The Effectiveness of Exercise on Improving Cognitive Function in Older People: A Systematic Review

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ABSTRACT

Background: The well-documented physical benefits of exercise and the value of exercise for improving mental health have raised the profile and role of exercise in health care. However, studies evaluating the effects of exercise on neurocognitive function have produced equivocal results.

Purpose: This study was designed to examine the effectiveness of exercise on improving cognitive function in older people.

Methods: Researchers used a narrative synthesis approach in this review and conducted a computer-based search in MEDLINE, CINAHL, Cochrane Library, and Airiti Library (Chinese) from 2006 to 2009 using the search terms exercise, physical activity, and cognition. Research quality appraisal was rated using Consolidated Standards of Reporting Trials criteria.

Result: This review included 12 medium- to high-quality randomized controlled trials. Most studies examined used a 60-minute exercise regimen scheduled three times per week that was continued for 24 weeks. Of the 12 studies, 8 revealed that exercise can improve cognitive function. Five studies focused on healthy older people and three studied older people who had impaired cognition at baseline. Analysis of the studies showed simple, one-component exercise as better for older people with cognitive impairment and multicomponent exercise as better for those without such impairment.

Conclusions/Implications for Practice: This systematic review demonstrated that an exercise regimen of 6 weeks and at least 3 times per week for 60 minutes had a positive effect on cognition. Whether multicomponent exercise is significantly more effective in improving cognitive function, particularly in healthy older people, should be tested using larger trials with more rigorous methodology.

Key Words: exercise, cognitive function, older people.

Introduction

Taiwan’s population of adults aged 65 years or over accounted for 10.7% of the total population at the end of 2010 (Department of Statistics, Ministry of the Interior, 2011). This population is expected to continue to grow through the next 30 years. Thus, aging is an increasingly important focus of Taiwan public health. Aging affects the functioning of central nervous, skeletalmuscular, cardiopulmonary, and other organ systems. Particularly, as a person ages, brain weight decreases 10% to 20%, blood flow slows by 30% to 40%, and the cranial nerve filament becomes entwined and develops plaque. These changes culminate in memory loss, reduced learning ability, and degradation of cognitive function, all of which undermine the independence of older people in their activities of daily living and generate stress on the family, society, the healthcare system, and the economy (Pang et al., 2002). As a population ages, the need for effective methods to slow the decline of cognitive function and even improve older adults’ cognitive performance to maintain their independent function has become increasingly urgent.

As such, the well-documented physical benefits of exercise and the value of exercise for improving mental health have grown in importance (Hoffman et al., 2008). In the last decade, the use of exercise to slow cognitive decline and maintain the fluid intelligence of older people has greatly increased. Several mechanisms have been suggested to explain the relationship between exercise and cognitive functioning. First, the main hypothesis is that exercise directly affects brain structure and functions. Increases in aerobic capacity are thought to augment cerebral blood flow, improve the utilization of oxygen and glucose in the brain, accelerate the transport of biochemical waste substances to maintain a stable flow of blood, and enhance blood antioxidant enzyme (glutathione peroxidase, GSH-Px) activity to clear oxidative free radicals rapidly away (Radak et al., 2001). Second, exercise can promote the synthesis of neurogrowth factors such
as brain-derived neurotrophic factor and insulin-like growth factor, stimulate neurogenesis, increase interconnections between synapses, and even enhance nerve message processing capacity (Pereira et al., 2007). Third, exercise can regulate neurotransmitter synthesis and stimulate the release of calcium, resulting in dopamine secretion and increased acetylcholine. All of these are necessary to maintain nerve functions, foster a positive mood, and enhance cognitive function (Cotman & Berchtold, 2002). Furthermore, exercise can increase the cognitive reserve capacity of the brain, reduce the rate of brain aging, and lower the risk of developing neurological diseases (Richard & Sacker, 2003). Lastly, psychological factors may play a role in mediating the relationship between exercise and cognition. Exercise improves psychological well-being by giving people positive feelings, resulting in relaxation; mediating stress responses; increasing self-confidence; and improving the quality of sleep among other things. Psychological well-being has been associated with good cognitive functioning (Netz, Wu, Becker, & Tenenbaum, 2005).

However, studies evaluating the effects of exercise on neurocognitive function have produced equivocal results. Such inconsistencies stem from the diversity of research methodologies used in terms of content, duration, intensity, exercise program frequency, inclusive and exclusive criteria for samples, and cognitive measure tools (Hoffman et al., 2008; Lautenschlager et al., 2008; Marmeleira, Godinho, & Fernandes, 2009).

In light of such inconsistencies, we review the relevant literature related to the effectiveness of exercise on improving cognitive function in older people to confirm its effect and find the applicability of population to provide a reference to clinical practitioners or researchers in applying exercise program.

The Review
Exercise is a subcategory of physical activity that is defined as planned, structured, repetitive, and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective. Exercise is commonly used to refer to physical activity performed during leisure time, with the primary purpose of improving or maintaining physical fitness, physical performance, or health (Centers for Disease Control and Prevention [CDC], 2009). This study adopted an operational definition for this review based on the CDC definition of exercise. Exercise and physical activity have been used interchangeably in the past. To avoid missing potential relevant articles for this evidence report, we still used both terms as valid search terms but rechecked those studies on physical activity to ensure that only those that meet the operational definition of exercise by the CDC were included. The aim of this review was to provide a critical appraisal of the effectiveness of exercise on improving cognitive function in older people. The authors used a narrative synthesis approach for this review.

Methods
Search Strategy
Two full systematic review reports on similar topics have previously been published (Angevaren et al., 2008; Yu, Kolanowski, Strumpf, & Eslinger, 2006). In these reports, literature articles up to 2005 were reviewed. One focused on people without cognitive impairment (Angevaren et al., 2008) and one focused on subject groups with Alzheimer’s disease (Yu et al., 2006). This study extended the review further to include literature published from 2006 to 2009 and subject groups with/without cognitive impairment. Relevant studies were searched independently in the MEDLINE, CINAHL, Cochrane library (2006 to 2009), and Airiti Library (Taiwan Electronic Periodical Services and Electronic Theses and Dissertations System, from the earliest records up to 2009) databases using the search terms exercise, physical activity, and cognition. The literature search was limited to older adult populations, and only articles published in English or Chinese were included. Study selections and citations were assessed by the authors following predetermined inclusion/exclusion criteria to identify the potential relevance for full review after duplicates were removed.

Inclusion Criteria
Included trials met the following criteria: (1) participants were older adults (age ≥65 years); (2) the intervention involved a planned, structured, repetitive, and purposive exercise training or physical activity program; (3) outcomes included cognitive function; and (4) type of trial was a randomized controlled trial (RCT).

Exclusion Criteria
Excluded from this systematic review were studies that (1) did not examine the effects of exercise training on cognitive function, (2) provided no comparison group, (3) included participants diagnosed with psychiatric disorders, (4) were review articles or systematic review articles.

Search Outcome
The literature search process identified 141 references, of which 129 were excluded, leaving a total of 12 for review (Figure 1).

Quality Appraisal
This study used Consolidated Standards of Reporting Trials criteria to assess the quality of all 12 trials, with only studies evaluated at either a medium or high level (Consolidated Standards of Reporting Trials score of 11 or higher) used to enhance the generalization of results (Bennett, 2005). All 12
trials were identified at medium to high quality, with three ranked high quality (16–22) and nine ranked medium quality (11–15). Table 1 summarizes research programs, measures, and results.

**Data Abstraction and Data Synthesis**

Study data were analyzed according to study design, setting, participant and provider characteristics, country of intervention, duration and types of intervention, the way the intervention was conducted, cognitive measure tools used, results, and attrition rate. Extracted data were collated and displayed in tabular summaries. Cross-checking was used to reduce data handling error risk. The narrative synthesis of findings from selected trials was constructed from textual descriptions, complemented with tabular summaries and results.

**Results**

**Trial Characteristics**

All 12 trials examined used randomized controlled designs. Most (66.7%) were conducted by a multidisciplinary research team, and most took place in the United States. The first authors’ professional areas tended to be in the sports sciences (58.3%) rather than in medicine, physical therapy, or nursing. The number of participants in each trial ranged from 30 to 202. Older adult participants with and without cognitive impairment were 50%, respectively, and only 16.7% of the trials focused on female participants.

**Intervention Duration and Types**

The wide range of exercise regimens used included walking, treadmill running, extremity stretching exercise, weight-bearing strength training, and swimming. The interventions used in the trials included moderate- and high-intensity resistance exercise programs that were often designed for a healthy older population (Carral & Perez, 2007; Cassilhas et al., 2007) and aerobic and strength-and-flexibility activities (Colcombe et al., 2006; Hoffman et al., 2008; Smiley-Oyen, Lowry, Francois, Kohut, & Ekkekakis, 2008). The duration of interventions ranged from 6 weeks to 12 months (Colcombe et al., 2006; Kwak, Um, Son, & Kim, 2008). The majority lasted 24 weeks. The exercise sessions themselves lasted from anywhere from an unknown amount of time (Hoffman et al., 2008) to 2 hours (Christofoletti et al., 2008). Five trials (41.7%) with exercise sessions of 60 minutes comprised the majority. Only one trial had a session lasting 2 hours. Three times per week was the most common frequency (10 trials, 83.3%).

**Cognitive Measure Tools**

Cognitive measure tools vary based on trial requirements (Table 1). The 12 trials examined in this study employed a total of 63 different cognitive tests. Cognitive measure tools in the study samples can be summarized into global and domain specific. The Mini-Mental State Examination (MMSE), Alzheimer’s Disease Assessment Scale–Cognitive Behavior section, Clinical Dementia Rating, and MRI brain volume were included in the global cognitive measures. Domain-specific cognitive measures included memory, executive functions, verbal fluency, information processing.
<table>
<thead>
<tr>
<th>Author/QA</th>
<th>Setting</th>
<th>Participant</th>
<th>Intervention</th>
<th>Measuring Time and Cognitive Tool</th>
<th>Results</th>
<th>AR</th>
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<tr>
<td>Carral and Perez (2007) QA = 14</td>
<td>Indoor sports center</td>
<td>62 healthy older individuals in Spain</td>
<td>Conducted in group 45 min/session 5 days/week 5 months’ duration G1: aquatic exercise + strength training (n = 27) G2: aquatic exercise + calisthenics training (n = 29)</td>
<td>Time: 0 months, 5 months Tool: MMSE</td>
<td>G1 and G2 achieved a significant improvement in their cognitive capacity after the program (p = .03 and p = .02, respectively).</td>
<td>9.7%</td>
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<tr>
<td>Cassilhas et al. (2007) QA = 11</td>
<td>Psychobiologic center</td>
<td>62 healthy older individuals in Brazil</td>
<td>Conducted in group by professionals of a psychobiologic center 60 min/session 3 days/week 24 weeks’ duration *75% attendance or greater was eventually analyzed Control group: stretching (n = 23) Moderate resistance training group: 50% of 1 RM load training (n = 19) High resistance training group: 80% of 1 RM load training (n = 20)</td>
<td>Time: 0 weeks, 24 weeks Tools 1. WAIS III: three tests 2. WMS-R: three tests 3. Toulous-Pieron’s concentration attention test 4. Rey-Osterrieth</td>
<td>Two experimental groups performed significantly better than the control group in (1) digit span (forward), (2) Corsi’s block-tapping (backward, similarities), (3) Toulous-Pieron (error), and (4) Rey-Osterrieth (immediate recall).</td>
<td>0%</td>
</tr>
<tr>
<td>Christofoletti et al. (2008) QA = 14</td>
<td>Institution</td>
<td>54 institutionalized older individuals with dementia in Brazil</td>
<td>Individual exercise conducted by a physiotherapist; in-group occupational activities conducted by an occupational therapist G1: 2 hours per session, 5 days/week G2: 60 min/session, 3 days/week 6 months’ duration G1: physiotherapy + occupational therapy + physical education (n = 12) G2: kinesitherapeutic exercises (n = 12) G3: control (n = 17)</td>
<td>Time: 0 months, 6 months Tools 1. MMSE 2. Brief Cognitive Screening Battery: eight tests</td>
<td>There was a main effect of time (F = 9.0, p &lt; .05; effect size = 0.94), indicating cognitive decline in all groups after 6 months. No benefits on cognitive functions between G1 and G3 and G2 and G3, except in the clock drawing test (F = 4.4, p &lt; .05) and verbal fluency test (F = 26.5, p &lt; .05)</td>
<td>24.1%</td>
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<th>Author/QA</th>
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<tr>
<td>Colcombe et al. (2006)</td>
<td>Campus</td>
<td>62 healthy older individuals in the United States F: 34 vs. M: 28 Age: 66.20 years Education: 13.75 years MMSE: 29.2</td>
<td>Conducted individually by a trained exercise leader 60 min/session 3 days/week 6 months’ duration Aerobic group: kept 60%–70% HR reserve (n = NR) Nonaerobic group: stretching and toning movement (n = NR)</td>
<td>Time: 0 months, 6 months Tool: MRI brain volume, VO\textsubscript{2}</td>
<td>The aerobic group showed a significant increase in VO\textsubscript{2} and brain volume of the dorsal anterior cingulate cortex/ supplementary motor area, middle frontal gyrus (rIFG), left superior temporal lobe, and anterior white matter tracts, compared with older adult controls.</td>
<td>0%</td>
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<td>Hoffman et al. (2008)</td>
<td>Gymnasium and home</td>
<td>202 depressed older individuals in the United States F: 153 vs. M: 49 Age: 51.7 years Education: 15.80 years</td>
<td>Conducted individually by a trained exercise physiologist NR min/session 3 days/week 16 weeks’ duration Supervised exercise group: kept 70%–85% of HR reserves by an exercise physiologist (n = NR) Home-based exercise group: kept 70%–85% of HR reserves by themselves (n = NR) Sertraline group (n = 42) Placebo pill group (n = 35)</td>
<td>Time: 0 weeks, 16 weeks Tool 1. Executive function: four tests 2. Verbal memory: two tests 3. Verbal fluency/ working memory: three tests</td>
<td>After 16 weeks of treatment, both exercise groups showed no more significant improvement than did the placebo pill group in executive function, verbal memory, and verbal fluency/working memory.</td>
<td>20.8%</td>
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<tr>
<td>Kwak, Um, Son, and Kim (2008)</td>
<td>Not reported</td>
<td>30 patients with dementia in Korea F: 30 vs. M: 0 Age: 80.97 years Years of education: NR MMSE: 14</td>
<td>Conducted 30–60 minutes per session 3 days/week 12 months’ duration Exercise group: upper and lower extremity exercise (n = 15) Control group: no intervention (n = 15)</td>
<td>Time: 0 months, 6 months Tool: MMSE months, 12 months</td>
<td>Exercise group: the MMSE score increased by 20% and 30% at 6 and 12 months. 0 months: 14.53 6 months: 17.47 (p &lt; .05) 12 months: 19.07 (p &lt; .01) Control group: the MMSE score did not change in the control group.</td>
<td>0%</td>
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### TABLE 1. Characteristics of Included Trials, continued

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<tr>
<td>Lautenschlager et al. (2008) QA = 20</td>
<td>Home</td>
<td>170 older individuals with Alzheimer in Australia F: 86 vs. M: 84 Age: 68.65 years Education: 12.35 years ADAS-Cog: 7.00</td>
<td>Conducted individually by client 50 min/session 3 days/week 24 weeks’ duration *People in each group who achieved the equivalent of 70,000 steps or more per week were eventually analyzed. Exercise group: walking + strength training (n = 69) Education group: received educational material (n = 69)</td>
<td>Time: 0 months, 6 months, 6 months (F/U), 12 months (F/U) Tools 1. ADAS-Cog 2. CERAD: four tests 3. CDR</td>
<td>The exercise group had more significant improvement than the educational group in ADAS-Cog (p = .04), Words list delay recalled (p = .02), and CDR sum of boxes (p = .09).</td>
<td>18.8%</td>
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<td>Marmeleira et al. (2009) QA = 11.5</td>
<td>Gymnasium</td>
<td>32 healthy older individuals in Portugal F: 7 vs. M: 25 Age: 68.3 years Education: 4.95 years MMSE: 28.5</td>
<td>Conducted 60 min/session 3 days/week 12 weeks’ duration Exercise group: physical activities (n = 16) Control group: normal daily activities (n = 16)</td>
<td>Time: 0 weeks, 12 weeks Tools 1. Single-task condition: five tests 2. Dual-task condition: three tests 3. Useful field of view: three tests 4. Time-to-contact: two tests 5. Foot tap test 6. Timed up-and-go test 7. Functional reach test 8. Trail-making test, part B 9. SCWT</td>
<td>1. Single-task condition: The exercise group showed significant improvements than did the control group in reaction time (−7%; p = .01), movement time (−15%; p = .002), and response time (−10%; p = .001). 2. Dual-task condition: The exercise group showed significant improvements than did the control group in reaction time (−11%; p = .001), movement time (−16%, p = .001), and response time (−13%; p &lt; .001). 3. Useful field of view: speed of visual processing was significantly greater in the exercise group than in the control group (−66% vs. 2%; p = .032)</td>
<td>0%</td>
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<td>Author/QA</td>
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<td>Scherder et al. (2005) QA = 11.5</td>
<td>Nursing home</td>
<td>43 older individuals with mild cognitive impairment in the Netherlands F: 38 vs. M: 5 Age: 86.33 years Education: 2.73 years MMSE: 9.61</td>
<td>Conducted individually 30 min/session 3 day/week 6 weeks' duration Walking group: walking (n = 15) Hand/Face exercise group: hand/face exercise (n = 13) Control group: social visits (n = 15)</td>
<td>Time: 0 weeks, 6 weeks, 6 weeks (F/U) Tools 1. Executive functions at 6 weeks (1) Category naming Walking group was better than control group, F(1, 27) = 5.02; p = .02, effect size = .16 Hand/Face exercise group was better than control group, F(1, 25) = 3.27; p = .04, effect size = .12 (2) Trail-making A + B Walking group was better than control group, F(1, 23) = 2.45; p = .07, effect size = .1 Hand/Face exercise group was better than control group, F(1, 21) = 5.03; p = .02, effect size = .19 2. Memory: No difference among the three groups. 3. Reaction time: Four tests 2. Stroop test: Three tests 3. WCST: Three tests</td>
<td>1. Executive functions at 6 weeks 0%</td>
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<tr>
<td>Smiley-Oyen, Lowry, Francois, Kohut, and Ekkekakis (2008) QA = 16.5</td>
<td>NR</td>
<td>57 healthy older individuals in the United States F: 41 vs. M: 16 Age: 70.19 years Education: 15.31 years MMSE: NR</td>
<td>Conducted by a qualified exercise leader 50 min/session 3 days/week 10 months' duration CARDIO group: aerobic exercise (n = 28) FLEX-TONE group: strength, flexibility, and balance exercise (n = 29)</td>
<td>Time: 1 month, 4–5 months, 10 months Tools 1. Reaction time tests: four tests 2. Stroop test: three tests 3. WCST: three tests</td>
<td>At 10 months, the cognitive function of the two exercise groups surpassed that both at 4–5 months and 1 month. Particularly in the CARDIO group, the Stroop test such as word–color conflict (p = .001) and word–color conflict error (p = .002), had a significant improvement.</td>
<td>0%</td>
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speed, recognition, and reaction time. Only 3 trials used global cognitive measures, with the rest using a combination of global and domain-specific cognitive measures.

Because some trials listed only the items measured and not the tools employed, it was difficult to determine whether a consistent tool had been used to measure the same item from study to study. Therefore, this review did not analyze cognitive measuring tools.

Participants

The systematic review included participants who were divided into two groups with normal cognitive function and impaired cognitive function, as described in the following. The cognitive status of trial participants, normal or impaired, was adopted per the author's definition in the trial and not by cognitive tests.

**Effectiveness of exercise on older people with normal cognitive function**

Of 12 exercise trials, 6 focused on older people with normal cognitive function. Colcombe et al. (2006) randomly assigned 59 healthy older adults (average MMSE score = 29.4) to participate in either a cardiovascular exercise group (EG) or a nonaerobic exercise control group (CG) for three 1-hour exercise training sessions per week lasting for a 6-month
period. They measured magnetic resonance imaging and maximal oxygen uptake before and after the 6-month fitness intervention. After the intervention, the aerobically exercising older adults showed a significant increase in maximal oxygen uptake and brain volume in the dorsal anterior cingulate cortex supplemenary motor area, middle frontal gyrus, left superior temporal lobe, and anterior white matter tracts as compared with the older adult controls.

Carral and Perez (2007) selected 62 community-dwelling older women with MMSE scores ≥22 participating in a randomized trial. They assigned participants either to a combined program of aquatic exercise plus high-intensity strength training (Group 1) or calisthenic training (Group 2). Both groups trained 5 days a week for 5 months. After the program, both groups obtained significant cognitive improvement in MMSE scores (Group 1, p = .034; Group 2, p = .021).

Cassilhas et al. (2007) reported that a 24-week (3 days/week) regimen of moderate- and high-intensity resistance exercise program designed for healthy older people produced equally beneficial effects on cognitive function. Sixty-two participants were randomly assigned to control (n = 23), moderate-resistance (n = 19), and high-resistance (n = 20) groups. The results showed the two experimental groups performed significantly better than the CG in forward digit span, Corsi’s block-tapping (backward, similarities), Toulous-Pieron test (error), and Rey-Osterrieth (immediate recall). Smiley-Oyen et al. (2008) designed an RCT consisting of two interventions and pre-post tests. Fifty-seven older adults participated in either thrice weekly aerobics (CARDIO group, n = 28) or strength-and-flexibility (FLEX-TONE group, n = 29) exercise training for 10 months. Cognitive function at 10 months for the two EGs both surpassed levels at 4–5 months and at 1 month. Particularly in the CARDIO group, Stroop test values such as word–color conflict (p = .001) and word–color conflict error (p = .002) showed significant improvement.

Marmeleira et al. (2009) randomly assigned 32 healthy older individuals (MMSE scores ≥28) to either an EG (n = 16) or a CG (n = 16). Participants in the EG in the supervised exercise program faced largely cognitive demands, including activities such as dual-tasking, working with peripheral vision, planning and decision making, dependence on working memory, targeting speed processing, and response inhibition. Each session lasted approximately 60 minutes, 3 days a week for 12 weeks. Significant positive cognitive effects from participation in the EG were identified at the 12-week follow-up.

In conclusion, the results of the previously mentioned studies indicated a positive effect of exercise on cognitive function in healthy older people. On the contrary, Hoffman et al. (2008) concluded little evidence to support the benefits of an aerobic exercise intervention on neurocognitive performance in patients with major depressive disorder but without a bipolar disorder or psychotic depression. A total of 202 sedentary advanced older individuals with major depressive disorder with no cognitive impairment were randomly assigned to one of four groups, namely, (1) supervised exercise, (2) home-based exercise, (3) sertraline (an antidepressant of the selective serotonin reuptake inhibitor), and (4) placebo pill. After the 16-week treatment, the performance of participants who exercised was no better than that of participants who received placebo across all neuropsychological tests (executive function, verbal memory, verbal fluency/working memory).

**Effectiveness of exercise on older people with impaired cognitive function**

Six exercise trials were designed for older people who had impaired cognitive function. Scherder et al. (2005) compared the effectiveness of two types of exercise with varying intensities: walking and hand/face exercises. The study randomly assigned the 43 older individuals with mild cognition impairment (mean short form MMSE score = 9.61) into three groups, namely, walking, hand/face exercises, and control (n = 15, 13, 15, respectively). All participants received individual treatment for 30 minutes a day, three times a week, for 6 weeks. Performance on Category Naming and Trail-making A + B was significantly better in both EGs after 6 weeks of treatment, but no significant difference among the three groups at the 12-week follow-up was observed. These findings suggested that the treatment effect could not be maintained during nontreatment periods. However, only 2 of 12 trials continued to track the long-term effects after exercise intervention, and both focused on the cognitively impaired older people.

Kwak et al. (2008) conducted a trial with a prospective, two-group design, where 30 female patients with senile dementia who participated in the study were assigned into two groups: an EG (n = 15) and a CG (n = 15). The EG completed an exercise program, such as stretching, upper extremity exercise, lower extremity exercise, and walking, lasting 30–60 minutes per day, two to three times per week, for 12 months. The exercise program resulted in significant improvements in MMSE scores (pre: 14.53, post: 19.07; p < .01), as compared with those in the CG.

In another study by Lautenschager et al. (2008), a significant difference in the Alzheimer’s Disease Assessment Scale–Cognitive Behavior section, words list delay recall, and Clinical Dementia Rating sum of boxes between the experimental group and the CG was observed after a walking exercise program trial in older adults at risk for Alzheimer for 50-minute sessions, three times a week, over a 24-week span.

However, opposite results have also been observed. Christofoletti et al. (2008) recruited 54 institutionalized older people with mixed dementia (mean MMSE score = 15.3) and allocated them into three groups, namely, Group 1, an interdisciplinary program composed of physiotherapy, occupational therapy, and physical education (n = 17); Group 2, physiotherapy program (n = 17); and Group 3, control (n = 20). The two experimental groups received physiotherapy of varying intensities for 6 months. Results showed that global cognition did not improve through treatment, but...
attenuation was observed in the decline of global cognition on two specific cognitive domains (clock drawing, verbal fluency test) in Group 3.

Stevens and Killeen (2006) also found results showing exercise as ineffective. They examined the cognitive effect of exercise on nursing home residents with mild to moderate dementia. Seventy-five residents were randomly assigned to three groups. Group 1 (n = 30) received no intervention; Group 2 (n = 21) received a social visit equivalent in duration and frequency to the exercise program in group 3; and Group 3 (n = 24) undertook a 30-minute group exercise program three times per week for 12 weeks. Findings from the clock drawing test indicated that exercise may slow the dementia-related decline of cognitive symptoms, although results lacked statistical significance (p = .524).

Researchers van Uffelen, Chinapaw, van Mechelen, and Hopman-Rock (2008) designed an RCT in which 152 participants with mild cognitive impairment were assigned to two interventions. These included (1) either a 60-minute, twice-weekly, group-based program of moderate-intensity walking (n = 77) or a low-intensity placebo activity program (n = 75) for 1 year and (2) daily vitamin B complex pills (n = 78) or placebo pills (n = 74) for 1 year. Findings revealed that the walking program and/or vitamin B supplementation did not improve cognition in either the 6-month or 1-year follow-up. However, in the walking program, each percentage increase in attendance by women enhanced their attention performance (Stroop Color Word Test–Attention, p = .04). Men with at least 75% attendance showed memory benefits (Auditory Verbal Learning Test, p = .04).

Discussion

Although the 12 trials followed disparate exercise regimens, frequency, intensity, and duration were similar. Trials showed a positive effect for exercise on cognition when the exercise regimen lasted for 6 weeks and occurred at least three times per week for 60 minutes. However, there were issues about research design and quality, participants, tools, and results that should be further clarified and discussed.

In terms of research design and quality, although all trials were randomized, prospective, two-or-more group pre-post test designs, only three trials used large samples sizes (Hoffman et al., 2008; Lautenschlager et al., 2008; van Uffelen et al., 2008). The trials included in this systematic review were relatively small, with trial participants unevenly distributed between healthy and cognitively impaired older individuals. The score for reporting quality was centralized at 11 points (medium quality). However, only two (16.7%) studies (Lautenschlager et al., 2008; van Uffelen et al., 2008) reported explicitly on concealment of allocation, appropriate blinding, and the use of intention-to-treat for handling attrition in the analysis. Thus, application of the findings of this study should relatively conservative due to the ambiguous methodological description of the trials examined.

Although 2 of the 12 studies (Lautenschlager et al., 2008; Scherder et al., 2005), both focusing on older people with impaired cognition, followed up on the long-term effects of exercise intervention, their findings were completely opposite from one another. In examining the results of two trials, we found that Lautenschlager et al. (2008) analyzed only participants who achieved the equivalent of 70,000 steps or more per week after the exercise program, thus correlating high compliance and continuous exercise with continued positive effects on cognitive function.

In terms of subject issues, participants covered in this study were of two cognitive function types, namely, normal and impaired. The cognitive function presented by the MMSE score was not consistent in terms of “healthy” or “impaired” status. The average MMSE score for older people with impaired cognition (van Uffelen et al., 2008; MMSE score = 27–28) was greater than in those with normal cognitive function (Carral & Perez, 2007; MMSE score = 22.07–24.39).

Four trials, however, did not present MMSE scores (Cassilhas et al., 2007; Hoffman et al., 2008; Smiley-Oyen et al., 2008; Stevens & Killeen, 2006). In addition, MMSE score was profoundly influenced by years of education and age (Anthony, Leresche, Nia, VonKorff, & Folstein, 1982; Tombaugh & McIntyre, 1992). However, most studies examined did not record years of education in their demographic data or the adjusted MMSE cutoff score by years of education (Carral & Perez, 2007; Cassilhas et al., 2007; Kwak et al., 2008; Stevens & Killeen, 2006; van Uffelen et al., 2008). Therefore, any inferences that the positive effect on cognition was found more frequently in the trials designed for healthy older people should be carefully considered.

Subsequently, discussing research tools, most studies adopted multiple domain-specific cognitive measures. Marmeleira et al. (2009) applied 17 cognitive tests, and Smiley-Oyen et al. (2008) spent up to 90 minutes for cognitive tests. Because of the need for a special computer or instruments for measuring, testing often took place in a laboratory rather than clinical setting. Such a complicating, time-consuming, and difficult implementation of cognitive tests in a scientific setting may obstruct observations of cognition in terms of the intended effects as well as disallow comparison of cognitive effects on various trials. Angevaren et al. (2008) recommended the development and use of a smaller battery of cognitive tests to render research on cognition transparent and heighten result reproducibility.

Finally, 8 of the 12 trials (66.7%) demonstrated the positive effect of exercise on cognition when the exercise regimen lasted for 6 weeks and occurred at least three times per week for 30 minutes. This finding is similar to the one reported in the meta-analysis by Colcombe and Kramer (2003), whereby they concluded that 30-minute aerobic exercise enhanced the cognitive capacity of adults aged 65–70 years.

From analysis of the five studies that focused on healthy older people and the three that focused on older people who had impaired cognition at baseline that showed positive
effects, it appeared that simple, one-component exercise was better for older people with cognitive impairment (2/8, 25%). Healthy older people demonstrated positive effects with multicomponent exercise (5/8, 62.5%; Table 2). This indicated that exercise programs should not be too complicated for cognitively impaired older people and be diversified for healthy older people.

Limitations
Strengths of the current review are its selection of RCTs with medium to high quality and its focus on older people. Positive findings added support to the beneficial effects of exercise on cognitive function in older adults. This review continued the work of two previous systematic reviews. Because of the short review time, the limited number of research articles may have biased the results. Also, as only articles published in English were selected, it should not be ruled out that studies in which exercise demonstrated statistically significant effects on cognitive function have been published in other languages. Finally, all included trials differed in several dimensions, including participant characteristics, inclusion/exclusion criteria, exercise content, and outcome evaluations, which may limit the generalizability of exercise as a therapeutic modality for improving cognitive function in older people.

Implications for Nursing Research
Findings suggest the potential of exercise to improve older people’s cognitive function. However, additional larger research trials with more rigorous methodology are required to evaluate the sustained effectiveness of exercise on cognitive function and to determine whether multicomponent exercise is more effective in improving cognitive function, particularly for healthy older people. The use of the MMSE as a cognitive screening tool must include the MMSE score, and years of education must be part of demographic data. In addition, an adjusted MMSE with a cutoff score by years of education should be included. Consequently, one could compare the cognitive function of participants at baseline and infer whether the positive effect on cognition is found more frequently in the studies designed for healthy older people.

Finally, the attrition rate in the examined studies ranged from 0% to 24.1%. This factor is crucial to assessing the effectiveness of exercise on cognitive function. Personal preference, type of exercise, and motivation in older people should also be considered. Qualitative research should be used to interview those older people unable to sustain exercise in order to ascertain the reasons for such. On the basis of qualitative results, researchers would then be better equipped to design individualized exercise programs and introduce incentives for older people to enhance exercise participation and decrease dropout rates.

Conclusions
This review highlighted the efficacy of exercise intervention in enhancing cognitive function in older people. However, generally small sample sizes; variations in frequency, intensity, and duration of exercise; lack of evaluation of sustained effects; various outcome measures of cognition; and generally high dropout rates were prevalent weaknesses and limitations in these studies. There continues to be an urgent need in this research area for good-quality research with appropriately larger sample sizes. It would be beneficial to develop an appropriate and sustainable exercise regimen to put into practice, monitor short- and long-term effects on cognitive function, and derive and validate simple indices for cognitive assessment. Such should be examined in future studies.

References
*References marked with an asterisk indicate studies included in the meta-analysis.


運動對改善老人認知功能之成效——系統性文獻回顧

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背 景
運動對身體的好處已廣為證實，且運動在改善心智健康上也越顯其重要性。然而，運動對老人認知功能的成效為何，研究結果仍然不一致。

目 的
本研究旨在了解運動在改善老人認知功能的成效。

方 法
本文獻回顧採用敘事合成法，搜尋2006年到2009 MEDLINE、CINAHL、Cochrane Library、Airiti Library（中文期刊論文）等資料庫，使用的關鍵詞包括運動、身體活動、認知功能，研究對象為老人的研究，並運用CONSOR標準作為研究品質的評估。

結 果
共有12篇中至高品質的研究納入此次文獻回顧。本研究結果發現：每次60分鐘，每週3次，持續24週的運動計畫為多數研究採用；而12篇研究中有8篇顯示運動可以改善認知功能，其中研究對象有5篇是健康老人，3篇是認知受損老人；此外，單一項目運動對改善認知功能受損老人的成效較健康老人佳，而對健康老人而言，多面向運動則更具正向的效果。

結 論／實務應用
每次60分鐘、每週3次，持續6週的運動對老人認知功能即具有正向效益。而關於多面向運動對健康老人認知功能改善的成效，則需要採更嚴謹的研究方法及足夠樣本數來進一步證實。

關鍵詞：運動、認知功能、老人。