Acceptability and effectiveness of stationary bike intervention on health outcomes among older adults: a systematic review of intervention studies

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Systematic Review

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Abstract

Background: A systematic search was conducted across seven databases - PubMed, Web of Science, Scopus, Cochrane Library, SportDiscus, CINAHL, and PsychInfo - following PRISMA guidelines until June 18, 2023, with no year limitations. After excluding duplicates, studies were screened by two independent reviewers in a two-stage process. This review included all original intervention studies with baseline and post-intervention outcomes involving SB as a health assessment tool, and/or a part of an intervention method among people aged 60 years or over.

Methods: Using PRISMA guidelines, seven databases were searched until June 18, 2023, without year limitations. After removing duplicates, two reviewers independently screened studies in two stages. This review included original intervention studies with baseline and post-intervention outcomes involving SB as a health assessment tool or intervention method among individuals aged 60 years, or older.

Results: Out of 8,022 citations, 47 English-language articles were included: 28 Randomized Controlled Trials (RCTs) and 19 (40.43%) Non-RCTs, including Pretest-posttest and Quasi-Experimental studies. The most common focus points of the included studies were Cognitive function, Motor and Balance, Physiological and Psychological changes, Cardiovascular, and Executive function. The most common study populations had neurological problems (15/47, 31.91% studies). Among the 47 included studies, the highest participants' acceptance rate was 38% (18/47 studies), while the retention rate was 15% (07/47 studies), the adherence rate was 6% (3/47 studies), and the lowest dropout rate was 13% (06/47 studies). Significant health outcomes after SBI included aerobic capacity (VO2 max), cognition, executive function, cycling efficiency, quality of life (QOL), and mobility (Timed up and Go test), mentioned in at least 5 studies. Virtual reality (VR)-assisted SBI showed better improvement in executive function compared to non-VR groups.

Conclusion: This review reveals varying rates of acceptability, retention, adherence, and dropout in SBI, highlighting challenges in participant engagement. However, despite these challenges, SBI shows promise in enhancing physical activity among seniors, with potential benefits across various health domains. Particularly noteworthy is the effectiveness of VR-assisted SBI in improving executive function among older adults, suggesting promising avenues for intervention. These results stress the significance of incorporating SBI into health interventions for older adults.

Introduction

Regular physical activity (PA) confers significant health benefits across all age groups, with particular emphasis on older individuals, facilitating prolonged years of active independent living. The World Health Organization (WHO) projects a notable increase in the global population aged 60 years and above, estimated to rise from 12% to 22% between 2015 and 2050, with 1 in 6 individuals worldwide expected to be aged 60 years or older by 2030 [1]. Engagement in regular physical exercise and sports across the lifespan positively impacts cardiovascular, respiratory, metabolic, neurological, and social well-being [2].

Consequently, the WHO recommends that individuals aged 65 years and above partake in at least 150 minutes of moderate-intensity aerobic physical activity per week, or 75 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of both. This regimen aims to bolster cardiorespiratory and muscular fitness, bone and functional health, and mitigate the risk of non-communicable diseases (NCDs), depression, and cognitive decline [3].

Various modes of endurance exercise training, including static bicycle (cycle ergometer) training [4], walking or jogging [5], and treadmill training [6], have been shown to be effective for improving health outcomes. Among these, stationary bike (SB) training stands out as an attractive option due to its ease of use, safety, and low risk of injury [7]. SB exercise is also beneficial for its non-weight-bearing nature, which reduces joint impact and overall bodily stress compared to jogging or other high-impact activities [8]. Additionally, SB training requires less postural control than treadmill walking, making it a suitable option for individuals with balance issues [6].

While the health benefits of cycle ergometer exercise [9] and the effects of SB training on gait and balance [10] are well-documented, systematic reviews focusing on the overall acceptability and effectiveness of stationary bike interventions (SBIs) in health outcomes, particularly among older adults aged 60 years and above, are lacking. To address this gap, it is essential to comprehensively review all relevant literature to obtain a holistic understanding of the acceptability and effectiveness of SBIs among older adults. Therefore, the primary objectives of this systematic review were to identify the key themes of published articles and to evaluate the acceptability and effectiveness of SBIs on health outcomes. In this study, the research questions addressed were:
a) What evidence exists regarding the acceptability of SB among older adults, and

b) What evidence exists for the effectiveness of SBI on health outcomes? Acceptability in this study referred to participant acceptance, dropout, retention, and adherence rates of SBI.
Older adults were defined as individuals aged 60 years and above [11], with further categorization into younger older adults (aged 60-75 years) and older adults (aged ≥76 years) to classify study subjects [12].

Methodology

Inclusion criteria and study selection criteria:

The eligibility criteria were established through a two-stage screening process. Initially, screening was performed based on the title and abstract, guided by specific criteria delineating studies centred on bicycles, cycling, or bicycling, particularly those involving older adults or explicitly mentioning an age range of 60 years and above.
For the second stage screening, after obtaining the full texts of potentially eligible studies, the following criteria were applied for inclusion:

1. All types of quantitative studies of any duration, assessing the effectiveness of an intervention (randomised or non-randomised),

2. Outcomes measured at baseline and post-intervention, with or without follow-up,
3. The studies should focus on a subgroup of the aged population aged 60 years and above,
4. Addressing stationary biking as a health assessment tool and/or part of an intervention method, and published in the English language.

Exclusion criteria

The exclusion criteria for this review encompassed several parameters:

1. Observational studies, including cross-sectional association or correlation studies, were excluded due to their limited ability to establish causality,
2. Qualitative studies were excluded as they typically focus on exploring subjective experiences rather than quantifiable outcomes,
3. Unpublished or under-review articles, conference abstracts, and publications in languages other than English were excluded to ensure access to peer-reviewed, scientifically rigorous research,
4. Furthermore, studies involving forms of bicycling other than stationary bicycling, such as outdoor bicycling or indoor bicycling not part of an intervention, were excluded to maintain consistency in the intervention modality under investigation,
5. Study protocols, letters, and commentaries were also excluded from the review due to their preliminary or opinion-based nature. However, relevant references from these excluded sources were screened to identify any articles meeting the inclusion criteria, ensuring a comprehensive examination of the literature.

Search Strategy and study identification

We systematically searched for intervention studies utilizing Sedentary Behaviour (SB) as a health assessment tool and/or intervention method among older adults, encompassing publications until June 18th, 2023, without geographical or temporal restrictions. Our methodology adhered to the PRISMA statement [13]. English-language articles were identified across 7 electronic databases, namely PubMed, Web of Science, Scopus, Cochrane Library, SportDiscus, CINAHL, and PsychInfo, without employing any filters. We employed a combination of keywords, including variations of terms such as "old people," "older people," "elderly," "aging," "old men," "old women," "older persons," "older adults," "seniors," along with cycling-related keywords like "bicycling," "cycling," "biking," "bike," or "bicycle". The initial search retrieved 8,022 hits, which were screened for duplicates, resulting in 6,639 unique articles. After screening the titles and abstracts, 126 full-text articles were evaluated for eligibility, following the exclusion of 6,513 irrelevant articles. Ultimately, 47 articles meeting the inclusion criteria were selected for systematic review. All citations were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; www.covidence.org) and an Excel sheet for the screening process and qualitative synthesis. Additionally, citations were imported into EndNote x9 (Clarivate Analytics, Philadelphia, PA, USA) software for reference management. Article screening was independently conducted by two reviewers (TA, and MK), with conflicts resolved through discussion and consultation with a third reviewer.

Data extraction

The selected studies were meticulously organised based on various parameters including the author's first name, year of publication, country of origin, age range, and gender of the population under study. Moreover, distinctions were made based on the study design, categorising them as either Randomised Controlled Trials (RCT) or Non-RCT studies.

Further segmentation was performed to delineate the focus points of the study, types of sedentary behaviour (SB) employed for physical activity (PA) intervention, and their associated features. This encompassed a range of SB modalities such as Recumbent SB with virtual aid, Upright bicycle ergometer, and Ergometer, among others. Additionally, pertinent details regarding the health condition of the study group, recruitment rate, dropout rate, retention rate, adherence rate, effectiveness, and PA outcome following SB intervention were meticulously documented. However, it is noteworthy that two studies [14, 15] out of the 47 included studies could not be tabulated for outcome analysis as specific outcome "p" values were not available. In such instances, evidence-based theories were judiciously applied for calculation purposes, thereby ensuring methodological rigour and consistency in data analysis.

Study Quality and Risk of Bias Assessment:

In assessing the quality of randomized controlled trials (RCTs) within the scope of this study, two established evaluation tools were utilized: the "PEDro" scale [16] and the Cochrane Handbook for the Risk of Bias Tool, version 2 (ROB 2.0). The "PEDro" scale evaluates studies across eleven criteria, covering aspects such as randomization, blinding, and statistical analysis. Ratings on this scale range from 0 to 10, with scores exceeding 4 indicating fair quality, scores between 6 and 8 denoting good quality, and scores surpassing 8 indicating excellent quality studies.

Conversely, non-randomized studies included in this systematic review underwent assessment using the Newcastle-Ottawa Scale (NOS) [17] to gauge their quality and methodological rigor. The NOS evaluates studies based on three primary domains: selection of study groups, comparability of groups, and ascertainment of outcomes. Scores are assigned within these domains to facilitate the critical appraisal of study quality and risk of bias.

Results

General characteristics of included studies:

Table 1 outlines the characteristics of 47 included studies, encompassing a total study population of 2,500 individuals engaged in stationary bike (SB) physical activity interventions. Among these, 28 (59.57%) studies were Randomized Controlled Trials (RCTs), while 19 (40.43%) were Non-Randomized Controlled Trials (non-RCTs), including Pretest-posttest and Quasi-Experimental studies. A demographic breakdown reveals that 16 (34.04%) studies[10, 18–32] targeted younger older adults aged 60 to 75 years, 5 studies (10.64%) [33–37] focused on older older adults (aged ≥76), and 26 (55.32%) [14, 15, 37–60] included both age groups.

Various types of SB interventions were identified, with ergometers being the most common (61.70%), followed by Cybercycle (SB with virtual aid) in 12 studies (25.53%) [27, 33, 34, 39–43, 49, 52, 54, 59], Recumbent SB in 5 studies (10.63%) [23, 36, 44, 58, 61] and upright bicycle ergometers and aqua cycles (SB in water) each appearing in 2 studies (4.26%) [31, 60] separately. The majority of studies (48.93%) exclusively utilized SB interventions, while 34.04% incorporated SB with virtual aid, 14.89% employed combined interventions (exercise/cognitive training), and a single study combined SB intervention with medication (see details in Table 1).

The trend of publications, spanning from 1975 to 2023 with a half-decade interval, is illustrated in Supplementary Figure 1. It encompasses combined interventions (exercise/cognitive training) and, notably, a single study combining SB intervention with medication.

Focus Points:

Figure 2 illustrates the primary areas of investigation in the 47 included studies. Cognitive function emerged as the most frequent focus, with 12 studies [24, 27, 33, 34, 39, 40, 42, 43, 47, 54, 59, 61]. Other prominent categories include Motor and Balance (seven studies)[10, 22, 32, 38, 44, 48, 51], Physiological and psychological changes (nine studies) [15, 18, 20, 30, 45, 50, 53, 56, 58], Cardiovascular (five studies) [19, 25, 28, 29, 60], Executive function (three studies) [23, 26, 36], Cycling efficiency and Quality of life (four studies each) [14, 21, 46, 52], VR-induced training, and Feasibility and effectiveness (four studies each) [15, 35, 41, 49]. Additionally, studies related to the Musculoskeletal system were represented by two studies [31, 55].

Evidence related to the acceptability and effectiveness of SB intervention:

Acceptability:

Figures 3 and 4 demonstrate that among the 47 studies included in the systematic review on sedentary behaviour interventions in physical activity, complete feasibility was observed with a 100% acceptance rate in 18 studies [18, 20, 21, 24, 25, 27, 29, 30, 36, 41, 42, 44, 46, 50–52, 56], a retention rate of 100% in 7 studies [27, 32, 43, 49, 53, 54, 57], and an adherence rate of 100% in 3 studies [32, 39, 54]. Additionally, a dropout rate of 0% was reported in 6 studies [32, 43, 49, 53, 54, 57]. [19, 23, 38, 40, 47–49, 60]The second highest range was observed in between 81-90% in total 17 studies where the acceptance rate mentioned in 8 studies [19, 23, 38, 40, 47–49, 60], retention rate in 6 studies [19, 21, 23, 34–36], and adherence rate in 3 studies [15, 23, 49], followed by the 91-99.9% range in 12 studies where acceptance rate mentioned in 6 studies [22, 32–34, 36, 61], retention mentioned in 5 studies [20, 28, 31, 56, 60] and adherence in one study [37], and 71-80% range lies withing 12 studies among them acceptance rate mentioned in 5 [37, 39, 43, 55, 59], retention in 5 [15, 22, 39, 40, 55], and adherence in 2 studies [39, 56]. 8 studies reported rates within 41-50% range where acceptance rate mentioned in 4 studies [10, 26, 28, 35], retention in 2 studies [36, 42], and adherence in 2 studies [42, 45]. With the lowest number of studies (6) in the 61-70% range where the acceptance rate mentioned in 2 [31, 58], retention rate in 3 [33, 37, 48], and adherence rate in one study [55].

Dropout rates ranged from 0% to 60%, with 9 studies [19, 21–23, 34, 35, 47, 55, 61] falling within an acceptable range of 11-20% for experimental sedentary behaviour interventions (Figure 4). Total 19 studies [19–23, 28, 31, 32, 34, 35, 43, 47, 49, 53–55, 57, 60, 61] show below 20% drop out rate. More than 20% dropout rate was found in 8 studies [15, 33, 36, 37, 39, 40, 42] with the highest percentage observed in the 21-30% range in 4 studies [15, 33, 39, 40]. Additionally, two RCT studies [23, 32] and one Non-RCT study [49] demonstrated feasibility with over 80% acceptance, retention, and adherence rates and less than 20% dropout rate. After considering 100% as the highest acceptance, retention, and adherence rate, and 0% as the lowest dropout rate, the acceptability rate of the study was found to be 38% (18/47 studies) for acceptance rate, 15% (7/47 studies) for retention rate, 6% (3/47 studies) for adherence rate, and 13% (6/47 studies) for dropout rate.

Effectiveness:

Table 2 outlines the effectiveness of all 47 included single studies. The results based on different outcomes are presented below (see also Supplementary Table 1).

Effects on Aerobic capacity (VO2 max)

The most common health outcome investigated across the studies was "Aerobic capacity (VO2 max)", utilized as a physiological function and cardiac fitness assessment parameter in 10 studies. The study populations varied, including physically inactive individuals [25, 30, 56], those with chronic obstructive pulmonary disease (COPD) [20, 21], healthy subjects [18], individuals diagnosed with Alzheimer's disease (AD) [58, 60], those with existing comorbidities [28], and one study that did not clearly specify the health status of the population [45]. Among these studies, four demonstrated statistically significant effects (p=<0.05) compared to control groups, walk-jogging groups, post-ergometer exercise, and stretching groups [18, 25, 45, 58]. Additionally, four studies reported highly significant effects (p=<0.001), showing improved aerobic capacity following post-ergometer intervention [20, 21] and compared to control groups [56]. However, two studies did not observe significant improvements after short aerobic exercise and supervised SB training among men aged ≤75 years [28, 60].

Effects on executive function

To evaluate executive function, the Colour Trails Test showed statistically significant improvements in performance across three studies (p=0.002, 0.007, 0.02). Specifically, enhanced performance was observed among healthy individuals in two studies and among individuals with type 2 diabetes in one study when compared to traditional exercise, non-diabetic, and exergaming groups, respectively [39, 40, 43]. Additionally, the Stroop A/C test demonstrated highly significant and statistically significant results ($p<0.001$, $p<0.05$) in two studies, indicating improved executive function among individuals with mild to moderate cognitive impairment and healthy individuals compared to the exercise bike with virtual tour group and participants' baseline fitness, respectively[26, 42]. However, in contrast, one study found no significant difference in executive function between the sedentary behaviour group and the exergaming intervention group among healthy individuals [43]. Moreover, ergometer intervention did not yield improved executive function compared to stretching among participants with mild to moderate Alzheimer's disease dementia [61].

Effects on Cognition

To assess cognition, a reduction in choice reaction (CR) time was observed, indicative of improved cognition ($p < 0.001$), as reported in two studies among healthy individuals and those diagnosed with AD dementia, compared to younger populations and post-ergometer intervention respectively [2, 24]. Conversely, an increase in CR time, signifying a lack of cognitive improvement ($p < 0.001$, $p \leq 0.05$), was noted in two studies involving healthy and moderately dementia populations when compared with interventions involving "Ergometer with video game" and "Exergaming" respectively [27, 54]. Additionally, two studies reported enhanced overall cognition ($p = 0.01$, $p = 0.006$) when compared with a non-virtual reality (VR) motor training group and post-ergometer intervention among individuals with impaired cognition and AD dementia respectively [34, 54]. However, Yu et al. (2021) found no significant improvement in cognition compared to a stretching intervention group among AD participants [61].

Effects on Quality of Life (QOL)

Quality of life (QOL) was evaluated as an outcome measure in five distinct studies. Among these, two studies focusing on COPD patients demonstrated highly significant improvements (p=<0.001) in QOL following ergometer intervention compared to both post-intervention and controlled (non-exercise) groups [35, 50]. Additionally, in a study by Ferrai et al. (2004), QOL was significantly enhanced (+) among

COPD participants, with a post-ergometer intervention QOL score of 7/9 [21]. Furthermore, there was a statistically significant improvement ($p<0.05$) in QOL observed among Alzheimer's disease (AD) participants after supervised stationary bicycle (SB) training, particularly among men aged ≤75 years [60]. Notably, another study reported that QOL improved significantly more with SB intervention compared to stationary bicycle intervention in participants experiencing mobility difficulties [32].

Effects on Cycling efficiency

Cycling efficiency outcomes were reported in five studies. Three of these studies demonstrated statistically significant increases in competitiveness, repetitive participation, and feasibility for sleep hygiene and interval training among healthy, impaired cognition, and sleep-impaired populations compared to post-virtual reality (VR) SBI [14, 41, 53]. Conversely, a study by Briswalter et al. (2014) found decreased cycling efficiency ($p <0.05$) in the group aged over 60 compared to the 50-59 years group post SBI among healthy individuals [46]. Another study by D’Cunha et al. (2021) noted that SB intervention was significantly challenging and immersive ($p=0.012$) among mildly to moderately cognition-impaired populations compared to the post-SB controlled condition [33].

Effects on Mobility, Gait and Balance

The Timed Up and Go (TUG) test is specific for mobility assessment, observed as an outcome in five studies. Three studies reported statistically significant ($p<0.05$) improvements in mobility function among healthy, physically inactive, and Parkinson's disease (PD) diagnosed participants compared to control groups engaging in daily activities, stretching exercises and post-SBI [30, 44, 57]. However, two studies failed to demonstrate any mobility improvement after SBI. Abbas et al. (2022) found a significant ($p= <0.05$) reduction in mobility improvements among moderate to severe dementia patients after SBI compared to groups undergoing post-ergometer and ergometer with high-intensity functional exercise (HIFE) interventions [38]. In another study, an ergometer and treadmill-based programme were found to be less effective than a video-based programme in improving mobility among populations with existing comorbidities [48].

Walking capacity also significantly improved among COPD and PD diagnosed patients [22, 49]; however, no improvement was observed among participants with mobility difficulties [32]. "Gait" outcomes showed improvement ($p<0.01$) in two studies [35, 58] and no improvement was observed among physically inactive participants (single study) [23].

The SBI interventions also yielded various positive and negative effects on physical activity-related health outcomes. The Berg Balance Scale (BBS) test indicated improved balance ($p<0.05$) in three studies [38, 48, 62], while no improvement was observed among participants with mobility difficulties (single study) [63].

Effects of SB with and without VR intervention on executive function:

Two studies investigated the application of SB with virtual reality (VR) compared to SB without VR to assess executive function. Both studies implemented a three-month intervention with 45-minute sessions five times per week. The Colour Trails test, used to assess executive function, showed that the cybercycle group outperformed the traditional SB group, with medium effect sizes of d=0.50 and d=0.69, respectively [39, 40]. Please refer to Table 3 for details.

Effects of SB with and without VR intervention on cycling efficiency:

In this study, three articles were identified that applied SB with VR to assess cycling efficiency. Following two sessions lasting 60 minutes each, with intervals of 1-7 days between sessions, participants in the SB with VR intervention group exhibited significantly higher cycling distance in repeated sessions compared to those in the SB without VR group [27]. Additionally, after three months of engaging in a minimum of 2-3 rides per week with 60% maximum heart rate, participants in the post-VR assisted SB intervention group demonstrated increased exercise efforts. Conversely, participants in the VR-assisted SB group, who engaged in a single self-paced session lasting 25 minutes at a speed of 1.83 m/s, found the exercise more challenging compared to traditional SB exercisers. Please refer to Table 4 for detail.

Miscellaneous

Two studies demonstrated improved memory outcomes among both healthy and hypertensive participants [18, 24], while no improvement was observed in participants diagnosed with AD [61]. Two studies reported a decrease in blood pressure [30, 45], while one study failed to show improvement [19]. Additionally, each of the physical activity-related health outcomes, such as gait, pain reduction, and heart rate lowering, were mentioned twice, as detailed in supplementary table 1.

Outcomes of RCT studies:

Out of 28 RCT studies, positive outcomes were noted, notably improved aerobic capacity (VO2 max) in 4 studies (p=<0.05) [6, 7, 18, 31]. The "Colour Trails" test improved in 2 studies (p=<0.05) [39, 43], and the "Stroop a/c" test in another 2 studies (p=<0.05) found improved as part of executive function respectively [10, 42]. Mobility (TUG test) showed improvement in 3 studies (p=<0.05) [6, 44, 58]. Quality of Life (QOL) also significantly improved in 3 different studies (p=<0.05) respectively [3, 64, 65]. Improved overall cognitive function was found in 2 different studies (p=<0.05) without specifying the outcome of Choice Reaction (CR) time [26, 54]. Memory improved in 2 different studies (p=<0.05) [18, 24]. Cycling efficiency with and without virtual aid (VA) increased in 2 different studies distinctly (p=<0.05) [16, 41]. However, Balance (BBS test), Walking capacity, Gait, Pain reduction, & lowering of BP showed the least significant improvement, each presented in a single study separately ((p=<0.05) [14, 30, 38, 57, 58].

Upon analysing all the RCTs, several outcomes failed to show any improvements. Notably, Cognitive function was stated in 3 studies, among them 2 showed increased Choice Reaction time indicating decreased cognitive function (p=<0.05) [11, 66], and another study showed an overall decrease in Cognitive function (p=<0.05) [61]. The Stroop test and overall executive function as part of Executive function, and Aerobic Capacity both failed to show any improvement in 2 different studies individually (p<0.05) [28, 43, 60, 61]. Additionally, Cycling with VA and Mobility (TUG) failed to show any improvement as stated in 2 different studies (p=<0.05) [33, 38]. However, QOL, Balance, and Walking Capacity each of the outcomes failed to show any improvement as stated in a single study (p=<0.05) [67].

Study Quality and Risk of Bias Assessment of all RCTs :

In RCT studies assessed using the Pedro scale, six studies [22, 28, 31, 36, 53, 54] achieved a perfect score of 10, while two studies [23, 33] scored 9. Thirteen studies [18, 30, 32, 34, 35, 38, 41, 42, 44, 50, 57, 58, 61] scored between 6-8, and seven studies [26, 27, 29, 39, 43, 56, 60] scored above 4. Please refer to Supplementary Table 2 for further details.

Regarding ROB 2.0, eleven studies [18, 22, 23, 28, 29, 31, 39, 53, 54, 58, 68] were classified as low risk of bias, while two studies [35, 42] were deemed to have high risk of bias due to issues with randomization and missing outcome data. Other studies [26, 27, 29, 33, 34, 36, 38, 41, 43, 44, 50, 56, 57, 60, 61] raised overall concerns related to randomization, selection of reported results, and outcome measurement. Please refer to Supplementary Table 3 for further details.

Study Quality of all Non-RCTs:

Among the remaining 19 non-RCT studies assessed with the Newcastle-Ottawa Scale, nine studies [19, 24, 25, 37, 47–49, 51, 59] achieved the highest scores of 9, indicating strong performance across assessment criteria and robust methodology. Following closely were other studies [10, 20, 21, 52] with a score of 8, highlighting commendable methodological quality. Four studies [14, 40, 46, 55] received a score of 7, indicating a good level of quality in design and execution. One study[45] scored 5, reflecting a lower level of methodological quality, while another study [15] scored 3 due to design limitations and lack of methodological details.See Supplementary Table 4 for further details.

Discussion

This systematic review represents the first comprehensive analysis focusing on the acceptability and effectiveness of SBI (stationary bike intervention) concerning health outcomes among individuals aged 60 and above. Encompassing 47 intervention studies, including 28 RCTs and 19 non-RCT studies, the review revealed an overall acceptability rate of 38%, retention rate of 15%, adherence rate of 6%, and dropout rate of 13%. Collectively, these studies highlight the wide-ranging positive impacts of SBI across multiple domains, including cognitive function, motor skills and balance, physiological and psychological well-being, cardiovascular health, executive function, cycling efficiency, quality of life, musculoskeletal health, as well as feasibility and long-term effectiveness.

According to the current evidence, SB is proposed as a suitable form of endurance training for promoting overall physical health among older adults over 60, primarily due to its relative ease of performance and safety, with no associated injuries reported [7]. Furthermore, the use of a bicycle ergometer in SB presents advantages over treadmill walking, particularly for older frail individuals, as it requires less upper body motion, facilitating the recording of vital signs and blood sample collection [69].

Specifically, our study indicates that VR-assisted ergometer intervention yields better executive function [39, 40]. Two quasi-experimental studies compared the study group (SB with VR) to a control or comparator group (SB without VR), resulting in medium effect sizes of d=0.50 and d=0.69, respectively, suggesting that VR-assisted SB is an effective intervention for improving executive function. Additionally, two studies demonstrated that VR-assisted SB increased cycling efficiency on a given task at a minimum threshold level among healthy and cognitively impaired populations, respectively [41, 52]. However, cognitively impaired participants found virtual cycling more challenging than traditional SB exercise at a self-paced threshold. Further research is warranted to evaluate the effectiveness of VR-assisted SB intervention on cycling efficiency.

Comparison with other studies

Although numerous systematic reviews have explored the benefits of SB for the general population, there is a dearth of studies focusing specifically on older adults aged 60 and above. Bouaziz et al. (2015) conducted a systematic review that highlighted the positive effects of cycling on cardio-respiratory performance, functional status, and physiological and psychological outcomes in older adults over 70 [9]. However, our study expands upon this research by removing the age limitation and including participants aged 60 and above. Additionally, our findings encompass a broader range of outcomes, including VR assisted SB's impact on executive function, cycling efficiency, quality of life, mobility, balance, and pain reduction. By delving into more specific intervention studies, our review provides a comprehensive overview of the health benefits of SB intervention for older adults over 70.

Our study revealed that setting a self-paced threshold speed (1.83 m/s) for virtual SB cycling renders the activity more challenging compared to traditional SB cycling, thereby reducing cycling efficiency. This finding underscores the need for further research in this area. Fang et al. (2021) observed that a minimum of twenty sessions of functional electrical stimulation (FES) cycling training is necessary to enhance walking ability and lower limb strength among participants with spinal cord injuries [66]. However, their study was restricted by age limitations and did not provide recommendations for individuals over 60. Furthermore, while FES-cycling may be effective for participants with limited leg movement, our study participants exhibited no such limitations. Therefore, we advocate for more research into VR assisted SB cycling to enhance cycling efficiency.

To date, there has been no systematic review specifically examining the acceptability and effectiveness of SB interventions for older adults over 60. Given that a majority of our study participants had neurological issues, it is pertinent to focus on the effective health outcomes related to executive function, cognition, and memory. A systematic review by Chueh et al. (2022) demonstrated that interrupting prolonged sitting with physical activity breaks improves memory and cognition [70]. In our study, we assessed the acceptability of SB interventions among participants, detailed the effective health outcomes, and recommend VR assisted SB cycling as a valuable tool for enhancing executive function. We also advocate for further research in this area to improve cycling efficiency. These distinct characteristics set our study apart from others and highlight its significance in the field.

Strength of the study

The robustness of this review lies in its comprehensive approach to data collection and analysis. By searching seven databases across diverse disciplines, we ensured a thorough exploration of existing literature on the topic. Our extensive search strategies and broad study selection criteria enabled us to capture a wide range of relevant studies, enhancing the comprehensiveness of our findings.Moreover, our team-based approach, involving independent review and multiple testing of the data inclusion and extraction process, ensured the reliability and accuracy of our results. We applied evidence-based theories for acceptability assessment, further strengthening the methodological rigor of our study. Additionally, the use of the PEDro scale for quality analysis, where most of our studies were good quality, as well as low risk of bias found among most of the studies assessed using the Cochrane Handbook "ROB 2.0" tools which enhanced the robustness of our review.Another notable strength of our review is its focus on a previously neglected population: older adults over the age of 60. By targeting this specific demographic group, we were able to provide valuable insights into an understudied area of research, ultimately yielding robust outcomes.

Weakness of the study

We encountered challenges in selecting a standardized tool for assessing acceptability, primarily due to the paucity of robust scientific evidence concerning SB interventions. Consequently, we deemed studies as fully acceptable only if they demonstrated a 100% acceptance, adherence, and retention rate, with no dropouts reported. It is worth noting that the absence of complete data during acceptability analysis may have influenced the calculated acceptability percentage. Additionally, the dropout rate is inversely related to participants' acceptance, retention, and adherence rates, complicating the interpretation of results. Despite these limitations, this review offers valuable insights into the extent of evidence regarding the efficacy of stationary bikes in PA interventions among older adults.

Conclusion

The analysis of 47 studies in this review our analysis revealed varying degrees of acceptability, retention, adherence, and dropout rates in SBI, highlighting the nuanced landscape of intervention effectiveness and participant engagement. While the overall acceptability rate was moderate at 38%, retention and adherence rates were notably lower, suggesting challenges in sustained participant involvement. Nonetheless, our findings underscore the potential of VR assisted SBIs in enhancing executive function among older adults, demonstrating promising results compared to non-VR interventions. This highlights the feasibility of integrating VR technology into cognitive enhancement programs for this population. However, further research is imperative to fully elucidate the efficiency and effectiveness of VR-assisted cycling testing. Future investigations should delve into the long-term impact, optimal duration and frequency of VR interventions, and feasibility of incorporating VR technology into routine clinical practice. Additionally, exploring acceptability, retention, adherence, and dropout rates in larger and more diverse populations would provide valuable insights into the broader applicability and scalability of VR-assisted interventions for cognitive enhancement in older adults.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

This review did not utilize primary data. Refer to the cited paper for primary data sources. All data in this study are publicly accessible and previously published. The compiled dataset analyzed in this study can be obtained from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

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Authors’ contributions

TA and MK conceptualized the study, formulated the methodology and design, conducted literature searches and reviews, and drafted the initial manuscript. MM provided support in literature search, review, writing results, and contributed to subsequent drafts. KM participated in writing results and contributed to subsequent drafts. All authors critically reviewed and approved the final version of the manuscript.

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References

1. Ageing and health. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health. Accessed 5 Apr 2024.
2. Schwarck S, Busse N, Ziegler G, Glanz W, Becke A, Düzel E. Heart Rate Variability During Physical Exercise Is Associated With Improved Cognitive Performance in Alzheimer's Dementia Patients—A Longitudinal Feasibility Study. Front Sports Act Living. 2021;3:684089.
3. Global recommendations on physical activity for health. https://www.who.int/publications-detail-redirect/9789241599979. Accessed 5 Apr 2024.
4. Vogel T, Leprêtre P-M, Brechat P-H, Lonsdorfer E, Benetos A, Kaltenbach G, et al. Effects of a short-term personalized Intermittent Work Exercise Program (IWEP) on maximal cardio-respiratory function and endurance parameters among healthy young and older seniors. J Nutr Health Aging. 2011;15:905–11.
5. Cheng SP, Yang CY, Tang FI, Chen IJ. Training effects of a 12-week walking program on Parkinson disease patients and community-dwelling older adults. NeuroRehabilitation. 2013;32:967–76.
6. Oh-Park M, Holtzer R, Mahoney J, Wang C, Verghese J. Effect of treadmill training on specific gait parameters in older adults with frailty: case series. J Geriatr Phys Ther. 2011;34:184–8.
7. Sanderson B, Askew C, Stewart I, Walker P, Gibbs H, Green S. Short-term effects of cycle and treadmill training on exercise tolerance in peripheral arterial disease. J Vasc Surg. 2006;44:119–27.
8. Bauman AE, Rissel C. Cycling and health: an opportunity for positive change? Medical Journal of Australia. 2009;190:347–8.
9. Bouaziz W, Schmitt E, Kaltenbach G, Geny B, Vogel T. Health benefits of cycle ergometer training for older adults over 70: a review. Eur Rev Aging Phys Act. 2015;12:8.
10. Lee C-W, Cho G-H. Effect of stationary cycle exercise on gait and balance of elderly women. J Phys Ther Sci. 2014;26:431–3.
11. Lyness JM, Caine ED, King DA, Cox C, Yoediono Z. Psychiatric disorders in older primary care patients. J Gen Intern Med. 1999;14:249–54.
12. Schnitzspahn KM, Kliegel M. Age effects in prospective memory performance within older adults: the paradoxical impact of implementation intentions. Eur J Ageing. 2009;6:147–55.

13. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
14. Gaesser G, Tucker WJ, Sawyer BJ, Bhammar DM, Angadi S. Cycling efficiency and energy cost of walking in young and older adults. Journal of Applied Physiology. 2018;124:414–20.
15. Yu F. Improving recruitment, retention, and adherence to 6-month cycling in Alzheimer's disease. Geriatr Nurs. 2013;34:181–6.
16. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003;83:713–21.
17. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;25:603–5.
18. Antunes HK, De Mello MT, Santos-Galduróz RF, Galduróz JCF, Aquino Lemos V, Tufik S, et al. Effects of a physical fitness program on memory and blood viscosity in sedentary elderly men. Brazilian Journal of Medical and Biological Research. 2015;48:805–12.
19. Cunha RM, Arsa G, Oliveira-Silva I, Ferreira Rocha I, Machado Lehnen A. Acute Blood Pressure Effects in Older Adults with Hypertension After Different Modalities of Exercise: An Experimental Study. J Aging Phys Act. 2021;29:952–8.
20. Emery CF. Effect of age on physiological and psychological functioning among COPD patients in an exercise program. Journal of agining and health. 1994;6:3–16.
21. Ferrari M, Vangelista A, Vedovi E, Falso M, Segattini C, Brotto E, et al. Minimally supervised home rehabilitation improves exercise capacity and health status in patients with COPD. Am J Phys Med Rehabil. 2004;83:337–43.
22. Ferraz DD, Trippo KV, Duarte GP, Neto MG, Bernardes Santos KO, Filho JO. The Effects of Functional Training, Bicycle Exercise, and Exergaming on Walking Capacity of Elderly Patients With Parkinson Disease: A Pilot Randomized Controlled Single-blinded Trial. Arch Phys Med Rehabil. 2018;99:826–33.
23. Hou H-Y, Chen J, Hai L, Wang P, Zhang J-X, Li H-J. Effects of exergame and bicycle exercise intervention on blood pressure and executive function in older adults with hypertension: A three-group randomized controlled study. Exp Gerontol. 2023;173:112099.
24. Joyce J, Smyth PJ, Donnelly AE, Davranche K. The Simon task and aging: does acute moderate exercise influence cognitive control? Med Sci Sports Exerc. 2014;46:630–9.
25. Katyal S, Freeman M, Miller JA, Thomas SG. Short-term aerobic training and circulatory function in women: age and hormone- replacement therapy. 2003.
26. Lebeau JC, Mason J, Roque N, Tenenbaum G. The effects of acute exercise on driving and executive functions in healthy older adults. International Journal of Sport and Exercise Psychology. 2022;20:283–301.
27. López-García J, Colado JC, Guzmán JF. Acute Effects of Aerobic Exercise and Active Videogames on Cognitive Flexibility, Reaction Time, and Perceived Exertion in Older Adults. Games Health J. 2019;8:371–9.

28. Madden KM, Lockhart C, Cuff D, Potter TF, Meneilly GS. Short-term aerobic exercise reduces arterial stiffness in older adults with type 2 diabetes, hypertension, and hypercholesterolemia. Diabetes Care. 2009;32:1531–5.
29. Morita N, Okita K. Is gender a factor in the reduction of cardiovascular risks with exercise training? Circ J. 2013;77:646–51.
30. Nocera JR, Mammino K, Kommula Y, Wharton W, Crosson B, McGregor KM. Effects of Combined Aerobic Exercise and Cognitive Training on Verbal Fluency in Older Adults. Gerontol Geriatr Med. 2020;6:2333721419896884.
31. Rezasoltani Z, Sanati E, Kazempour Mofrad R, Azizi S, Dadarkhah A, Najafi S. Randomized Controlled Trial of Aquatic Cycling for Treatment of Knee Osteoarthritis in Elderly People. Topics in Geriatric Rehabilitation. 2020;36:103.
32. Tollár J, Nagy F, Tóth BE, Török K, Szita K, Csutorás B, et al. Exercise Effects on Multiple Sclerosis Quality of Life and Clinical-Motor Symptoms. Med Sci Sports Exerc. 2020;52:1007–14.
33. D'Cunha NM, Isbel ST, Frost J, Fearon A, McKune AJ, Naumovski N, et al. Effects of a virtual group cycling experience on people living with dementia: A mixed method pilot study. Dementia (London). 2021;20:1518–35.
34. Kwan RYC, Liu JYW, Fong KNK, Qin J, Leung PK-Y, Sin OSK, et al. Feasibility and Effects of Virtual Reality Motor-Cognitive Training in Community-Dwelling Older People With Cognitive Frailty: Pilot Randomized Controlled Trial. JMIR Serious Games. 2021;9:e28400.
35. Van Roie E, Martien S, Hurkmans E, Pelssers J, Seghers J, Boen F, et al. Ergometer-cycling with strict versus minimal contact supervision among the oldest adults: A cluster-randomised controlled trial. Archives of Gerontology and Geriatrics. 2017;70:112–22.
36. Wu S, Ji H, Won J, Jo E-A, Kim Y-S, Park J-J. The Effects of Exergaming on Executive and Physical Functions in Older Adults With Dementia: Randomized Controlled Trial. J Med Internet Res. 2023;25:e39993.
37. Yu F, Savik K, Wyman JF, Bronas UG. Maintaining physical fitness and function in Alzheimer's disease: a pilot study. Am J Alzheimers Dis Other Demen. 2011;26:406–12.
38. Abbas RL, Saab IM, Al-Sharif HK, Naja N, El-Khatib A. Effect of Adding Motorized Cycle Ergometer Over Exercise Training on Balance in Older Adults with Dementia: A Randomized Controlled Trial. Experimental Aging Research. 2023;49:100–11.
39. Anderson-Hanley C, Arciero PJ, Brickman AM, Nimon JP, Okuma N, Westen SC, et al. Exergaming and older adult cognition: a cluster randomized clinical trial. Am J Prev Med. 2012;42:109–19.
40. Anderson-Hanley C, Arciero PJ, Westen SC, Nimon J, Zimmerman E. Neuropsychological Benefits of Stationary Bike Exercise and a Cybercycle Exergame for Older Adults with Diabetes: An Exploratory Analysis. J Diabetes Sci Technol. 2012;6:849–57.
41. Anderson-Hanley C, Arciero P, Snyder. Social facilitation in virtual reality-enhanced exercise: competitiveness moderates exercise effort of older adults. CIA. 2011;:275.

42. Anderson-Hanley C, Barcelos NM, Zimmerman EA, Gillen RW, Dunnam M, Cohen BD, et al. The Aerobic and Cognitive Exercise Study (ACES) for Community-Dwelling Older Adults With or At-Risk for Mild Cognitive Impairment (MCI): Neuropsychological, Neurobiological and Neuroimaging Outcomes of a Randomized Clinical Trial. Front Aging Neurosci. 2018;10:76.
43. Barcelos N, Shah N, Cohen K, Hogan MJ, Mulkerrin E, Arciero PJ, et al. Aerobic and Cognitive Exercise (ACE) Pilot Study for Older Adults: Executive Function Improves with Cognitive Challenge While Exergaming. Journal of the International Neuropsychological Society. 2015;21:768–79.
44. Bellumori M, Uygur M, Knight CA. High-Speed Cycling Intervention Improves Rate-Dependent Mobility in Older Adults. Medicine & Science in Sports & Exercise. 2017;49:106–14.
45. Buccola VA, Stone WJ. Effects of jogging and cycling programs on physiological and personality variables in aged men. Res Q. 1975;46:134–9.
46. Brisswalter J, Wu SSX, Sultana F, Bernard T, Abbiss CR. Age difference in efficiency of locomotion and maximal power output in well-trained triathletes. Eur J Appl Physiol. 2014;114:2579–86.
47. Callow DD, Pena GS, Stark CEL, Smith JC. Effects of acute aerobic exercise on mnemonic discrimination performance in older adults. J Int Neuropsychol Soc. 2023;29:519–28.
48. Cicek A, Ozdincler AR, Tarakci E. Interactive video game-based approaches improve mobility and mood in older adults: A nonrandomized, controlled trial. J Bodyw Mov Ther. 2020;24:252–9.
49. Colombo V, Mondellini M, Fumagalli A, Aliverti A, Sacco M. A virtual reality-based endurance training program for COPD patients: acceptability and user experience. Disabil Rehabil Assist Technol. 2023;:1–10.
50. Gitlin LN, Lawton MP, Windsor-landsberg lisa A, Kleban MH, Sands laura P, Posner J. In search of Psychological benefits exercise in healthy older adults. Journal of agining and health. 1992;4:174–92.
51. Hill MW, Oxford SW, Duncan MJ, Price MJ. The effects of arm crank ergometry, cycle ergometry and treadmill walking on postural sway in healthy older females. Gait Posture. 2015;41:252–7.
52. Loggia G, Gauthier A, Lemiere F, Drigny J, Desvergee A, Leconte P, et al. Cycle more with virtual reality: a proof of concept study in an institutionalised able-bodied geriatric population. Age Ageing. 2021;50:1422–5.
53. Mahajan A, Mahajan S, Tilekar S. A Pilot Randomized Controlled Trial of Interval Training and Sleep Hygiene for Improving Sleep in Older Adults. J Aging Phys Act. 2021;29:993–1002.
54. Miki E, Kataoka T, Okamura H. Feasibility and efficacy of speed-feedback therapy with a bicycle ergometer on cognitive function in elderly cancer patients in Japan. Psychooncology. 2014;23:906–13.
55. Pauwels C, Roren A, Gautier A, Linières J, Rannou F, Poiraudeau S, et al. Home-based cycling program tailored to older people with lumbar spinal stenosis: Barriers and facilitators. Ann Phys Rehabil Med. 2018;61:144–50.
56. Posner JD, Gorman KM, Windsor-Landsberg L, Larsen J, Bleiman M, Shaw C, et al. Low to moderate intensity endurance training in healthy older adults: physiological responses after four months. J Am

Geriatr Soc. 1992;40:1–7.

57. Ridgel AL, Ault DL. High-Cadence Cycling Promotes Sustained Improvement in Bradykinesia, Rigidity, and Mobility in Individuals with Mild-Moderate Parkinson's Disease. Parkinson's Disease. 2019;2019:1–7.
58. Salisbury D, Mathiason MA, Yu F. Exercise Dose and Aerobic Fitness Response in Alzheimer's Dementia: Findings from the FIT-AD Trial. Int J Sports Med. 2022;43:850–8.
59. Schwarck S, Busse N, Ziegler G, Glanz W, Becke A, Düzel E. Heart Rate Variability During Physical Exercise Is Associated With Improved Cognitive Performance in Alzheimer's Dementia Patients-A Longitudinal Feasibility Study. Frontiers in Sports and Active Living. 2021;3.
60. Willenheimer R, Erhardt L, Cline C, Rydberg E, Israelsson B. Exercise training in heart failure improves quality of life and exercise capacity. Eur Heart J. 1998;19:774–81.
61. Yu F, Vock DM, Zhang L, Salisbury D, Nelson NW, Chow LS, et al. Cognitive Effects of Aerobic Exercise in Alzheimer's Disease: A Pilot Randomized Controlled Trial. J Alzheimers Dis. 2021;80:233–44.
62. Lepretre P-M, Vogel T, Brechat P-H, Dufour S, Richard R, Kaltenbach G, et al. Impact of short-term aerobic interval training on maximal exercise in sedentary aged subjects. Int J Clin Pract. 2009;63:1472–8.
63. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–73.
64. Vogel T, Brechat P-H, Leprêtre P-M, Kaltenbach G, Berthel M, Lonsdorfer J. Health benefits of physical activity in older patients: a review. Int J Clin Pract. 2009;63:303–20.
65. Graves JM, Iyer KR, Willis MM, Ebel BE, Rivara FP, Vavilala MS. Emergency department-reported injuries associated with mechanical home exercise equipment in the USA. Inj Prev. 2014;20:281–5.
66. Fang Yu null. Guiding research and practice: a conceptual model for aerobic exercise training in Alzheimer's disease. Am J Alzheimers Dis Other Demen. 2011;26:184–94.
67. Tollár J, Nagy F, Moizs M, Tóth BE, Sanders LMJ, Hortobágyi T. Diverse Exercises Similarly Reduce Older Adults' Mobility Limitations. Medicine & Science in Sports & Exercise. 2019;51:1809–16.
68. Tabak R, Aquije G, Fisher BE. Aerobic exercise to improve executive function in Parkinson disease: a case series. J Neurol Phys Ther. 2013;37:58–64.
69. Pang MYC, Eng JJ, Dawson AS, Gylfadóttir S. The use of aerobic exercise training in improving aerobic capacity in individuals with stroke: a meta-analysis. Clin Rehabil. 2006;20:97–111.
70. Chueh T-Y, Chen Y-C, Hung T-M. Acute effect of breaking up prolonged sitting on cognition: a systematic review. BMJ Open. 2022;12:e050458.

Tables

Tables 1 to 4 are available in the Supplementary Files section

Figures

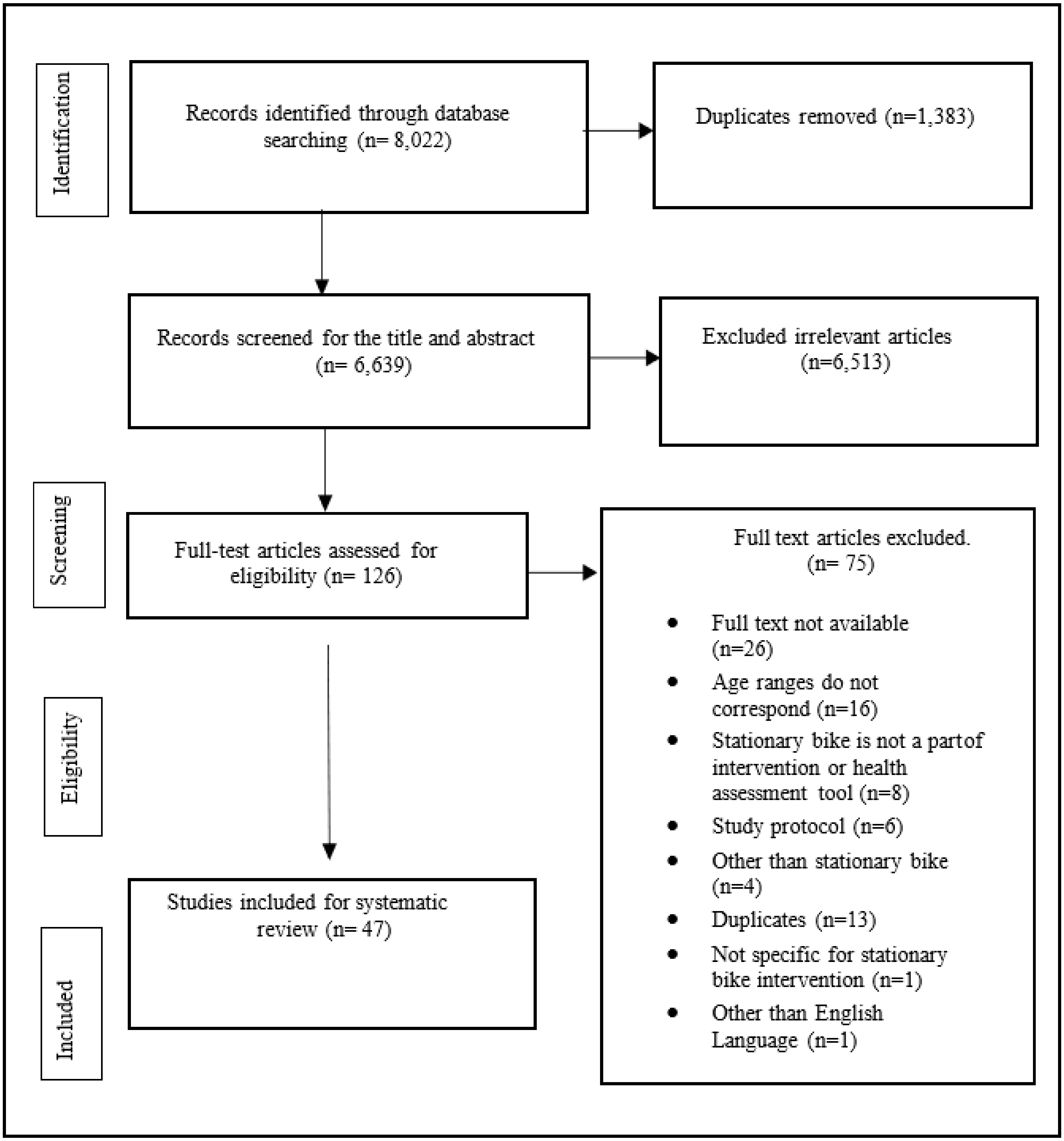
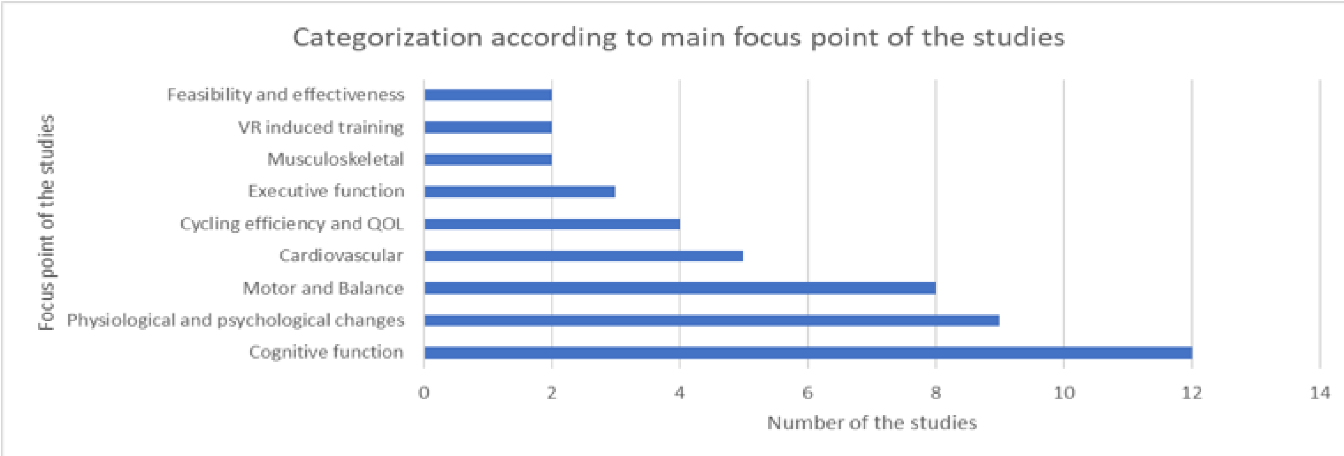


Figure 1

PRISMA Flow Diagram-Systematic Review: Study selection process



QOL=Quality of Life, VR=Virtual reality

Figure 2

Categorization according to focus points of the studies

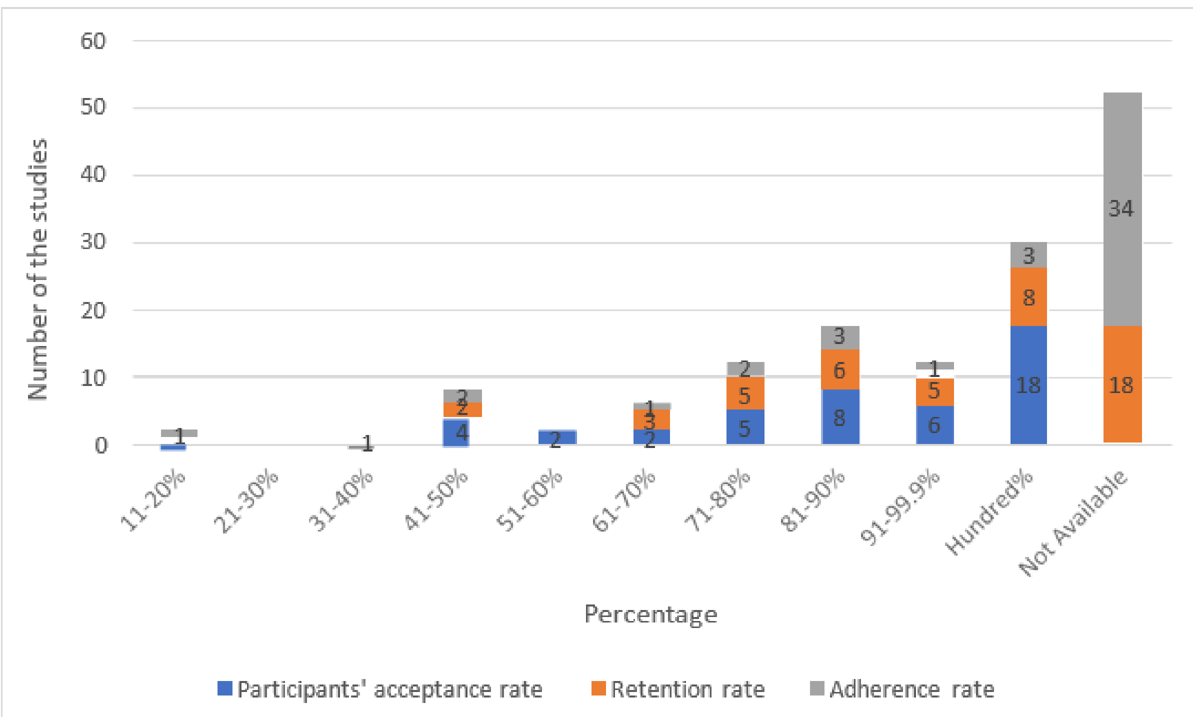


Figure 3

Acceptance, retention, and adherence rate of stationary bikes among the study population

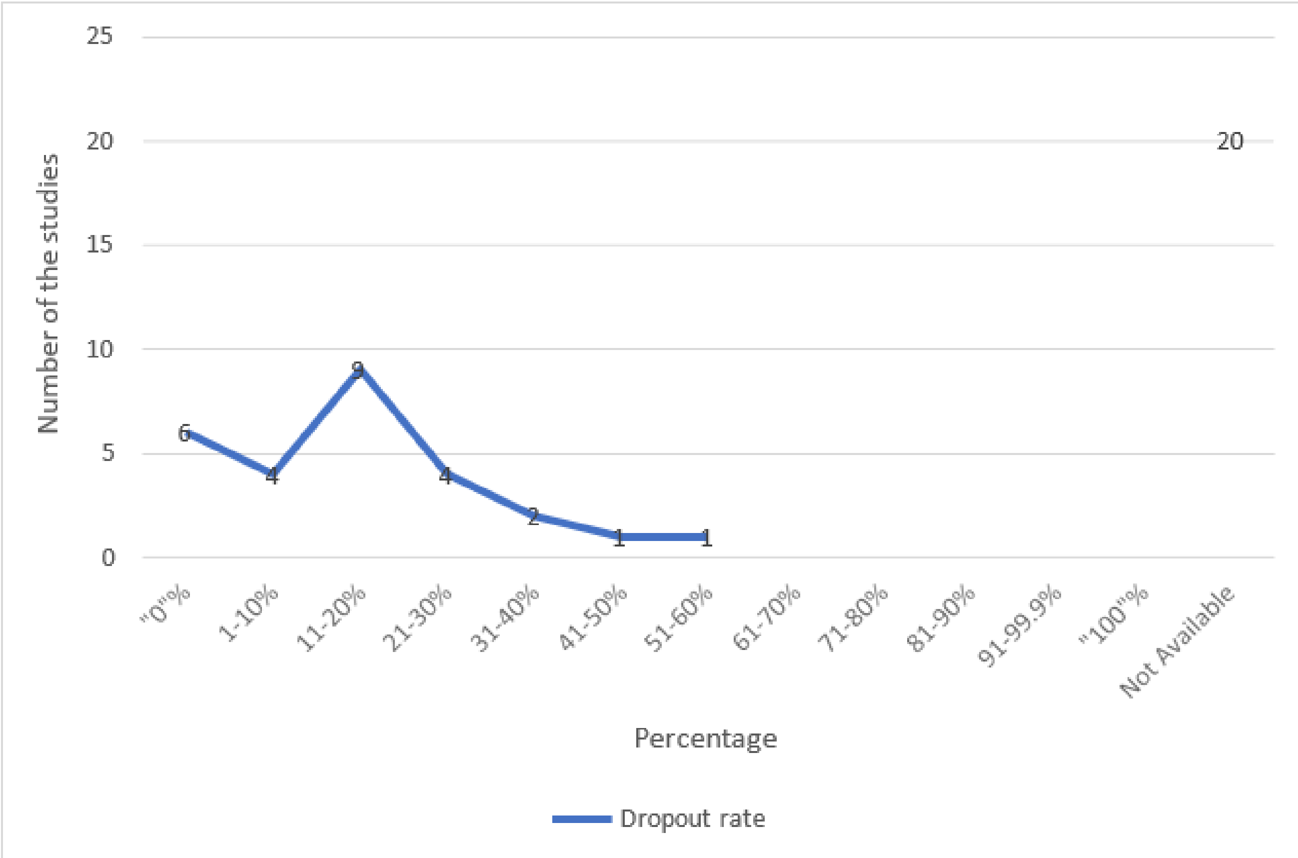


Figure 4

Dropout rate of stationary bikes among study population

Supplementary Files

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