-ADL* Alzheimer's Disease Cooperative Study – Activities of Daily Living, *CBF* Cerebral Blood Flow, *Trails B* Trail Making Test Part B, *DEXA* Dual-Energy X-ray Absorptiometry, *IMGD* Intramuscular Glycogen Depletion, *FPI* Foot Posture Index, *HDL* High-Density Lipoprotein, *IGF-I* Insulin-like Growth Factor I, *GDS-15* Geriatric Depression Scale – 15 items, *MNA* Mini Nutritional Assessment, *PGCMS* Philadelphia Geriatric Center Morale Scale, *PASE* Physical Activity Scale for the Elderly, *STS* Sit-to-Stand Test, *SUVR* Standardized Uptake Value Ratio (used in PET scans), *30-s CST* 30-Second Chair Stand Test, *VO_2max* Maximal Oxygen Uptake

with dementia and/or MCI and that it yields improvements in physical, cognitive and daily living outcomes.

In the following sections, all the findings will be discussed in detail.

Evidence of the feasibility of high intensity exercise training

Regarding the first research question, this work shows that HIET may be a feasible intervention for people with dementia and/or MCI. This consideration was proposed, by analyzing inclusion criteria, dropout rate and reasons, adherence to HIET, rate of subjects who were included in HIET interventions, as well as rate of subjects who completed HIET programs. Another aspect considered to evaluate the feasibility of this intervention was the execution of a CPET before starting the program.

First, the inclusion of subjects with various comorbidities (cardiac, pulmonary, metabolic, articular) also supports the feasibility of HIET. This could demonstrate that this training modality is extensible to a large pool of users.

Regarding dropout, as mentioned before, all subjects who completed the HIET programs did not report injuries due to the exercise. Going into specific analysis, the main reason for abandonment was the decline in health; while other dropout causes were dissatisfaction with exercise or lack of motivation [25, 28, 32, 36, 38], death during the training period [5, 16, 23, 25, 32, 47] and worsening of health status [23, 25, 26, 28, 30, 33, 39, 43]. Only one study reported that a death occurring after a training session could be related to the program, so exercise cannot be excluded as a primary cause of death [47].

Beyond dropout and completion rates, adherence throughout the intervention period represents a critical indicator of feasibility. In the present review, the majority of included studies reported quantitative adherence data, most commonly expressed as session attendance or percentage of sessions completed [16, 23–25, 28, 30–35, 39, 47, 48, 51, 53]. Reported adherence values were generally moderate to high. Importantly, adherence remained within these ranges even in long-duration interventions lasting up to six months [23, 24, 38, 39].

These findings suggest that participants with dementia and/or MCI were not only able to initiate HIET programs but were also capable of sustaining regular participation over time. This is particularly relevant given the cognitive, motivational and physical challenges typically associated with this population. The observation that adherence was maintained in protocols requiring moderate-to-high or high exercise intensities further supports the feasibility of HIET when interventions are adequately supervised and individualized.

Regarding the subjects' inclusion percentage in the intervention groups, as previously mentioned, 40% of the screened subjects were then randomized. Among these subjects, 84% finished the trial. Therefore, although only a part of the screened subjects was then included, almost all of them successfully completed the training period.

About maximal exercise testing, only few studies included a CPET in their measurements [30, 33, 38, 43, 51]. In all included HIET studies, CPET was not performed as a screening or eligibility tool, but was used exclusively to assess maximal aerobic capacity. ACSM exercise guidelines, state that it is not mandatory to perform a CPET before engaging in HIET [11]. The guidelines provide detailed recommendations on the use of CPET in various situations and suggest its application in cases of significant cardiovascular risk factors, respiratory diseases and unstable/acute health conditions [11]. In the studies included in this review, participants were generally assessed as clinically stable based on predefined inclusion and exclusion criteria, and no study required CPET as a prerequisite for participation.

Eventually, although only a minority of studies used CPET testing to prescribe training intensity, this does not appear to represent a barrier to feasibility. In most trials, exercise intensity was regulated using pragmatic and clinically applicable methods, such as heart rate monitoring, perceived exertion scales, repetition maximum–based resistance training and supervised workload progression. This approach reflects real-world clinical practice in populations with dementia and/or MCI, in which maximal testing may be challenging or not always feasible, yet high-intensity exercise can still be safely and effectively implemented under appropriate supervision. Nevertheless, the absence of systematic baseline capacity testing may have resulted in heterogeneity in the actual exercise intensity achieved across studies, potentially affecting the precision with which interventions can be classified as "high-intensity." While this limitation does not undermine the feasibility or safety of HIET interventions, it may reduce comparability across trials and should be considered when interpreting effectiveness outcomes. In this context, future research should aim to balance methodological rigor with clinical feasibility by adopting standardized yet pragmatic approaches to intensity prescription, such as validated submaximal testing protocols or combined heart rate and perceived exertion algorithms. This would improve reproducibility while maintaining accessibility in clinical dementia care settings.

Overall, the findings of this review suggest that HIET may be feasible for people with dementia and/or MCI and/or mild cognitive impairment. Feasibility was supported by generally acceptable dropout rates, moderate-to-high adherence, and high completion rates among participants who initiated the interventions, including individuals with stable comorbidities. The limited use of

cardiopulmonary exercise testing across studies, consistent with current ACSM guidelines, does not appear to represent a major barrier to feasibility.

Evidence of the effects of high intensity training on physical performance

Regarding the training effects on physical performance, it seems that HIET primarily improves VO_2max [28, 31, 33, 36] and the parameters relating to the walking speed [16, 23, 34, 35]. These ameliorations often seem to be associated with the cognitive improvement of the patients [30, 31, 35–39].

As known, VO_2max is an important parameter that is widely recognized as the best functional assessment of cardiopulmonary capacity and is a predictor of longevity. The increases in this parameter following the intervention of HIET could be considered as a strength for HIET.

Since there is no direct possibility to compare the effects of high-intensity and moderate-intensity exercise on cardiopulmonary capacity in the population analyzed by this review, other studies are required. It has been seen that HIET has a higher capacity to increase VO_2max both in healthy populations and in pathological populations. Furthermore, another strength point is that HIET is time saving compared to moderate activity.

Evidence of the effects of high intensity training on cognitive/psychological/neuropsychiatric aspects

As far as the cognitive-psychological part is concerned, most of the studies reported changes especially in the ADAS-Cog and NPI (which were the most used tests to assess global cognitive ability) in the studies with the aerobic HIET protocol [28], also in those with strength HIET exercise [31, 38, 39] and in those with combined aerobic and strength HIET [31, 38, 39]. Even the apathy level, depressive symptoms and motivation had a significant reduction [31]. However, almost half of the studies did not report improvements in cognitive outcomes [16, 23–26, 32–34, 40]. What is important to underline is that the literature analyzed by this review (except for three studies) seems to univocally point towards the positive relationship between HIET and changes in cognitive parameters. Analyzing the results of some studies that proposed a low/moderate intensity exercise protocol, literature is instead divided. Some studies did not report significant changes in cognitive parameters, while others suggested that low/moderate exercise can lead to significant changes in these parameters.

Evidence of the effects of high intensity training on ADLs

As for the results in the analysis of ADLs, most of the studies did not report significant results [5, 16, 26, 31, 33, 34, 41, 51]. What must be underlined is a general trend towards better results, not however significant. This could be explained by the training protocols not directly aimed at improving the ADLs as much as they were aimed at training physical performance. The hypothesis that training the typical gestures of daily living activities would improve the results of ADLs cannot be rejected by this review.

Evidence of the effects of high intensity exercise training on quality of life

HIET does not show improvements in the quality of life in this population [16, 26, 30], exception for one study [42]. Although the studies that assessed this aspect report that the experimental group tends to have a higher quality-of-life score compared to the control group, this may be due to a higher baseline score and not necessarily to a positive effect of the training intervention.

Limitations of the review

Some critical points need to be highlighted in this review. One initial consideration is that some studies lacked precise information on dementia, including treatment and disease-related variables (e.g., treatment type and status, disease grade and stage), which could potentially confound the results. Moreover, other confounding variables that must be taken into account and could influence the results include baseline activity levels, medication use, and dietary habits of the subjects. Furthermore, there is a clear focus of studies on western countries (United States, Europe, Australia) which underlines a lack of research in the continents of Africa and Asia, therefore, an ethnic generalization of the results cannot be taken into account. There would be a need to broaden the research field also in other geographical areas to implement the range of ethnicities taken into consideration. Another limitation is that exercise intensity was often based on perceived exertion rather than the results of a maximal cardiopulmonary exercise test. For this reason, participants did not exercise rigorously at the same intensity within the designated high-intensity zone. Consequently, it can be inferred that some results could be influenced by this fact. Furthermore, the limited use of maximal pre-intervention exercise testing across the included studies represents an additional methodological limitation. The absence of systematic baseline capacity assessments may have introduced heterogeneity in the actual exercise intensity achieved by participants and reduced the precision with which interventions could be classified as high-intensity.

Conclusions

This review suggests that HIET may be a feasible intervention for individuals with dementia and/or MCI. Feasibility is supported by acceptable dropout rates, moderate-to-high adherence, and high completion rates

among participants who initiated the interventions. However, evidence regarding the effectiveness of HIET on cognitive and functional outcomes remains limited and heterogeneous, and conclusions should therefore be interpreted with caution. Given these considerations, it is advisable to conduct larger-scale studies to more comprehensively explore the relationship between HIET and dementia and/or MCI. Based on the results of this review and the limitations identified in the included studies, future research should aim to determine the optimal intensity, frequency, and duration of HIET protocols, as well as to identify patient subgroups most likely to benefit. Advancing research in these areas could help refine clinical guidelines and support the incorporation of HIET into standard dementia care.

Abbreviations

ADLs	Activities of Daily Living
IADLs	Instrumental Activities of Daily Living
ICD-11	International Classification of Diseases 11th Revision
PA	Physical Activity
HIET	High-Intensity Exercise Training
CSA	Cross-Sectional Area
AD	Alzheimer's Disease
MCI	Mild Cognitive Impairment
ACSM	American College of Sports Medicine
HRR	Heart Rate Reserve
HRmax	Maximum Heart Rate
1RM	1 Repetition Maximum
CPET	Cardiopulmonary Exercise Testing
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
MMSE	Mini-Mental State Examination
MeSH	Medical Subject Headings
PEDro	Physiotherapy Evidence Database
RoB 2	Revised Cochrane Risk of Bias Tool for Randomized Trials
TUG	Time Up & Go Test
BADLs	Basic Activities of Daily Living
FIM	Functional Independence Measure
BI	Barthel Index
6MWT	6 Minutes Walking Test
$\dot{V}O_2$peak/$\dot{V}O_2$max	Peak / Maximum Oxygen Uptake
BBS	Berg Balance Scale
SPPB	Short Physical Performance Battery
QUALID	Quality of Life in Late-Stage Dementia
QoL-AD	Quality of Life in Alzheimer's Disease
DEMQoL	Dementia Quality of Life
EQ-5D	EuroQol five-dimension scale
ADAS-Cog	Alzheimer's Disease Assessment Scale – Cognitive Subscale
NPI	Neuropsychiatric Inventory
SDMT	Symbol Digit Modalities Test
ZBI	Zarit Burden Inventory

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NA.

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C.B., A.P. and M.V. contributed to the conception of the study. C.B. and A.P. developed the literature analysis. M.V. verified the methods and discussed with C.B. and A.P. about the results. All authors have read and agreed to the published version of the manuscript.

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All data extracted and analyzed in this systematic review are already publicly available in the original published studies cited in this manuscript. No new datasets were generated.

Declarations

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