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REVIEW ARTICLE

Effects of horticultural therapy on health in the elderly: A review and meta-analysis

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Abstract

Aim Given the current aging population, the demand on medical facilities, facilities for elderly care, and even their high prevalence, it is crucial to investigate the advantages of older people. The purpose of our study was to systematically review the existing literature on the health effects of horticultural therapy as a treatment option for the elderly.

Subject and methods Article searches were conducted through five databases: Web of science, Science Direct, PubMed, EBSCO, and Google Scholar, according to the standard method of systematic evaluation and meta-analysis. Thirty-two published articles were included, and 27 relevant variables were meta-analyzed to assess the benefits of horticultural therapy in terms of physical and psychological functioning in the elderly.

Results Results show that horticultural therapy may be helpful in helping seniors lose weight -0.195 (95% CI -0.507,0.117), reduce their waist circumference -0.327 (95% CI -0.637, -0.017), lower their stress -0.339 (95% CI -0.610, -0.069) and cortisol -0.902 (95% CI -0.728, -0.002) levels, improve their physical flexibility 0.302 (95% CI 0.036, 0.569), social interaction 0.370, (95% CI 0.115, 0.624), and daily vegetables and fruit consumption 0.688 (95% CI: 0.287, 1.089).

Conclusion Horticultural therapy may be a useful tool for enhancing the physical, mental and social aspects of the elderly. However, there is substantial heterogeneity and wide variation in the quality of the included studies. Further high-quality studies, rigorous controls and adjustments for significant confounding variables, and larger populations are needed in the future to further our understanding of the link between horticultural therapy and elder health.

Keywords Horticultural Therapy · The elderly · Health benefits · Literature review · Meta-analysis

Introduction

With increasing life expectancy, there is a significant increase in the proportion of elderly and very elderly population and the problems caused by age-related diseases. Social support for the elderly is also becoming increasingly prominent. Sustained attention toward these problems is of highly important for medical expenditure and policy planning, labor trend forecast, and economic orientation of a country.

Older individuals are more vulnerable to physical decline, cognitive decline, and social inequality because of a variety of factors. There are three major enablers for these declines and issues. The first enabler is body composition changes and changes in physical function and metabolic risk factors associated with aging (Wilson and Kannel 2002). Brain diseases (cerebral arteriosclerosis, cerebral hemorrhage, and senile dementia) (Lyons et al. 2017; Parkar 2015), cardiovascular diseases (heart failure and coronary heart disease), digestive system diseases (chronic gastritis, constipation, and cirrhosis), respiratory system diseases, bone and muscle mass loss, and other common diseases of the elderly pose a great threat to their health and life (Bauer et al. 2020). The second enabler is psychological diseases, with common diseases including depression, anxiety, and suspicious (Abdoli et al. 2021). In addition, previous studies have shown that social concerns, including ageism and prejudice (Li et al. 2021), reduced social interaction in the family or community (Gyasi et al. 2020), and lifestyle-related issues (such as sedentary behavior, dietary risks, decreased fruit and vegetable consumption), are also important factors affecting the health of the elderly. These risks greatly affect the survival of the

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elderly. Especially since the COVID-19 outbreak, quarantine measures and social panic in some areas have led to reduced physical activity and sleep disturbances, as well as increased psychological symptoms among elderly (Gorenko et al. 2021; Lebrasseur et al. 2021; McKinlay et al. 2021).

WHO has proposed that the main indicators of health evaluation in elderly should not only focus on death and illness but should also pay attention to the quality of life and activities of daily living among elderly (Siegrist 2000). When they are in poor health, happiness will reduce, and the quality of life will decline (Nina 1992). Access to medical and/or pharmacological intervention alone is not sufficient to control these conditions (Afrooz et al. 2015). We have found strong recent evidence indicating that horticultural therapy (HT) can reduce morbidity, are cost effective, and achieve better outcomes in the elderly who are already in poor health conditions (Söderback et al. 2004). In the past, we believed that gardening, which is the work of growing, caring for plants, and maintaining the attraction of gardens, as an art or science other than botany (Smith 1998). Gardening is now often understood as a form of leisure, or as a means that is the easiest to achieve easy accessibility to a green space, or as a special therapeutic program (Joseph et al. 2017). The benefits of gardening may not only be limited to improved diet of individuals and increased ornamental value of a space but also include improved physical function, improved quality of life, and/or development of a social skill (e.g., via shared open spaces, skill building, and social bonding) (Rebecca et al. 2019). For some people, HT may help promote the mind-body-spirit connection (Chan et al. 2017). However, the definition of HT is complicated, and therapeutic gardening is thought to have the same meaning. Therefore, the definition of HT by the American society of horticultural therapy (AHTA) was adopted. HT is an effective complementary therapy for the social, educational, psychological, and physical adjustment of people in need of physical and mental assistance in the use of plant cultivation and gardening activities, assisted by trained therapists (Smith 1998). Although HT was introduced by the British scholar Linato Mecca in 1699, it has considerably evolved in the recent decades (Blake and Mitchell 2016). HT has been shown to improve or ease memory problems in patients (Shimada et al. 2019), especially those with Alzheimer's disease, helping them focus and gain confidence (Pedrinolla et al. 2019). It is also another effective nonpharmacological method for delaying the negative effects of aging. HT has been proven to enhance telomerase activity that can ameliorate DNA damage and stimulate DNA Damage Repair (DDR) (Lu et al. 2001), preventing not only replicating senescence but also senescence induced by oxidative stress and, thus, senescence-related age-related macular degeneration (AMD) (Christine et al. 2013). Potted flowers, flower bed making, plant pruning, and other gardening activities can help the elderly improve their living habits, forget worries, and improve their sleep quality (Gorenko et al. 2021). While participating in sowing, transplanting, watering, fertilizing, and harvesting activities (Makizako et al. 2015; Sin-Ae et al. 2020), the elderly sit, stand, and bend, using their eyes, head, fingers, hands, and feet at the same time for a comprehensive movement, leading to effective movement and preventing aging (Mallory et al. 2016). For elderly with limited access to social and material resources, HT has the potential to increase social interaction (Gonzalez et al. 2011). For example, participants share gardening diaries as a topic, which can foster coordination with others, improve social skills, reduce loneliness, and improve self-satisfaction and quality of life. However, there is also evidence showing that HT is less effective with time (Agnes and Custers 2011).

Although a growing body of literature attempts to quantify the association between HT and health well-being among elderly, systematic evaluations in this field have mainly focused on trial-controlled outcomes (Nicholas et al. 2019) or on a single indicator (Lin et al. 2022b). Previous reviews on this topic have been limited to 10 scopes (Lin et al. 2022a), causing a lack of robustness of evidence. To systematically determine the effects of HT on the physical and mental health of elderly as well as on their quality of life, different types of studies were considered for quality assessment and for a more rigorous analysis of between-group effects. In this review, 32 recent studies were systematically reviewed, and their quality was evaluated.

Methods

Search strategy

The search strategy was adopted according to the Standard Method (PRISMA) of systematic evaluation and meta-analysis, using various terms to identify and eliminate interfering results. The search was performed by retrieving data from five databases: Web of science, Science Direct, PubMed, EBSCO, and Google Scholar (Yao et al. 2021). Search terms related to horticultural therapy, indoor gardening, green health, and elderly, elderly patients, etc. The search was limited to articles published in peer-reviewed journals before July 2022. In PubMed and Web of Science, we combined various terms to search. The search strategy for Google Scholar was to combine each simplified word and free word related to horticultural therapy and select the top 100 records with the highest correlation. The complete search strategy is shown in the supplementary material (Table S1). Since the terminology of "horticultural therapy" is usually interchangeable and knowledge in the field is limited, we did not choose other restrictions, focusing on HT and covering

literature from clinical, medical and biological sciences, landscape architecture, and other disciplines.

Inclusion criteria

Therefore, to better and more objectively fit the purpose of our study, a comprehensive perspective was adopted, including original studies on HT and the elderly. Records in each database were independently screened by two reviewers (JY and TM) before full text reading. Duplicates and irrelevant papers were excluded using PICOS principles and the relevant papers were selected:

Participants: Individuals aged ≥ 60 years.

Intervention: As a means of intervention or complementary treatment, HT activities are not limited to indoor or outdoor locations. Selected articles focus on the use of plants as a material for work and production or performing various tasks under the guidance of a horticultural therapist as the main intervention; accordingly, it is not limited to just one method.

Comparator: A group of elders who participate in traditional activities or therapies, receive regular care or exercise, or attend educational classes, but do not participate in any gardening activities.

Outcome: Changes in physical or mental health or changes in lifestyle.

Interventional and observational studies were both included in our analysis. The sample of elders who participated in the study was selected regardless of their gender, physical or mental health conditions, and psychiatric conditions. Further, because the terms HT or gardening activities are often interchangeable, we examined the articles carefully, and the study was not confined to indoor or outdoor settings. Studies reporting on growing flowers, crops, or herbs or other horticultural activities were considered, and those reporting on growing only short-term ornamental plants or using plants for aromatherapy were excluded. Interventions should focus on gardening or specific tasks in gardening as the main activity, but there was no limit with regard to the duration of the intervention. More detailed information on the screening criteria is provided in Table 1.

In accordance with PICO declarations and the eligibility criteria, the relevant titles, keywords, and abstracts were manually filtered by two reviewers (JY and TM), and the search process was overseen by the librarian. The records from each database were downloaded and merged into Endnote X9, and duplicates were removed. The coincidence rate was 88.5%. Subsequently, an author (JY) independently evaluated the full texts of all eligible articles (Higgins et al. 2011), extracting data using standardized tables to identify studies that needed to be included in the system evaluation. Another author (JY) verified the accuracy of the selection against the same criteria. In case of a disagreement, the paper was submitted to a third-party reviewer (WF) for adjudication and discussion until consensus was reached.

Data extraction

The full-text articles were thoroughly assessed for quality based on data filtering and extraction, and the articles that were deemed unsuitable for our search were excluded. The reasons for exclusion included a focus on primary outcomes other than health and well-being of elders (e.g., assessing the number of calories burned in gardening activities), incomplete analysis, or the average age of the participants not meeting the requirements. The remaining articles were included in a standardized extract form, and the following information was extracted: author, publication date, study site, experiment design, information about older participants (e.g., The percentage of female, Mean age), intervention method, measures, study duration, follow-up details, and outcome.

Table 1 Detailed information on the screening criteria

Inclusion criteria	Exclusion criteria
Adopting the test of an empirical study of the relationship between horticultural treatment and the health of the elderly.	Empirical studies that do not use empirical evidence.
Selection of humans as participants in the study.	Exclusion of studies that do not use human participants.
Choose to grow flowers, crops, herbs or other horticultural activities or conduct research on horticultural tasks under the guidance of a horticulturist.	Exclusion of studies with only short-term ornamental plants or the use of plants for aromatherapy.
All studies had a control group that did not participate in horticultural treatment.	Exclusion of studies with a control group or no control group participating in horticultural therapy.
Examine the relationship between gardening in or after horticultural therapy and all physical, psychological, and life changes in older adults, including the study of various indicators.	Studies in the absence of specific indicators were not examined.

Quality assessment

The PEDro scale (de Morton 2009) was used to assess the methodological quality of all interventional studies (Appendix A). The tool is based on eleven domains: (1) eligibility criteria; (2) random assignment; (3) concealed assignment; (4) baseline similarity; (5) subject blinding; (6) therapist blinding; (7) assessor blinding; (8) ≥85% retention; (9) no missed data, administration (intention to treat analysis); (10) statistical comparison between groups; (11) point measures and variable measures. Appraisals were discussed by two researchers (YJ and WF), until a consensus was reached. A total of eight criteria of the modified Newcastle–Ottawa scale (Kunpeuk et al. 2020) were used to assess observational studies and cross-sectional studies. The data are presented in full in the supplementary materials (Appendix B).

Synthesis and meta-analysis

After reviewing and extracting key data from each study, a narrative synthesis was performed. To be considered for meta-analysis, authors needed to provide 1) the mean, standard deviation (SD), and sample size for the horticultural and non-horticultural groups; and 2) report the health status of both groups and the measurement methods used in the study. Only two or more of data using the same measurement method were considered.

All data were directly obtained from articles and published supplementary materials, and STATA SE (version 15) was used for meta-analysis. The sample size and efficacy data for the HT and control group were extracted for studies to be included in the analysis. The combined effect size was evaluated by mean difference (MD), standard mean difference (SMD), and 95% confidence interval (CI) values for each parameter, and all results are shown as forest plots. Heterogeneity between data was quantified using I^2 statistics (Higgins et al. 2003), and a random effects model was selected. Publication bias of studies included in a meta-analysis can be intuitively assessed by Egger's test (Andreas et al. 1997). Moreover, we explored the causes through sensitivity analysis, and excluded each study to check its impact on the overall combined effect size, thus eliminating the need to maintain homogeneity. If data from different subgroups were provided, each subgroup was entered separately and combined using state software to determine the causes of heterogeneity.

Results

The selection process of each study is described in detail in Fig. 1. Overall, 65,915 studies were screened from five databases, of which 7,592 were excluded for duplication and 58,132 for apparent irrelevance of titles and abstracts. The remaining 191 studies were considered relevant for full-text reading and qualification assessment. Of these articles, 157 studies were excluded because of a lack of control group, no quantitative experiment, absence of required data, virtual gardening intervention, or other reasons. A total of 32 studies were finally included for quality assessment.

Study characteristics

Among the included studies, the number of studies published over the past decade showed a significant increase, indicating that horticultural therapy is gaining traction. The studies were conducted in different countries and regions. Most included studies were conducted in Asia, and the most frequently included countries were Japan (n=7) and China (n=6), followed by Korea (n=5). Six studies were conducted in the United States (Christina and Shannon 2005; Chen and Janke 2012; Jarrott and Gigliotti 2010; Barnicle and Midden 2003; Park et al. 2009; Wendy et al. 2018), two in the United Kingdom (Bail et al. 2018; Hawkins et al. 2011), and two in Italy (Marta et al. 2018; Pedrinolla et al. 2019). Further, three studies were conducted in Singapore (Kheng et al. 2018; Ng et al. 2018; Wong et al. 2021) and one in the Netherlands (van den Berg et al. 2010). A total of 11,779 participants recruited in nursing homes, geriatric community centers, hospitals, geriatric mental health centers, and geriatric welfare centers were included in all studies. The participant size varied from 16 (Suk-Young and Byung-Jin 2010) to 4576 (Lêng and Wang 2016). Further, nine studies focused on patient conditions (e.g., dementia (Christina and Shannon 2005; Jarrott and Gigliotti 2010; Mochizuki Kawai et al. 2021; Suk-Young and Byung-Jin 2010), psychological problems (Ah-Reum et al. 2018; Makizako et al. 2019; Yuka 2013), and cognitive decline (Tse 2010; Pedrinolla et al. 2019), or a frail state (Claudia et al. 2018)). Two studies identified specific populations (cancer survivors) (Wendy et al. 2018; Bail et al. 2018). Of the 33 articles included, 25 were identified as intervention studies and 8 as observational studies. Females outnumbered males in all 25 intervention studies except for two that did not report gender, and three of those included only female subjects.

Among the eight observation studies (Table 2), six were cohort studies, one was cross-sectional study, and one was a case-control study. Of the 25 intervention studies, 23 used parallel trials and two used crossover trials. HT intervention studies were conducted with different research settings and treatment options, including nursing homes (n=9) or senior community center (n=2), participants' homes (n=3), mental health center (n=1), welfare center (n=1), indoor therapeutic garden (n=1), university laboratory (n=1), and parks and nature reserve (n=2); four studies did not mention the specific site. There were 10 studies in which horticulturists

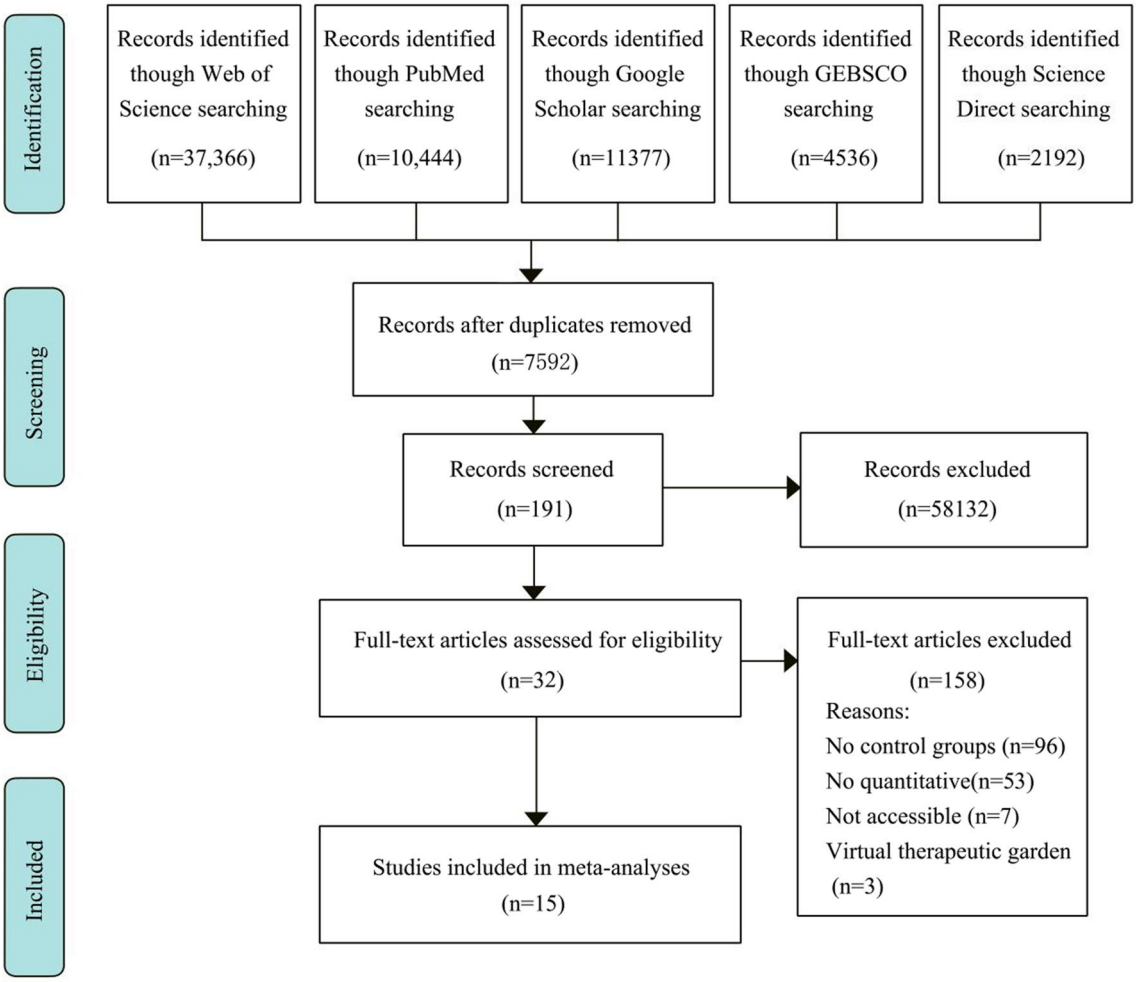

Fig. 1 The selection process of each study

were advisers. In the remaining studies, follow-ups were conducted and gardening plans were made by researchers and assistants, assisted by medical staff (certified nurse, geriatricians, and neuropsychologists), social workers, and research collaborators. There were no adverse events attributable to any intervention trial. There were 12 studies that did not clearly indicate the attendance rate of participants in HT activities. The details of each intervention experiment are documented in Table 3.

Methodological quality

Interventional studies

The PEDro scores for interventional studies were highly variable (Table S2), ranging from 5 to 9 (poor to good quality). With regard to therapist blindness, all studies were judged to have low scores because, given the nature of the trial, therapist blindness was not possible. Four studies (Bail et al. 2018; Wendy et al. 2018; Wong et al. 2021; Yuka 2013) were rated high quality because they used concealed allocation and subject blinding, i.e., the person determining whether a subject was eligible to participate in the trial or not was unaware of the group that the subject would be assigned to, and participants were randomly allocated to the experimental group. All studies scored 5 and above and described the selection criteria for determining who was eligible to participate in the study. However, the studies that did not involve blinding of participants (subjects, therapists, or assessors) or concealed assignment were considered to be of moderate quality. Eight of these studies had excessive missing data.

Observational studies

The methodological quality of the observation studies is shown in Table S3. All eight studies showed some risk of bias. They adequately reported on the process of sample selection and the measurement tools used to determine

Table 2 Details of observational studies

Study	Program Setting	Design	Participants	Female%	Mean age	Groups	Measures	Duration	Outcome
Christina and Shannon (2005)	Virginia (USA)	Cohort Studies	48 elderly people with dementia recruited in rural southwest Virginia	45.83	80, SD=±11.0	Gardening group and traditional activities group	Levels of engagement, MMSE	9 week × 1 × 30 min	HT activities promote participation and motivation in production activities compared to traditional activity groups
Park et al. (2009)	Manhattan (USA)	Cohort Studies	Recruited from the community including 11 active gardeners, 14 gardeners and 28 non-gardeners	64.15	71.94, SD=±7.81	Active gardeners,gardeners and Non-gardeners	BMI, own health assessment , hand function, BMD	—	There were no differences between the three groups in mental health or bone density, but leap gardeners and gardeners had greater hand and grip strength than non-gardeners.
Chen and Janke (2012)	Michigan (US)	Cohort Studies	1,585 gardeners and 1,652 non-gardeners from the Health and Retirement Study and the Consumption and activity mail survey	53	74.20, SD=±7.09	Gardeners and Non-gardeners	Balance, gait, falls and chronic disease incidence	—	Gardeners had significantly better balance and gait speed and less chronic disease and dysfunction than non-gardeners.
Lêng and Wang (2016)	TaiWan (China)	Cohort Studies	3,547 gardeners and 1,029 non-gardeners including a national sample of older adults and 50-year-olds from Taiwan	46.6	66.6, SD=±9.37	Gardeners and Non-gardeners	Risk of death, socioeconomic status, health behaviors and conditions, depression, activity limitations, and comorbidities	8.8, SD=±3.4years	Daily home gardening was associated with high survival rates, with significant effects for those with activity limitations and no effect for those without mobility restrictions who were not depressed

Table 2 (continued)

Study	Program Setting	Design	Participants	Female%	Mean age	Groups	Measures	Duration	Outcome
Machida (2019)	Japan	Cross-sectional study	500 gardeners and 500 non-gardeners recruited from the community	30.6	63.6, SD=±2.6	Gardeners and Non-gardeners	Subjective symptoms, regular visits to the doctor or due to illness or injury, health problems that affect daily life, subjective well-being, reasons for feeling alive, psychological distress and BMI	—	There was a significant relationship between gardening and exercise habits, physical activity, eating vegetables, and relationship with neighbors, no significant relationship with gardening frequency, and a significant relationship with duration.
Shimada et al. (2019)	Obu (Japan)	Case-control study	743 elderly people living in the community	54.29	71.1, SD=±4.5	Gardeners and Non-gardeners to field work or horticultural work	ADL, measurement of cognitive functions and incident AD, GDS	4 years	Working in the field or gardening can help people with mild cognitive impairment recover
van den Berg et al. (2010)	Netherlands	Cohort Studies	121 gardeners with allocated gardens and 63 respondents without gardens in 12 sites in the Netherlands	50.54	61.5, SD=±11.8	Allotment gardeners and their neighbors without an allotment	Self-reported indicators of health, indicators of well-being, and one self-assessed indicator of summer physical activity level reported	—	Allotment gardeners aged 62 and older scored significantly or slightly higher than their neighbors in the same age group on all indicators of health and well-being, with younger allotment gardeners not differing from their younger neighbors.

Table 2 (continued)

Study	Program Setting	Design	Participants	Female%	Mean age	Groups	Measures	Duration	Outcome
Soga et al. (2017)	Tokyo (Japan)	Cohort Studies	332 elderly people from questionnaire survey	53.31	61.46, SD=±12.97	Allotment gardeners and non-gardener	Perceived general health, subjective health complaints, BMI, mental health and social cohesion	—	Allotment gardeners, compared to non-gardeners, reported better perceived general health, subjective health complaints, mental health and social cohesion. BMI did not differ between gardeners and non-gardeners.

MMSE: mini-mental state examination; BMI: body mass index; BMD: bone mineral density; ADL: Activities of daily living; GDS: geriatric depression scale

exposure validation. The statistical tests of outcome data were clear and appropriate, and relevant measures, including confidence intervals or probability levels (P values) were provided. However, there was no mention of independent blinded assessment of outcomes in any of the included observational studies. Risk factor exposure assessment was mentioned in only one study (Chen and Janke 2012), and confounding factors were controlled in one study (Lêng and Wang 2016).

Meta-analysis

In all, 15 studies (112 comparisons) were included in a meta-analysis of the effects of HT on the health of elderly. The results of the 27 indicators and meta-analytic assessments are summarized in Table 4 and complete details are provided in Figs. S1–S26.

The results of physical functioning, psychological recovery, and life changes were investigated. Physical functioning parameters included body mass index (BMI), activities of daily living (IPAQ, ADL), weight, waist circumference, physical component score (SF-36v2, PCS), eight indicators of physical fitness test for elders (30-SEC chair stand, arm curl, 2-min step, 8-ft up-and-go, chair sit-and-reach, back scratch, grip force, and pinch force), hand dexterity, cognitive ability, blood pressure, telomerase activity, interleukin-6 levels, and serum BDNF levels. Psychological indicators included loneliness, stress, depression, and mental component score (SF-36v2, MCS). Life changes included social network and vegetable and fruit intake.

Impact of HT on physical functioning outcomes

There were I^2 indicators of physical functioning that did not show significant differences between the HT and control groups of elders. Elders in the HT group performed better in four indicators of ADL (IPAQ, Barthel Index), weight, and chair sit-and-reach, with *p*-values less than 0.00001. Further, both waist circumference (p=0.001) and hand dexterity (p=0.012) indicated that HT was effective in improving physical function among elderly. However, health-related quality of life (SF-36v2, PCS) and telomerase activity, which are associated with health in elderly, significantly negatively correlated with HT.

Impact of HT on psychological recovery outcomes

Except for fingernail cortisol (p=0.212), which was not significantly associated with improvement in stress among elderly, other psychological indicators showed a significantly positive effect of HT on loneliness ($p < 0.00001$), stress (SPSS-10, $p < 0.00001$ and salivary cortisol, p=0.021), depressive symptoms ($p < 0.00001$), and mental component

Table 3 Details of interventional studies

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/ Week × Duration/ Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Tse (2010)	Hong Kong (China)	Randomized parallel group	53 elderly people who can communicate in Cantonese, have good physical cognition and no history of allergies in nursing homes.	84.9	84.09, SD=6.71	Four nursing homes	Researcher and research assistants	Life satisfaction, loneliness, ADL, social network	Indoor gardening (*Experimental*): acquire information on gardening activities, gardening skills reinforced, planting diary, evaluate the gardening program,share experiences. Routine care (*Control*)	8 weeks × Depends on participants	—	Gardening groups were higher in life satisfaction and social network,lower in loneliness than control group,but physical activity has no different	NA	NA
Suk-Young and Byung-Jin (2010)	North Gyeongsang (South Korea)	Randomized parallel group	16 demented elderly people who were not taking medication and consented to a blood test were recruited by a geriatric hospital	75	79.82, SD=5.97	A nursing home and hospital for the elderly	Horticultural Therapists	Stress, Serum cortisol, MMSE	Gardening activity (*Experimental*): plant-themed stories, talking to gardeners; visual stimulation, identifying their fragrances, gardening activities, cutting and arranging flowers, daily tasks such as changing water, cutting branches, removing green leaves, etc., free play. Routine care (*Control*)	3 weeks × 2 × 40min	—	Obviously reduced the blood cortisol hormone level and stress	NA	NA
Hawkins et al. (2011)	Wales (UK)	Randomized parallel group	94 elderly people in various local activity groups	68.1	67.43, SD=8.56	Participant's home and an open space of Wales(UK)	Researcher and research assistants	Stress, social support, physical activity, PCS, MCS	Allotment gardening (*Experimental*): gardeners who assign gardening and home gardeners who garden on separate plots of land and in their own gardens, respectively. Indoor exercise (*Control*)	30 min	—	Significantly reduced stress than control group, no differences in levels of social support and physical activity	NA	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/Week × Duration/Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Park et al. (2016)	Seoul (South Korea)	Randomized parallel group	50 elderly people at senior community centers	100	82.05, SD=±5.36	A community centers	a horticultural therapist with three assistants	BMI, senior fitness test, hand function ability, cognitive ability, depression, docial engagement, physical activity level	Gardening activity (*Experimental*): design garden, making garden plots and signs, planting transplants, maintaining, fertilizing, marking flower garden and vegetable beds, organic fertilizers, planting, harvesting and sowing seeds, garden party. Daily activities (*Control*)	12 weeks × 2 × 50min	—	Improved the physical and psychological health	80%	NA
Park et al. (2017)	Seoul (South Korea)	Randomized parallel group	21 elderly people without cardiovascular disease from community	100	80.63, SD=±5.14	A senior community center	Researcher and a certified nurse	Blood lipid, BP, proteins that promote inflammation, oxidant proteins	Gardening activity (*Experimental*): planning garden, making garden plots and signs, planting transplants, hydroponics, fertilizing, making a flower bed, making a vegetable bed, making organic fertilizers, mulching, planting plants, harvesting produce, flower arrangement, sowing seeds, cooking with harvest. Waiting control (*Control*)	7.5 weeks × 2 × 50min	—	Positive effects on the blood lipid profiles, blood pressure, level of inflammatory markers in blood, and oxidative stress	NA	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/ Week × Duration/ Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Yao and Chen (2017)	Taiwan (China)	Randomized parallel group	85 elderly people from nursing homes	50.1	80.07, SD=±8.39	Seven nursing homes	Two to four nursing assistants and one social worker from each nursing home, and one administrative	ADL, happiness, meaning of life, interpersonal intimacy	Indoor gardening (*Experimental*): eight HT sessions with eight different themes was conducted: the joy of life, flower admiration and arrangement, 1000 decades of wealth and prosperity, miracles of flowers, happiness and luck, fortune cards, kingdom of herbs, the big harvest. Daily activities (*Control*)	8 weeks × 1 × 60min	—	Happiness, interpersonal intimacy scores of experimental group participants were significantly better than the scores of control group	96%	no serious adverse events
Bassi et al. (2018)	Milano (Italy)	Randomized crossover group	11 elderly people from a nursing home	81.8	81.18, SD=±4.17	Private nursing home	Agronomist (horticultural activities), educator (vocational activities), two researchers	Concentration, happiness, sociability, involvement, challenges, stakes, self-satisfaction	Gardening activity (*Experimental*): horticulture courses, seeding, planting, propagation, transplanting, flower arranging and plant growing. Daily activities (*Control*)	6 weeks× 1 × 60min	—	The gardening group offered higher challenges and risks than the occupational activity group, and increased self-satisfaction and happiness	93.75%	NA
Wendy et al. (2018)	Alabama (USA)	Randomized parallel group	46 elderly people cancer survivors without severe orthopedic, cardiovascular,or pulmonary disease	69.6	70.4, SD=±7.8	Survivors' homes	Master gardeners	Vegetable and fruit intake, anthropometric measurements, performance, biomarkers, QOL	Home-based vegetable gardening (*Experimental*): master gardeners were instructed to visit with the participant once a month and assess the home garden, participants follow the planting schedule and garden plan. Waiting control (*Control*)	48 weeks × Depends on participants	—	The gardening group had a significant increase in reassurance of worth, reduced waist circumference, and increased daily consumption of vegetables and fruit compared with the control group	91.30%	no serious adverse events

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/Week × Duration/Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Ah-Reum et al. (2018)	Suwon (South Korea)	Randomized parallel group	28 elderly people with mental health problems from two elderly mental health centers	85.7	78.75, SD=±4.76	Two elderly mental health centres	Researcher, four assistant therapists and staff member	Cortisol, senior fitness test	Gardening activity (*Experimental*): making garden plot and sign, fertilizing, planting, hydroponics, weeding, watering, mulching, setting up plant stakes, harvesting, tying stakes, picking a side, covering up crops with soil, making herb tea, farm party. Routine care (*Control*)	8 weeks × 1 × 90min	—	Cortisol levels significantly decreased and fitness levels significantly improved in the horticultural therapy group, while there was no significant improvement in the control group	86%	NA
Claudia et al. (2018)	Hong Kong (China)	Randomized parallel group	96 elderly people in a frail or pref-rail state from the 4 residential care homes	65.6	84.60, SD=±7.24	NA	One registered horticultural therapist, one trainee assistant	Happiness, depressive, self-efficacy, well-being, social network, social engagement	Gardening activity (*Experimental*): gardening courses, fertilization, replanting plants, watering, pruning, propagation, introduction to varieties and sowing of seeds. Daily activitiesv (*Control*)	8 weeks × Depends on participants	12 weeks	The results did not show a particular positive effect of gardening activity on other factors other than "happiness"	85%	NA
Chu et al. (2018)	Taiwan (China)	Randomized parallel group	150 elderly people in three nursing homes	62.7	79.2, -	Nursing homes	Researcher and four research assistants	Depression, loneliness	Gardening activity (*Experimental*): warm-up activities, gardening activities (including stringing, inserting, rolling, cutting, sticking, and binding motions), interpersonal interaction and group sharing activities. Daily activities (*Control*)	8 weeks × 1 × 90 to 120min	—	Reduced depression and loneliness	100%	Two participants in the control group dropped out due to chronic illness
Makizako et al. (2019)	Obu (Japan)	Randomized parallel group	89 elderly people with presence of depressive symptoms and memory problems from community	50.6	73.1, SD=±5.5	NA	Researcher and vegetable experts	Depression, memory	Gardening activity (*Experimental*): cultivating, growing, harvesting, group planting. Education course or exercise intervention (*Control*)	20 weeks × 1 × 60 to 90minute	48 weeks	None showed improvement, and the same 12 months later	84.50%	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/Week × Duration/Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Park et al. (2020)	Eunpyeong-gu (South Korea)	Randomized parallel group	40 elderly people at a senior welfare center	65	73.85, SD=±5.41	A senior welfare center	Researcher and a certified nurse	Cognitive ability, hand function ability, senior fitness test	Gardening activity (*Experimental*): design garden and making garden plot, planting transplants, making medicated plant garden beds, making vegetable garden beds, making organic fertilizers, maintaining garden, making flower garden beds, making herb garden beds, hydroponics, sowing seeds, cutting stems, harvesting and packing harvests, garden party. Waiting control (*Control*)	7 weeks × Depends on participants	—	Cognitive ability in the gardening group were significantly increased	NA	NA
Chu et al. (2021)	Tainan (China)	Randomized parallel group	88 elderly people aged 65 and over without mental illness from three nursing homes	55.68	65 years and older	Nursing homes	Researcher and four research assistants	Attitudes to ageing questionnaire, health hope index, hand eye coordination	Gardening activity (*Experimental*): warm-up activities, gardening activities (including stringing, inserting, rolling, cutting, sticking, and binding motions), interpersonal interaction and group sharing activities. Routine care (*Control*)	8 weeks × 1 × 120min	12 weeks	Improved attitudes to ageing questionnaire, health hope index, hand eye coordination in experimental group, the effects lasted up to two months.	100%	Two participants in the control group dropped out due to chronic illness
Mochizuki Kawai et al. (2021)	Tokyo (Japan)	Randomized parallel group	16 elderly people with dementia in a nursing home	—	90.3, SD=±6.8	A nursing home	One neuropsychologist, one occupational therapist and two assistants	QOL, CSDD	Indoor gardening (*Experimental*): select three flowers and place them on the absorbent foam markers (circles) to create floral artwork decorations. Routine care (*Control*)	5 days × Depends on participants	—	The mean health-related quality of life and total Cornell Scale for Depression in Dementia scores of experimental group significantly improved	100%	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/ Week × Duration/ Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Wong et al. (2021)	Singapore	Single-blind randomized parallel group	59 elderly people from a community	49.15	67.1, SD=±4.31	NA	A trained practitioner and volunteer, National Park Board (NPB) staff	BMI, Biomarkers included: BDNF,BP, DHEA, HS-CRP, IL	Indoor gardening (*Experimental*): horticulture courses, indoor gardening, ornamental plants, providing knowledge of various plants and landscapes, outdoor gardening (including education on weeding, seeding, herbal plants and fertilizer making). Waiting control (*Control*)	12 weeks × Depends on participants	12 weeks	HT is associated with increased numbers of naive CD8+ T cells and fewer CTLA4-expressing terminally differentiated effector CD4+ and CD8+ memory T cells re-expressing CD45RA (TEMRA). Furthermore, IL-6 levels were reduced during HT , and the frequencies of naive and TEMRA CD8+ T cells were found to be associated with IL-6 levels	≥90%	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/Week × Duration/Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Ng et al. (2018)	Singapore	Randomized parallel group	59 elderly people from community	49.15	67.1, SD=±4.31	Several parks/gardens and a nature reserve	An experienced coach and assistant	Cognitive functions, depression, anxiety , psychological well-being, social conceitedness and satisfaction with life, biomarkers included: IL-1β, IL-6, sgp-130, CXCL12/SDF-1α, CCL-5/RANTES, BDNF, hs-CRP, DHEA, cortisol	Gardening activity (*Experimental*): gardening sessions, from indoor gardening, planting, maintenance and harvesting of vegetables and herbs, to guided walks in various parks. Waiting control (*Control*)	12 weeks × Depends on participants	12 weeks	Horticultural therapy reduced plasma IL-6 and through maintaining plasma CXCL12 (SDF-1α), may maintain hematopoietic support to the brain and prevent inflammatory disorders	NA	NA
Barnicle and Midden (2003)	St.Louis(USA)	Randomized parallel group	62 elderly people aged 65 and over from two long-term care facilitation	90.32	65 years and older	NA	Researcher and research assistants	Balance, psychological well-being	Indoor gardening (*Experimental*): seed selection, planting, pruning, watering, transplanting, plant observation, horticulture courses. Waiting control (*Control*)	7 weeks × 1 × 120min	—	The horticulture group had a significant increase in psychological well-being, whereas the control group decreased	NA	NA
Masuya (2014)	Tokyo (Japan)	Randomized parallel group	18 elderly people residents of nursing homes	77.78	85.60, SD=±7.51	A nursing home	A specialist (author), care worker (facility staff), and research collaborator	VI, GDS, ADL, QOL, MMSE	Gardening activity (*Experimental*): taking care of plant and observation, grow vegetables, transplant flowers, pruning and harvesting of plants, sharing the workmanship of plants. Routine care (*Control*)	6 weeks × 1 × 30 to 40 min	—	GDS-15 score of Intervention Group Regarding decreased,and reduced depression and increased life satisfaction than control group	NA	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/ Week × Duration/ Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Yuka (2013)	Sendai (Japan)	Randomized crossover group	39 elderly people women with earthquake stress	100	66.15, SD=±4.52	A university lab	A horticultural therapist and clinical psychologists	CAPS, GDS, PTGI, QOL	Indoor gardening (*Experimental*): interactive lectures and practical horticultural training, six horticultural lessons, including topics such as designing a garden planter, seeding, watering, weeding, and picking flowers. Pressure education (*Control*)	8 weeks × 1 ×60 min	—	CAPS score, GDS score, PTGI-J score, and WHO-QOL26 score and salivary cortisol level in the intervention group was improved,the same as the follow up	NA	NA
Pedrinolla et al. (2019)	Verona (Italy)	Single-blind randomized parallel group	163 elderly people with Alzheimer's disease	74.23	76.4, SD=±4.3	An indoor therapeutic garden	Researchers, geriatricians and neuropsychologists	MMSE, NPI, biomarkers included: BI, BP, salivary cortisol, quetiapine	Indoor gardening (*Experimental*): walking in the therapeutic garden, touching plants and flowers, independent activities. Indoor exercise (*Control*)	24 weeks × 5 × 120 min	—	NPI scores were significantly improved, quetiapine dosage, blood pressure, and salivary cortisol concentrations were significantly reduced	66%	No major or relevant adverse events
Ng et al. (2021)	Singapore	Randomized parallel group	59 elderly people from a neighbourhood	78	67.10, SD=±4.31	Several parks and a nature reserve	NA	IL-6, PRWO	Gardening activity (*Experimental*): planting courses, planting journals, sowing seeds, making natural pesticides, caring for plants. Routine care (*Control*)	12 weeks × 1 × 60 min	24 weeks	PRWO and IL-6 level were significantly improved of intervention group,and the same 12 months later	NA	NA

Table 3 (continued)

Study	Country	Design	Participants	Female%	Mean age	HT site	Adviser	Measures	Intervention	Duration (Frequency/ Week × Duration/ Session)	Follow-up	Outcome	Intervention attendance	Adverse events
Jarrott and Gigliotti (2010)	Virginia (USA)	Randomized parallel group	129 elderly people with dementia from 8 care programs	53.1	80.09, SD=±8.05	Nursing homes	Horticultural therapist and gerontologist	Affective and behavioral responses	Gardening activity (*Experimental*): gardening courses, soil filling, plugs, spikes, planting. Daily activities (*Control*)	6 weeks × 2 × 50 min	—	No differences on affective domains,with the treatment group demonstrating higher levels of active	NA	NA
Bail et al. (2018)	Birmingham (UK)	Randomized parallel group	82 breast cancer survivors from hospital registries	—	60.5, SD=±9.4	Participants 'homes	Master Gardeners and management groups, and cooperative Extension agent	Vegetable consumption, physical activity, performance function, anthropometrics, biomarkers, QOL	Vegetable Gardening (*Experimental*): direct the planning, planting and maintenance of 3 (spring, summer and fall) home gardens over the course of a year, master Gardeners monthly home visits, garden photographs, and bimonthly e-mails and/or telephone calls were tracked by study staff. Wait-list control (*Control*)	48 weeks × Depends on participants	—	Compared with the controls, intervention participants reported significantly greater improvements in moderate activity , improved vegetable consumption.	≥80%	no serious adverse events

ADL: Activities of daily living; *MMES*: mini-mental state examination; *PCS*: self-reported physical health; *MCS*: self-reported mental health; *BMI*: body mass index; *QOL*: quality of life; *CSDD*: cornell scale for depression in dementia, *BDNF*: brain-derived neuro factor; *BP*: blood pressure; *DHEA*: dehydroepiandrosterone; *HS-CRP*: high-sensitivity C-reactive protein; *IL*: interleukin; *VI*: vitality index; *GDS*: geriatric depression scale; *CAPS*: traumatic stress disorder; *PTGI*: post traumatic growth inventory; *NPI*: neuropsychiatric questionnaire; *PRWO*: positive relations with others

score ($p < 0.00001$) in elders. Elders in one study (Wendy et al. 2018) showed a greater impact of HT on psychological component scores, with the study reporting no significant improvement in older cancer survivors after HT, whereas other studies (Hawkins et al. 2011; Bail et al. 2018) reported significantly higher scores in this indicator for the recruited subjects compared with elderly without the disease.

Impact of HT on life changes outcomes

Older adults receiving HT intervention showed significantly improved social interaction (p=0.038) and vegetable and fruit intake ($p < 0.000001$).

The results of the analysis showed low heterogeneity (<30%) in six of the indicators (Figs. 2, 3, 4, 5, 6 and 7), moderate heterogeneity (30%–60%) in four (Figs. 8, 9, 10 and 11), and severe heterogeneity (>60%) in the remaining 17 indicators. This suggests substantial heterogeneity between studies in terms of daily living, weight, waist circumference, SF-36v2, chair sit-and-reach, hand dexterity, cognitive ability, systolic blood pressure, loneliness, PSS-10, salivary cortisol, geriatric depression scale, social network - Lubben Social Network Scale (LSNS), and vegetable and fruit intake (EATS).

Moderator analysis

We used Galbraith plots and sensitivity analysis metrics ($I^2 > 60$) to explore the impact of individual studies on the overall heterogeneity. Articles that deviate significantly from the linear prediction were excluded, and the combined effect size and the effect of each article on the change in overall heterogeneity were compared by excluding each article. (Table S4 - Table S11). Because of the limited number of studies included in the meta-analysis, sensitivity analyses were not possible for fewer than two articles for each indicator. When three studies (Masuya 2014; Hyuma et al. 2019; Wendy et al. 2018) and five comparisons were removed, the results showed a reduction in heterogeneity, suggesting that these studies may be the source of heterogeneity.

Visually, the funnel plot (Fig. S28) was relatively stable and roughly symmetrical, no significant publication bias was found, and most studies were distributed in the middle of the funnel plot, indicating that the included studies had moderate sample sizes and moderate study precision. On conducting Egger's test, the results showed that publication bias (p=0.158) had a negligible effect on overall results (Fig. S29). We considered six factors (year of publication, country, mode of intervention, duration of intervention, gender, and presence of significant diseases) that could influence the study results, but very few articles showed significant missing data to be effectively addressed when performing meta-regression analyses.

Discussions

This review comprehensively searched studies from five databases to investigate the relationship between HT and health outcomes in older individuals, covering a large number of relevant international journals. It extensively analyzed 32 studies from eight different countries, with a total population size of 11,741. The meta-analysis provided evidence that HT is associated with health benefits in the elderly, with results showing that ADL (Minutes of weekly activities: 0.077, 95% CI: -0.146, 0.301, barthel index: 0.644, 95% CI: 0.352, 0.935), physical flexibility (chair sit-and-reach: 0.302, 95% CI: 0.036, 0.569), and manual dexterity (-0.495, 95% CI: -0.923, -0.067) were improved with HT. There were improvements in reduced loneliness (-2.804, 95% CI: -3.223, -2.385), depression (-0.947, 95% CI: -1.206, -0.687), stress (-0.339, 95% CI: -0.610, -0.069), cortisol concentrations (-0.902, 95% CI: -0.728, -0.002), improved social interaction (0.370, 95% CI: 0.115, 0.624) and daily vegetable and fruit consumption (0.688, 95% CI: 0.287, 1.089) with HT.

The I^2 of the Barthel Index and UCLA were 99.1% and 98.2%, respectively, indicating a high risk of statistical heterogeneity. We performed sensitivity analyses, excluding individual studies, and found an improvement in the pooled benefit volume after excluding three studies (Hyuma et al. 2019; Masuya 2014; Wendy et al. 2018). Three indicators (waist circumference, SF-36v2 PCS, and SF-36v2 MCS) were significantly reduced to low heterogeneity levels after excluding the study by Wendy in 2017. Probably the main reason for this is that the participants were all cancer survivors, and as time passed, reduced exercise and longer sedentary periods led to an increased risk of physical obesity and mortality (Berentzen et al. 2010; Haydon et al. 2006), but in this phase of the study, it was also demonstrated that the older adults who received HT showed attenuated increase in waist circumference compared with controls. This may also have contributed to excessive heterogeneity in the other two indicators. Heterogeneity of the combined effect of cognitive ability significantly decreased after removing the article by Hyuma Makizako (2019), according to the original data, the baseline cognitive ability of the control group subjects was higher than that of the experimental group subjects. The cognitive ability of the elderly in the experimental group was significantly better after HT, whereas that of the elderly in the control group decreased, and because of the short duration of HT (6 weeks), this could be the main reason for the heterogeneity difference (Stowell et al. 2018). In the analysis of sensitivity to depression in the experimental and control groups, the heterogeneity of the combined benefit of "Depression" indicator decreased by 74.4% after removing the study by Chu (2018). In contrast, the article showed

Table 4 Meta-analytic assessments

Outcomes	N (participants)	SMD (95% CI)	Heterogeneity I^2 (%)	*P*-value
Physical functioning				
BMI(kg/m^2)	4 (264)	0.072(-0.301, 0.157)	16.40%	0.305
Activities of daily living (min/week)	3 (276)	0.077 (-0.146, 0.301)	79.80%	**p<0.00001**
Activities of daily living (Barthel Index)	2 (248)	0.644 (0.352,0.935)	99.10%	**p<0.00001**
Weight(kg)	3 (170)	-0.195(-0.507,0.117)	90.30%	**p<0.00001**
Waist circumference(cm)	3 (170)	-0.327 (-0.637, -0.017)	85.40%	**0.001**
Health-related quality of life(SF-36v2, PCS)	3 (214)	-0.039 (-0.270, 0.192)	85.70%	**p<0.00001**
30-SEC Chair stand (n)	5 (236)	0.462 (0.200,0.724)	57.30%	0.053
8-ftzup-and-go (sce)	5 (236)	-0.547 (-0.810,-0.283)	55.10%	0.063
Chair sit-and-reach (cm)	5 (236)	0.302 (0.036, 0.569)	87.00%	**p<0.00001**
Back scratch (mm)	5 (236)	0.327 (0.068, 0.585)	0.00%	0.422
Grip force (kg)	3 (132)	0.280 (-0.086, 0.647)	45.00%	0.162
Pinch force (kg)	2 (90)	0.368 (0.062, 0.674)	0.00%	0.570
Hand dexterity(KS-301Lavisen)	2 (134)	-0.495 (-0.923,-0.067)	84.30%	**0.012**
Cognitive(K-MMSE)	4 (271)	0.883 (0.631, 1.135)	61.20%	0.052
Blood pressure--systolic blood pressure (mm Hg)	2 (184)	-0.411 (-0.704, -0.118)	61.40%	0.108
Blood pressure--diastolic blood pressure (mm Hg)	2 (184)	-0.395 (-0.687, -0.103)	0.00%	0.409
Telomerase activity	2 (120)	-0.437 (-0.824, -0.050)	96.40%	**p<0.00001**
Interleukin-6 (pg/mL)	2 (120)	-0.320 (-0.681, 0.041)	0.00%	0.697
Serum BDNF(ng/dl)	2 (81)	0.031 (-0.240, 0.302)	5.00%	0.995
Psychological indicators				
Loneliness (UCLA)	2 (203)	-2.804 (-3.223, -2.385)	98.20%	**p<0.00001**
Stress(PSS-10)	2 (136)	-0.339 (-0.610, -0.069)	86.70%	**p<0.00001**
Stress--Fingernail cortisol (ng/g)	2 (120)	-0.365 (-0.728, -0.002)	35.90%	0.212
Stress--salivary cortisol (ug/l)	2 (69)	-0.902 (-1.410, -0.395)	81.40%	**0.021**
Depression--Geriatric Depression Scale	5 (337)	-0.947 (-1.206, -0.687)	97.70%	**p<0.00001**
Mental component score (SF-36v2, MCS)	3 (214)	-0.045 (-0.275, 0.184)	82.60%	**p<0.00001**
Life changes				
Social network - Lubben Social Network Scale	2 (201)	0.370 (0.115, 0.624)	60.60%	**0.038**
Vegetable and fruit intake --EATS (serving/d)	2 (120)	0.688 (0.287, 1.089)	97.10%	**p<0.00001**

N: number of studies, *CI*: confidence interval

that older adults who participated in gardening activities showed reduced depression and loneliness, and the control group individuals who received usual care showed increased incidence of depression and loneliness. One possible explanation for this is that the usual care received by the control group subjects was not designed to address the specific needs of older adults, resulting in a disproportionate difference in outcomes (Kamioka et al. 2014). However, the results of this study suggest that participation in HT contributes to increased psychological well-being of older adults.

Previous studies have mentioned that telomerase activity decreases after HT (Wendy et al. 2018; Bail et al. 2018). However, current findings are similar to the long-term data reported by Ornish et al. (2013). on lifestyle interventions in prostate cancer survivors, wherein telomerase activity was found to declining over a 5-year period. While the amount of the telomerase may be predictive of longevity, it may also pose a potential threat to cancer by inhibiting the presence of abnormal cells that can unpredictably respond to prolonged intervention. Thus, these data give pause to the role of telomerase as a biomarker in cancer survivors. Two studies (Wendy et al. 2018; Bail et al. 2018) tested interleukin-6 in older adults after HT, but reported different results. Because the results were presented by only a few studies, we were not able to perform a formal subgroup analysis or determine whether this was the case for other health outcomes.

The results of this review are consistent with those of previous reviews on the effects of gardening on the health

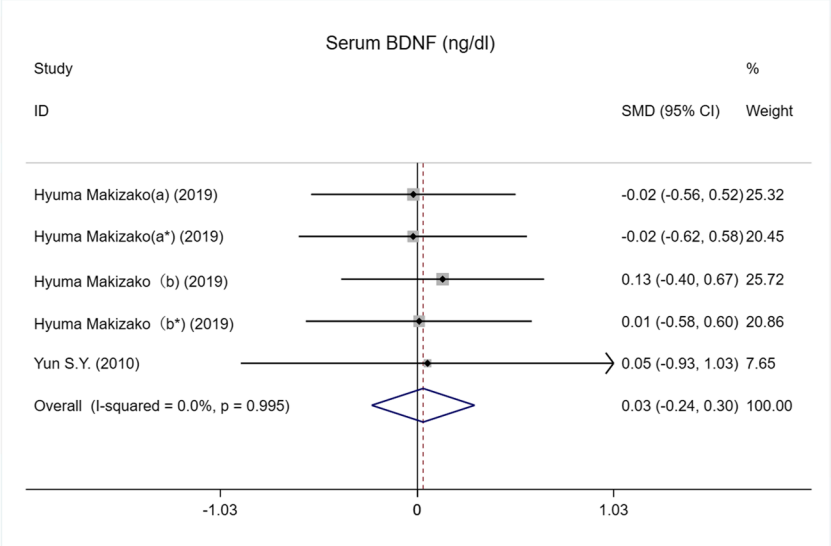

Fig. 2 Meta-analysis of the effects of experimental and control groups on body mass index (BMI). Note: a: assigned gardening group vs. indoor exercise group; b: assigned gardening group vs. walking group; c: home gardening group vs. indoor exercise group; d: home gardening group vs. walking group

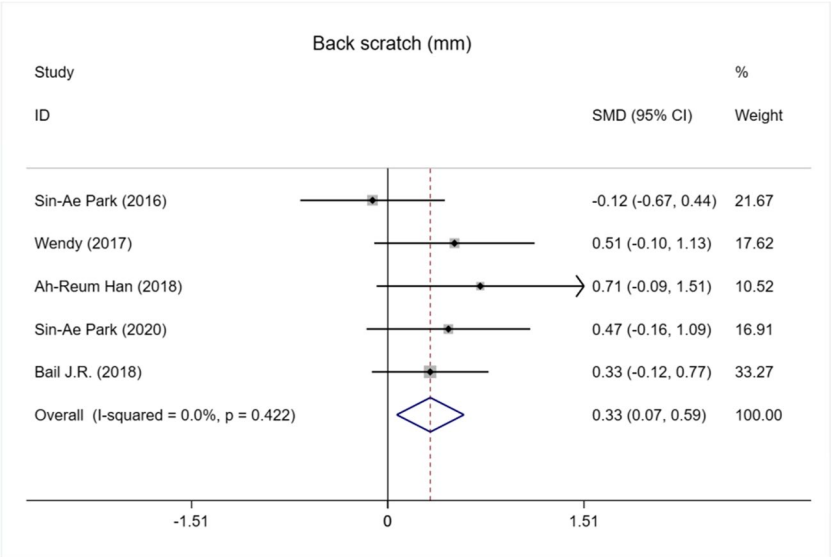

Fig. 3 Meta-analysis of the effects of experimental and control groups on back scratch

of older adults. Nicholas et al. (2019) systematically reviewed 20 studies and noted significant improvements in the quality of life, anxiety level, depression, social relationships, physical outcomes, and cognitive outcomes in patients after HT, and a reduction in body mass index (BMI) (Soga et al. 2017). Lin et al. (2022a) used meta-analysis techniques to assess the positive and negative effects of gardening on the health of older adults, and the random-effects model showed that HT significantly improved upper body flexibility and aerobic endurance in older cancer patients, which is consistent with our findings. However, these reviews cover a limited number of studies and lack the inclusion of observational studies and evaluation of other long-term indicators, such as waist circumference, activity level, and cognitive performance.

This review complements previous systematic evaluations (Kunpeuk et al. 2020; Forbes et al. 2020; Looijaard et al. 2018) of the health benefits of HT, particularly across multiple indicators. The main strength of this review is its inclusiveness. We did not exclude studies based on study design or horticultural treatment modalities. Accordingly, the 33 included studies identified a wide range of horticultural and older adult health consequences. However, the inclusiveness of this study can also be seen as a limitation because of the high heterogeneity between studies and the difficulty in comparing studies from small-scale intervention studies with large cross-sectional studies. Overall, this review contributes to the growing body of evidence showing the health benefits of HT in older adults.

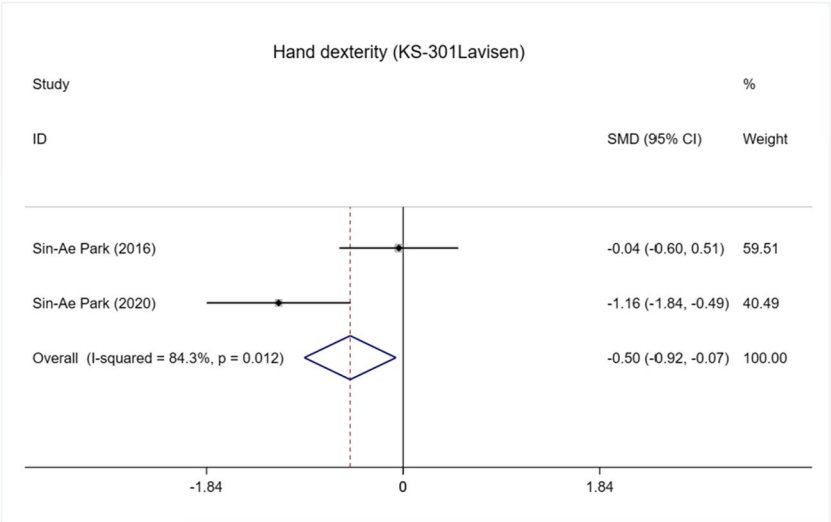

Fig. 4 Meta-analysis of the effects of experimental and control groups on hand dexterity

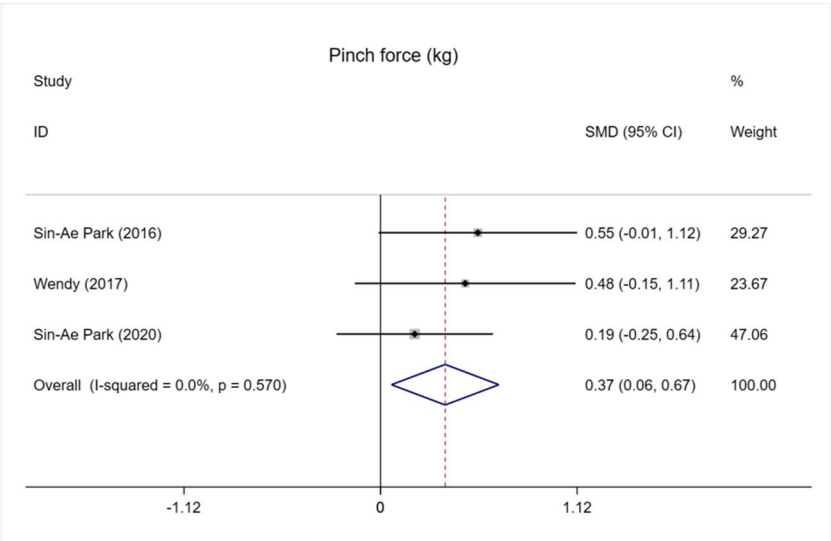

Fig. 5 Meta-analysis of the effects of experimental and control groups on pinch force

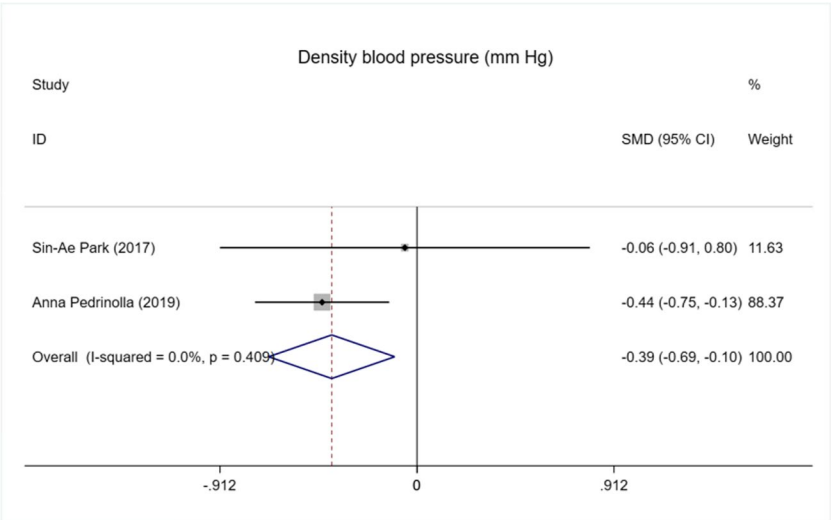

Fig. 6 Meta-analysis of the effects of experimental and control groups on diastolic blood pressure. Note: a: assigned gardening group vs. indoor exercise group; b: assigned gardening group vs. walking group; c: home gardening group vs. indoor exercise group; d: home gardening group vs. walking group

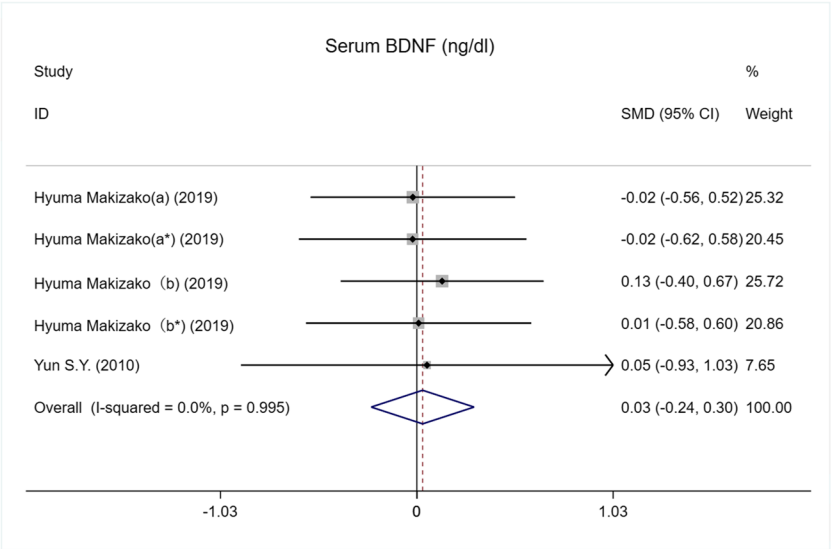

Fig. 7 Meta-analysis of the effects of experimental and control groups on serum BDNF. Note: a: assigned gardening group vs. indoor exercise group; b: assigned gardening group vs. walking group; c: home gardening group vs. indoor exercise group; d: home gardening group vs. walking group

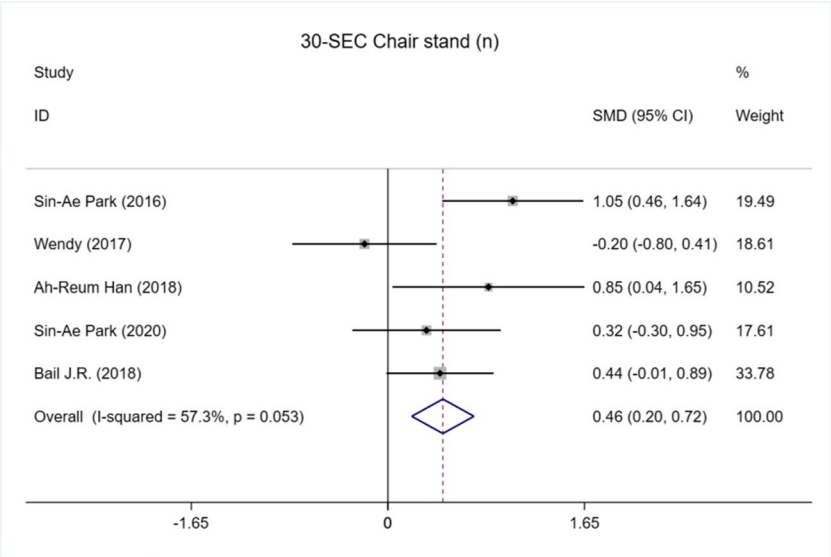

Fig. 8 Meta-analysis of the effects of experimental and control groups on 30-SEC Chair stand

It was evident from the number of included articles that small interventional studies made up the majority of the included studies, and the studies had a number of confounding factors (type of horticulture, duration of intervention, study site, sample size, gender, moderator, attendance, and adverse events) that may have influenced the results. Some of the included studies reported single- or double-blinded trials to reduce bias and increase article quality, which would help convince policy makers and healthcare professionals to encourage older adults to garden and spend more time gardening, especially individuals who are obese, have poor physical function, or need psychotherapy. Although this research well covers a wide range of aspects, there are still several significant knowledge gaps in this area, with the most common being the underlying mechanisms of the relationship between gardening and health and the long-term effects of HT. Further research is warranted and the results of this review should be considered with caution.

This review also has some limitations. First, the limited number of studies in this review and the high degree of heterogeneity prevented us from performing subgroup analyses and meta-regression analyses to determine the specific sources of heterogeneity. This likewise led to significant limitations in comparing the outcomes, and some studies were accordingly not included in the meta-analysis. Some

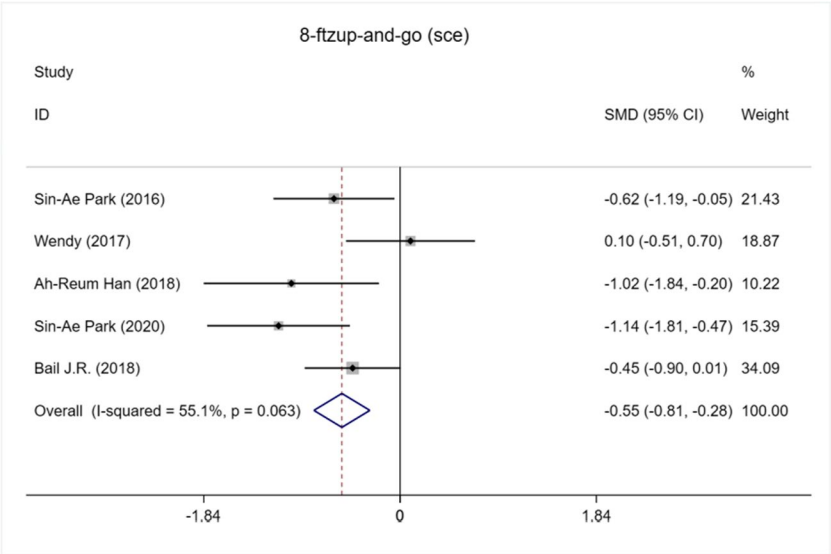

Fig. 9 Meta-analysis of the effects of experimental and control groups on 8-ftzup-and-go

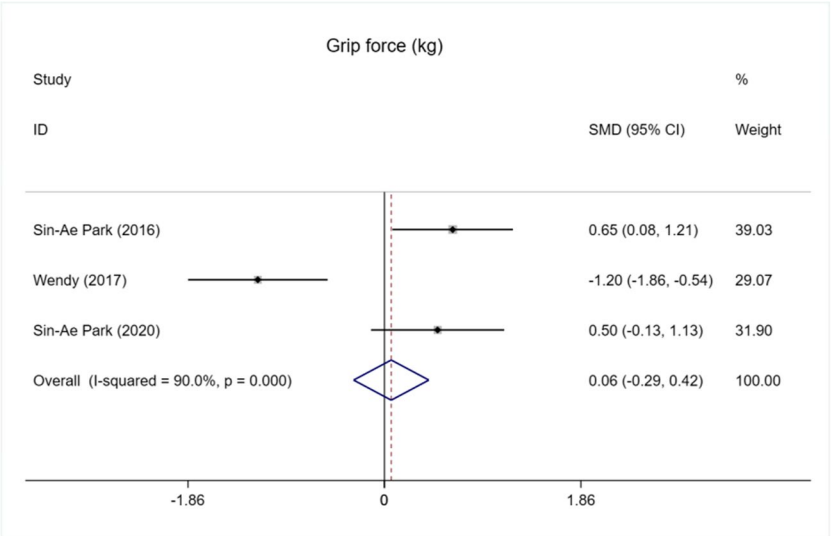

Fig. 10 Meta-analysis of the effects of experimental and control groups on grip force

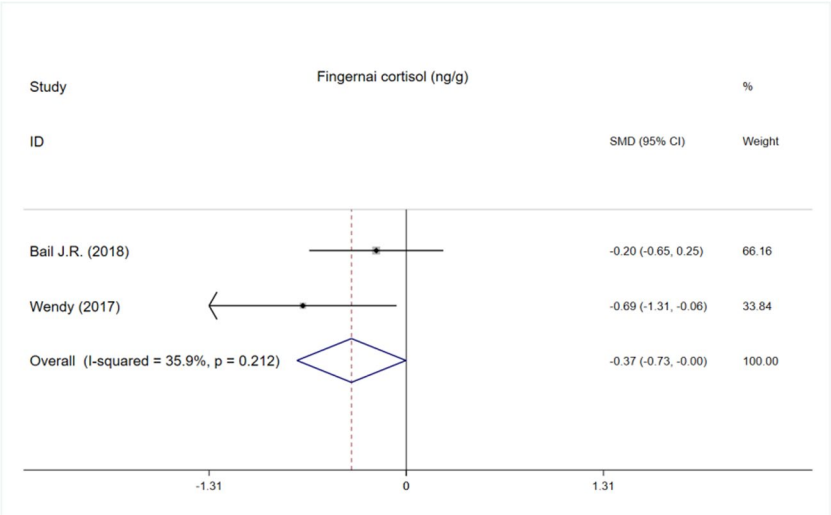

Fig. 11 Meta-analysis of the effects of experimental and control groups on fingernail cortisol

examples of these include monocyte counts, tumor necrosis factor levels, oxidase levels, brain waves, WBC, lactate levels and serotonin levels, among others (Hassan et al. 2018; Park et al. 2017, 2020).

Conclusion and future perspectives

In this systematic review, we included both interventional and observational studies that provide strong evidence on the relationship between HT and older adult health. However, the quality of the included studies varied widely. Results suggest that HT can be effective in helping older adults lose weight and waist circumference and increase physical flexibility. It can further be effective in reducing stress, alleviating depression and loneliness, and increasing interpersonal interactions and vegetable and fruit consumption. HT may be an effective means for improving physical and mental health as well as social health aspects in older adults. In the future, further high-quality research on more horticultural treatment modalities, rigorous control and adjustment of some important confounding variables, and larger populations are needed to improve our understanding of the relationship between HT and the health of older adults.

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Jiayue Yun: conceptualization, data collection and software processing, first draft writing;

Wenfei Yao: data review and result validation, paper revision and financial support;

Tian Meng: data organization and screening;

Zhiyue Mu: data organization and screening.

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Declarations

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