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# Effectiveness of animal-assisted therapy and pet-robot interventions in reducing depressive symptoms among older adults: A systematic review and meta-analysis☆

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ABSTRACT

*Background:* Systematic reviews suggest that animal-assisted therapy (AAT) and pet-robot interventions (PRI) achieve a reduction in mental health variables such as depressive symptoms. However, these systematic reviews include both randomised and non-randomised studies, which prevents an adequate assessment of the effect of confounding variables.
*Objective:* This systematic review and meta-analysis aimed to evaluate the comparative effectiveness of AAT and PRI through randomized controlled trials (RCTs) in reducing depression in older adults.
*Methods:* Our study is a systematic review. We searched three databases of scientific articles: SCOPUS, Web of Science and PubMed. We included studies that their population was older adults, aged 65 years or older, with or without a clinical condition, clinical diagnosis based on mental examination/test or documentation from medical records, accredited by the facilities' staff. We included trials in which the comparator was a passive intervention or an active intervention. We used the Cochrane risk-of-bias tool for randomised trials (RoB 2) to assess the risk of bias for each study. Our study was registered in PROSPERO (CRD42023393740).
*Results:* Twenty-three studies were included in this systematic review. However, only 19 trials were included in the meta-analysis. At the overall risk of bias level, 78.9% of the studies were at high risk of bias (n = 15). We found that AAT (g= −0.72; 95%CI −1.13 to −0.31; p = 0.001) has a moderate and statistically significant effect as an intervention to reduce depressive symptoms in older adults. However, the PRIs do not show a significant effect on reducing depressive symptoms in older adults. In addition, a sub-analysis based on dog-assisted therapy (g= −0.65; 95%CI −1.21 to −0.08; p = 0.025), a specific type of AAT, showed a modest effect on reducing depressive symptoms.
*Conclusions:* Our study concluded that AAT and DAT had a moderate and statistically significant effect as interventions to reduce depressive symptoms in older adults. On the other hand, PRI did not show a significant effect in reducing depressive symptoms.

☆ Note: First joint authorship.

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## 1. Background

Depression is common and one of the most disabling mental disorders in the world, ranking among the top 25 causes of death worldwide.[1] The World Health Organization (WHO) estimates that depression may affect 3.76% of the world's population [more than 279 million people].[1] In this vein, the Global Burden of Disease Study (GBD) reported a significant 27.6% [25.1–30.3%] increase in major depression with an estimated 53.2 million additional cases worldwide due to the COVID-19 pandemic.[2] In addition, adults over 60 years are the population at the highest risk of having depression, with a prevalence of 5.7% [4.94–6.55%].[1]

Depressive disorders in older adults are characterised by diagnostic complexity, accompanied by clinical outcomes (e.g., accelerated cognitive impairment) and a high risk of disability.[3] Older age can be the stage of increased emotional fragility, neurobiological degeneration, and physical and social changes. As a result, depression has a severe impact on quality of life (QoL) and increases morbidity and mortality.[4] Currently, several treatments are used to mediate the psychological and physical symptoms of depression. Pharmacotherapy is one of the most commonly used interventions; however, antidepressants tend to have adverse effects in older adults (i.e., recent myocardial infarction, glaucoma, or hepatic or renal impairment). In addition, prescription drugs in older adults are often administered for long and indefinite periods.[5] On the other hand, co-intervention with pharmacotherapy and psychotherapy is often more efficient, with lower dropout rates and lower medication adherence.[6]

In addition to traditional approaches (pharmacological and psychological), other complementary therapies may be effective, such as animal-assisted therapies (AATs). The American Veterinary Medical Association (AVMA) defines AATs as goal-directed, individually tailored therapy that is regularly evaluated and documented.[7] AATs are administered or managed by a certified animal handler and a trained animal, or it may be a health professional, handler and animal. Activities typically include petting, brushing, feeding, playing and talking with the dog.[4]

Several research studies have examined the health benefits of AATs in older people. Nine systematic reviews indicated that AATs were effective in the treatment of medical conditions (i.e., dementia, stroke, and cognitive impairment).[8–15] Across all studies, the most common diagnosis was dementia, and the most common animal used was the dog. Of the seven systematic reviews that assessed psychological variables (i.e., depression, anxiety, PTSD and loneliness), they concluded that AATs could be beneficial in reducing symptoms of mental disorders.[9–13,16,17] While the results of all studies suggest that AATs are beneficial in older adults, the results must be interpreted with caution due to the variability and poor methodological quality of the included studies.

However, studies have also shown that animals remain an unpredictable factor in interventions (e.g., allergies, fear of animals).[18] Therefore, Pet-robot Interventions (PRIs) have been proposed as an alternative to animal-assisted interventions. PRIs aim to provide the same benefits as live animals, with the difference that robotic animals do not need to be fed, cleaned or cared for as animals do.[19] In addition, pet-robots may be a suitable substitute for users with allergies or fears of animals. Studies of PRIs in nursing homes have used electronic cat robots (NeCoRo),[20] a dog-like robotic companion (AIBO) (https://us.aibo.com/), and the most commonly used, the sea-like interactive robot (PARO) (http://www.parorobots.com/index.asp). There have been positive results in improving physical symptoms (e.g., cognitive function, immune response, neuropsychiatric symptoms, motor activity) and mood in patients with dementia.[21,22] A systematic review also reported the benefits of PRIs on positive behavioural responses (e.g., hugging, socialising),[23] and two reviews reported improvements in mental health problems (e.g., anxiety, agitation, depression, loneliness).[22,24]

Although there are systematic reviews focusing on mental health variables such as depression for AATs, studies tend to mix randomised controlled trial (RCT) designs with other designs (i.e., non-RCT, quasi-experimental and qualitative cross-sectional), which prevents adequate assessment of the effect of confounding variables. In addition, although there are systematic reviews that focus on improving mental health problems with PRIs, most of these reviews report on general interest but do not evaluate the effectiveness of these interventions. Thus, there is still considerable uncertainty about the effectiveness of PRIs for depression. Therefore, the aim of the current systematic review and meta-analysis is to assess the effect of AATs and PRIs in reducing depression in older adults in RCTs.

## 2. Method

### 2.1. Protocol

We conducted a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (see Supplementary Material 1).[25] Our study was registered in PROSPERO (CRD42023393740).

### 2.2. Eligibility criteria

For this systematic review, we included all RCTs that evaluated depressive symptoms in AAT and PRI. The population was older adults, aged 65 years or older, with or without a clinical condition, clinical diagnosis based on mental examination/test or documented from medical records, accredited by the staff of facilities. We included trials in which the comparator was a passive intervention (i.e., waiting list, nothing, placebo) or an active intervention (i.e., psychotherapy, pharmacotherapy, animal-assisted therapy).

Exclusion criteria were: 1) single case study, revision, narrative review or systematic review; 2) not written in English or Spanish; 3) not conducted in older adults; and 4) not accessible in full text.

### 2.3. Information sources and search strategy

We performed a literature search in three databases (PubMed, Scopus and Web of Science) without publication date restriction until 7 October 2022. The search strategy was based on depression, RCTs, and the intervention AAT/PRI. The search strategy for each base is presented in Supplementary Material 2.

In addition, manual searches of related articles were conducted to identify additional potentially eligible studies from the reference lists of relevant systematic reviews.

### 2.4. Selection and data collection process

First, the search results were merged into a RIS file in EndNote to eliminate duplicate records. Second, titles and abstracts were screened, and eliminated to meet the exclusion criteria. Third, we reviewed the records in a full-text review, and those that did not meet the inclusion criteria were excluded. See Supplementary Material 3 from the list of articles excluded from the full-text review. This title, abstract and full-text screening process was performed in a double-blind peer review using the Rayyan platform. Two authors independently conducted the review process and resolved disagreements by consensus; if disagreements persisted, a third reviewer decided on the criteria.

### 2.5. Data extraction

Two independent authors extracted the following information from included studies in the full-text stage into a Microsoft Excel sheet: 1) general information (i.e., first author, year of publication, title, country, and language); 2) sample characteristics (i.e., age range, and women proportion); 3) setting intervention (e.g., length, frequency, animals used, and a brief description of the intervention); 4) comparator (e.g.,

length, frequency, placebo and/or activities; psychotherapy, AAT, and PRI); and 5) outcome assessment of depressive symptoms (i.e., psychiatric diagnosis, and psychometric scale). For the meta-analysis, the full-text articles included were reviewed again, and collected the following information: mean, SD, number of participants, effect size (i.e., Cohen's d, or standardized mean) for control and intervention group, and pre-intervention and post-intervention measurement groups.

### 2.6. Study risk of bias assessment

To assess the risk of bias in RCTs, we used the Cochrane Risk of Bias Tool (RoB2).[26] The RoB2 tool assesses each study by five bias domains and provides an overall risk-of-bias judgement score: low risk of bias, some concerns, or high risk of bias. Two reviewers independently evaluated the possibility of bias in the design of each included study. Any discrepancies were resolved through discussion or by a third reviewer.

### 2.7. Synthesis methods

#### 2.7.1. Main analysis

All analyses were performed using Review Manager version 5.4 (The Cochrane Collaboration, 2014, Nordic Cochrane Centre, Copenhagen, Denmark) and STATA version 16 (Stata Corporation, College Station, TX, USA). Meta-analyses were only performed if three RCTs with similar outcomes were available. The comparison of means and standard deviations (SDs) between intervention and control group measurements was analysed as the primary outcome of the study. If outcomes were assessed in only one trial, we performed the mean difference (MD) because no meta-analysis was performed. For outcomes measured on different scales in different studies, we used the standardised mean difference (SMD) with 95% confidence intervals (CIs) to summarise the statistics and meta-analyse the included studies. The SMD refers to the difference in means between the intervention and control groups divided by the combined SD.[27] We used Hedges' g as the standard measure of effect size in the analyses. Hedge's g, a variation of Cohen's d,[28] is a type of effect size for SMD that corrects for potential bias due to small sample sizes. Accordingly, small (SMD=0.2), moderate (SMD=0.5) and large (SMD > 0.8) effect sizes were determined based on the pooled effect of the intervention using Hedge's g.[29]

Heterogeneity between studies was assessed using: a) Cochran's Q-test statistics, significant heterogeneity was assumed with a p-value < 0.05 (5%); b) the $I^2$ Higgins statistic, the magnitude of heterogeneity was categorised as low ($I^2 > 25\%$), moderate ($I^2 > 50\%$), and high ($I^2 > 70\%$);[27] c) the $H^2$ index, the absence of heterogeneity is suggested with $H^2 = 1$ or lower;[27] and d) the between-study variance ($\tau^2$), no true heterogeneity among the effect estimates is assumed with a $\tau^2 = 0$.[30] We considered it appropriate to use random effects models because of the overall assessment of heterogeneity.

If more than 10 studies are available in the meta-analysis, a publication bias was assessed visually by the funnel plot and quantitatively by the Egger's regression test to detect small study effects and other potential reporting biases.[31] Publication bias is confirmed by an asymmetric distribution in the funnel plot and a significant Egger's test (p-value<0.05). If asymmetry was shown, the Duval and Tweedie trim-and-fill method was performed to estimate the number of missing studies from the meta-analysis.[32]

#### 2.7.2. Sub-analysis

We performed a subgroup analysis based on the type of animal used in AATs and PRIs (i.e., dogs, cats, horses, and birds). Subgroup analysis was only performed if each subgroup contained at least three studies. In addition, a sensitivity analysis was performed, including only studies with a low risk of bias. A two-tailed p-value of < 0.05 was considered statistically significant.

## 3. Results

### 3.1. Study selection

A PRISMA flow diagram of the overall study selection process is illustrated in Fig. 1. The three databases searched and identified 298 records. Subsequently, 86 duplicate records were removed, and 156 records were excluded based on title and abstract review. A total of 56 studies were evaluated in full-text and 33 were further excluded because they did not meet the inclusion criteria (see Supplementary Material 3). Finally, the overall screening process led to the inclusion of 23 RTCs in this systematic review.[19,33–54]

### 3.2. Characteristics of the included studies

The characteristics of the included trials are summarised in Table 1. Of the twenty-three RTC studies, fifteen were parallel-group RTCs, three were pilot RTCs, one was pilot crossover RTC, two were block design RCTs, one was cluster RTC, and one was an RCT with three arms. Almost all studies were conducted in Europe (n = 10), followed by Asia (n = 5), Oceania (n = 5) and North America (n = 3). The included studies were conducted in a variety of settings: nursing homes (n = 10), assisted living facilities (n = 4), and other settings (n = 9). The study sample yielded a total of 1219 older adults, of whom 659 (54.1%) received the AATs or PRIs, and 560 (45.9%) were control samples.

Sixteen studies conducted only an AAT programme, six with PRI, and one employed a combination of AAT and PRI. The interventions varied from 10 to 90 min, during a time-lapse of 6 weeks to 8 months, and frequency was from one to three times per week. The interventions included in their session's dogs (n = 16), cats (n = 1), a seal robot or PARO toy (n = 7), a bird (n = 1), and a toy cat (n = 1). Interventions were heterogeneous and usually involved interaction between the user and the animal - under the supervision of the handler - such as stroking the animal, playing with the animal, throwing and retrieving balls, playing with the animal and even coexistence between the two. About the control group, users received usual care (n = 19), such as pharmacological treatment, non-pharmacological treatment (i.e., occupational therapy, psychotherapy, psychiatry), leisure activities (i.e., reminiscence, music therapy, singing, exercise, crafts), or other control conditions (n = 4).

The follow-up time after the end of the intervention in the RTC studies varied, from immediately after the end of the intervention (n = 16) to between one week and three months (n = 7). Of the outcome measures that assessed depression, studies used the Geriatric Depression Scale (GDS) - the original version as well as other versions (n = 9); the Cornell Scale for Depression in Dementia (CSDD) (n = 10); and other scales (n = 4). For all scales, a score above the cut-off point indicates a higher likelihood of depression.

### 3.3. Risk of bias in studies

The risk of bias analysis was based on the studies included in one of the meta-analyses performed. Overall domain-specific quality assessment and the risk of bias assessment for each study were shown in Fig. 2A and B, respectively. One study was assessed as having a low risk of bias in all domains, with an overall low risk of bias.[48] The dimension of deviation from intended interventions was present in 68.4% (n = 13) of the low-risk of-bias studies. However, at the overall risk of bias level, 78.9% of studies were at high risk of bias (n = 15).

### 3.4. Synthesis of results and meta-analysis

From twenty-three RTCs included in the systematic review, four studies were removed from the meta-analysis due to the lack of information (i.e., mean or SD). Thus, the meta-analysis included nineteen RTCs with a total of 492 participants receiving the AATs or PRIs, and

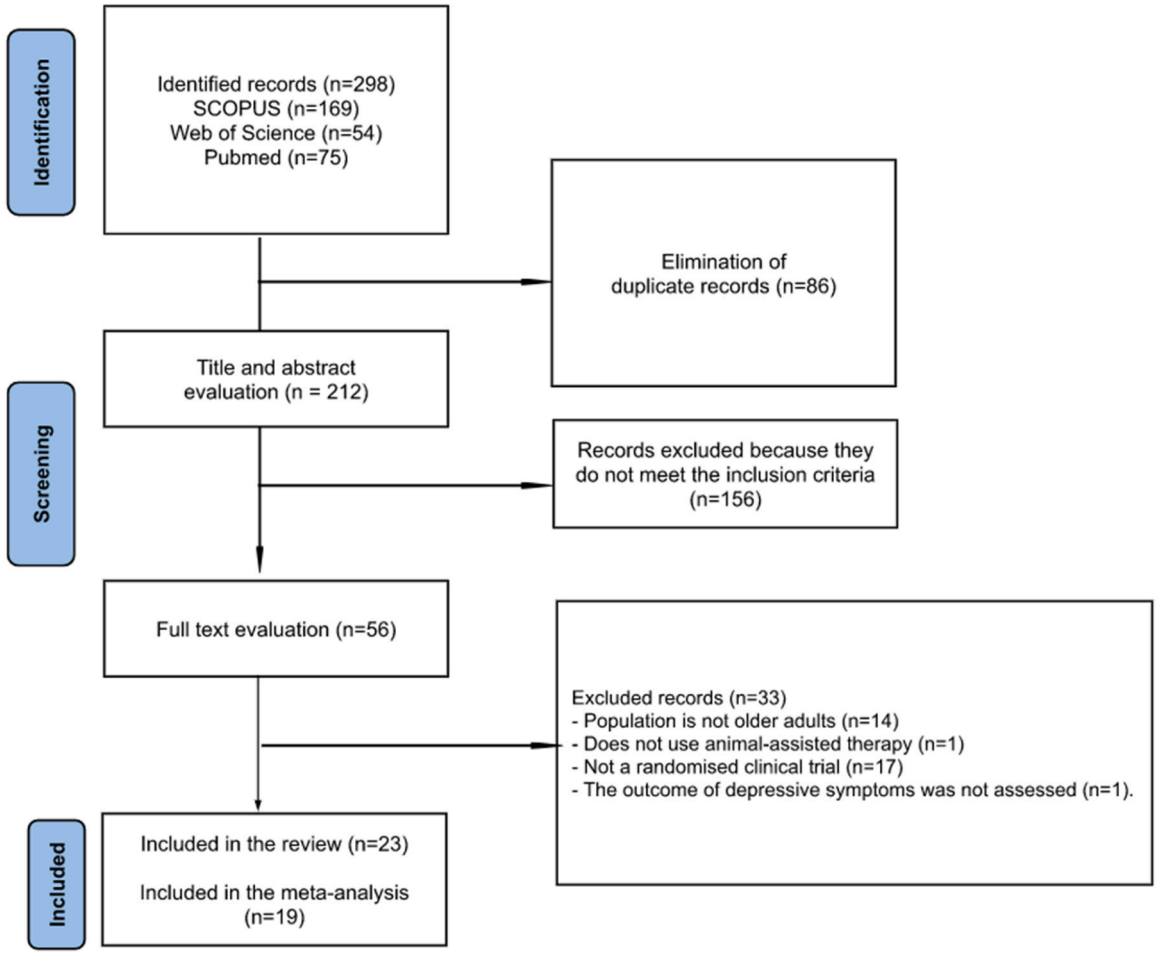


**Fig. 1.** Flowchart.

472 controls were analysed to determine the pooled effect on depression (Fig. 3A).

The meta-analysis showed that in the older adult population, AAT had a significant effect, with a moderate to large effect size (g= −0.72 [−1.13 to −0.31]; p = 0.001), on the reduction of depressive symptoms compared with controls (general gait training, usual care, waitlist, or human therapist). However, there was considerable heterogeneity among the studies analysed ($I^2$ = 81.0% [15.9% to 91.8%]; $H^2$ = 2.28 [1.09 to 3.48]; $\tau^2$ = 0.41). Regarding publication bias, the funnel plot analysis showed no evidence of bias (coefficient = −0.89 [−3.66 to 1.88]; p = 0.494) (see supplementary material 4). On the other hand, there was no evidence of an effect of ERP on depressive symptoms compared with usual care. Furthermore, the heterogeneity between studies was low ($I^2$ = 1.1% [0% to 61.4%]; $H^2$ = 1.00 [1.00 to 1.61]; $\tau^2$ = 0.00).

#### 3.4.1. Subgroup analyses

We performed separate analyses for each type of intervention and control. Specifically, we identified nine studies in which the intervention was AAT in dogs compared to a usual care control (see Fig. 3B). The meta-analysis revealed a significant reduction in depressive symptoms with a medium to large effect size (g = −0.65 [−1.21 to −0.08]; p = 0.025). However, there was marked heterogeneity between the included studies ($I^2$ = 85.4% [0% to 94.6%]; $H^2$ = 2.62 [1.00 to 4.30]; $\tau^2$ =0.58). Additional meta-analyses based on animal species and comparator could not be performed due to an insufficient number of relevant studies.

## 4. Discussion

### 4.1. Main findings

Our study conducted a systematic review and meta-analysis of randomized clinical trials of animal-assisted therapy (AAT) and pet-robot intervention (PRI) to reduce depressive symptoms in older adults. We found that the pooled analysis of all animal species used in AAT had a significant effect on the reduction of depressive symptoms compared to control situations. In addition, the sub-analysis for dog-assisted therapy alone had a significant effect on reducing depressive symptoms in older adults compared with usual care.

To sum up, our findings found benefits in depression using AATs, while we found no clear evidence of effect in PRIS. Given the above, AAT can be used as a complementary intervention for older depressed patients. However, PRI should not be used routinely as therapy for an adult population.

### 4.2. Animal-assisted therapy

Our results suggest that AATs positively affect depression outcomes, which is comparable to previous studies. Previous reviews and meta-analyses have reported that animal interventions improve mood changes (i.e., loneliness, anxiety, and depression), physiological effects (i.e., blood pressure reduction, neurochemical increases), quality of life (QoL), and social support in the elderly population.[9,16,24,55] However, the small sample size and studies in the previous reviews may leave the effectiveness of depression uncertain.

**Table 1**
Characteristics of the included studies (n = 23).

| First Author, Year | | Study Location | Trial design | Setting | Participants | | | Intervention | | Measure for depression |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Intervention | Control | Age | Experimental Group | Control Group | |
| 1 * | An (2021) | South Korea | parallel-group RTC | Rehabilitation hospital | 15 | 15 | 82.6 and control 87.1 years | AAT (Dog) | General gait training | BDI-II |
| 2 | Ambrosi (2019) | Italy | parallel-group RTC | Assisted living facilities | 17 | 14 | Range age: 65-90 years | AAT (Dog) | Usual treatment | GDS |
| 3 * | Baek (2020) | South Korea | parallel-group RTC | Hospital setting | 14 | 14 | Mean age: I= 82.3 years, C= 82.1 years | AAT (Dog) | Usual treatment | CSDD |
| 4 * | Bono (2015) | Italy | parallel-group RTC | Nursing home | 12 | 12 | Mean age: I= 82.1 years, C= 78.3 years | AAT (Dog) | Usual treatment | CSDD |
| 5 | Chen (2021) | China | parallel-group RTC | Assisted living facilities | 20 | 20 | Range age: 40-71 years | AAT (Dog) | Usual treatment | DASS-21 |
| 6 * | Friedman (2015) | USA | Pilot RCT | Assisted living facilities | 22 | 18 | Mean age: 80.72 years | AAT (Dog) | Usual treatment | CSDD |
| 7 * | Jessen (1996) | USA | RCT block design | Nursing home | 20 | 20 | 65 years or older | AAT (Bird) | Usual treatment | CSDD |
| 8 * * | Jøranson (2015) | Norway | Cluster RCT | Nursing home | 27 | 26 | Mean age: 83.9 years | PRI (PARO) | Usual treatment | CSDD |
| 9 * | Kil (2019a) | South Korea | parallel-group RTC | Nursing home | 6 | 6 | Mean age: 79.5 years | AAT (Dog) | Usual treatment | GDSSF-K |
| 10 * | Kil (2019b) | South Korea | parallel-group RTC | Nursing home | 10 | 10 | Mean age: 76.8 years | AAT (Dog) | Inactive (Waiting list) | GDSSF-K |
| 11 * * | Liang (2017) | New Zealand | Pilot RCT | Nursing home | 13 | 11 | Range age: 67-98 years | PRI (PARO) | Usual treatment | CSDD |
| 12 * | Májic (2013) | Germany | parallel-group RTC | Nursing home | 27 | 27 | Range age: 57-101 years | AAT (Dog) | Usual treatment | DMAS |
| 13 * | Menna (2019) | Italy | parallel-group RTC | Adult day care | 11 | 11 | 65 years or older | AAT (Dog) | Usual treatment | GDS |
| 14 * | Moretti (2010) | Italy | parallel-group RTC | Nursing home | 10 | 11 | Mean age: I= 86.5 years, C= 83 years | AAT (Dog) | Usual treatment | GDS |
| 15 * * | Moyle (2013) | Australia | Pilot crossover RCT | Residential care facility | 9 | 9 | Mean age: 85.3 years | PRI (PARO) | Usual treatment | GDS |
| 16 * | Olsen (2016) | Norway | parallel-group RTC | Day centre | 25 | 26 | 65 years or older | AAT (Dog) | Usual treatment | CSDD |
| 17 * | Parra (2021) | Spain | parallel-group RTC | Care centre | 171 | 163 | 65 years or older | AAT (Dog) | Usual treatment | CSDD |
| 18 | Mota Pereira (2018) | Portugal | parallel-group RTC | A day-care center | 30 | 30 | 65 years or older | AAT (Dog or cat) | Usual treatment | HAMD17 |
| 19 * * | Petersen (2017) | USA | RCT block design | Secure dementia units | 35 | 26 | Mean age. 83.4 years | PRI (PARO) | Usual treatment | CSDD |
| 20 * * | Pu (2020) | Australia | Pilot RCT | Nursing home | 21 | 22 | Mean age: 84.8 years | PRI (PARO) | Usual treatment | CSDD |
| 21 * * | Robinson (2013) | New Zealand | parallel-group RTC | Assisted living facilities | 17 | 17 | Range age: 55-100 | PRI (PARO) | Usual treatment | GDS |
| 22 | Thodberg (2016) | Denmark | RCT (three arms) | Nursing home | 100 | 24 | Mean age: 85.5 years | AAT & PRI (Dog, PARO, soft toy cat) | Dog and Placebo (soft toy cat) | GDS |
| 23 * | Travers (2013) | Australia | parallel-group RTC | Residential age care facility | 27 | 28 | 65 years or older | AAT (Dog) | Human-therapist (same intervention) | GDS-SF |

**Note:** BDI-II, Beck Depression Inventory; GDS-15, Geriatric Depression Scale; DASS-21, Depression Anxiety Stress Scale-21; CSDD, Cornell Scale for Depression in Dementia; GDSSF-K, Geriatric Depression Scale Short Form-Korea; DMAS, Dementia Mood Assessment Scale; HAMD17, Hamilton Rating Scale for Depression; GDS-SF, Geriatric Depression Scale Short Form. * Included in the meta-analysis for animal assisted therapy. * * Included in the meta-analysis for pet-robot intervention.

Given the significant effect of AATs on depressive symptoms, the reasons may be due to the social interaction when people receive animal therapy. Interaction with animals improves the user's mood by making the patient feel loved or needed, or by providing companionship.[56] From a different perspective, one study reported that dog handlers felt that AAT created a positive environment because the intervention was tailored to the needs of older people and promoted their emotional well-being.[57] In addition, depressive symptoms often accompany chronic pain and loss of interest in once-pleasurable activities, which can worsen in terms of duration, pain intensity and functional impairment,[58] especially in older people. Pets can also provide positive aspects of pain management, such as joy and laughter.[56] In addition, activities with the animal, such as brushing or walking the animal, increased the patient's physical activity. Interaction with animals may increase their self-efficacy by being able to provide meaningful care and feel more autonomous in older adulthood.[59] The psychological mechanism used to explain the positive relationship with animals is behavioural activation, where the demand for a companion animal limits people's maladaptive behaviour to pain and encourages more adaptive behaviour and the reactivation of reinforcing and valued activities such as hobbies and socialising.[56,60]

Our subgroup analysis for animal type in AATs showed that dog-

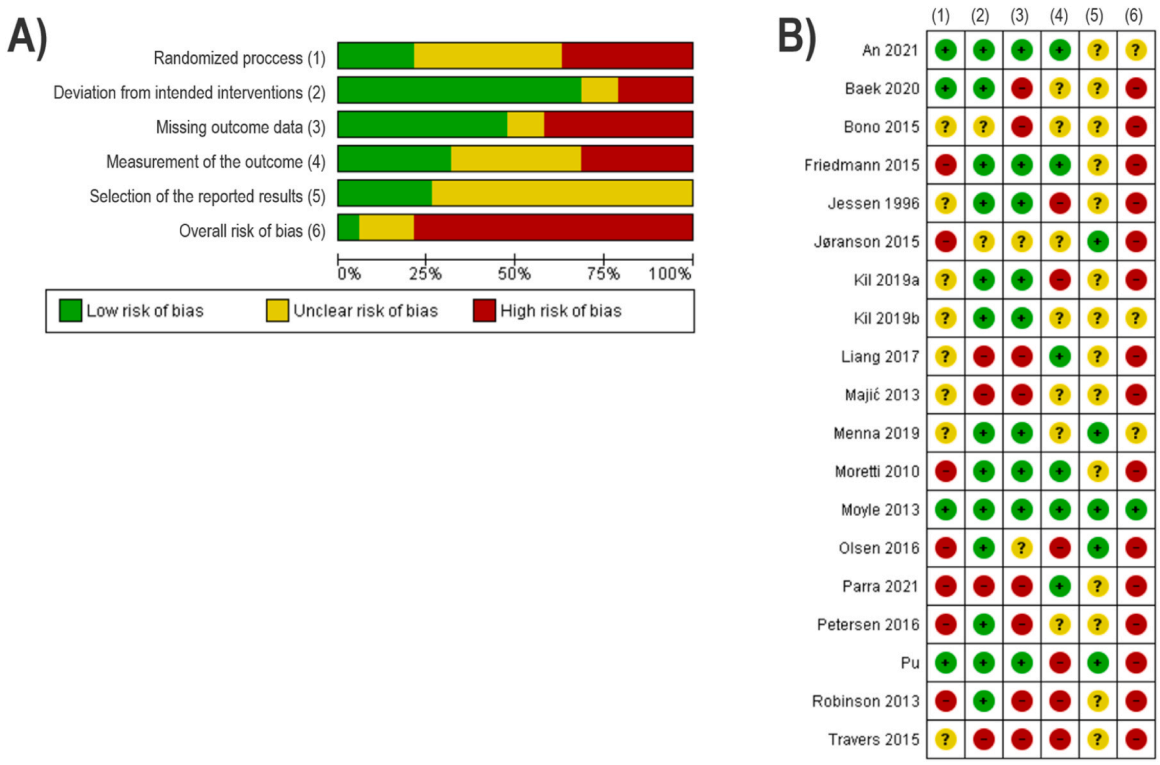


**Fig. 2.** Results of quality assessment of included studies using the Risk of Bias 2 tool. (A) Domain-specific quality assessment graph. (B) Detailed quality assessment summary.

assisted therapy (DAT) significantly reduced depression symptoms. The results reflect that the animals used in the intervention may influence the pooled effect size for depression outcomes. The dog is the most commonly used therapeutic animal in AAT interventions due to its ease and manageability for therapy.[38,61,62] As the use of animal interventions has increased in recent decades, AAT trials have chosen to include trained and certified animals as members of the AAT team.[63] Therefore, an AAT-certified animal ensures that the animal has a calm temperament and is amenable to training.[64] In addition, the potential benefits of DAT have been demonstrated in the elderly population with dementia.[65] Another study reported that DAT may be beneficial in reducing depression.[15] However, our results should be treated with caution, as noted by Zafra-Tanaka, some studies on DAT lacked methodological quality, which may have influenced the results and may not have shown the true benefit of AAT, especially in dogs.[15]

### 4.3. Pet-robot interventions

While therapy with animals has positive effects on mental health in older adults, AAT may present some potential disadvantages in terms of patient safety (i.e., allergies, fear), location (i.e., infrastructure costs), and even animal care (i.e., training, space, and cleanliness).[66] Given this, intervention with animal robots or pet-robot interventions (PRI) is an alternative that seeks to mimic the positive effect of having an animal. Also, PRI seeks to avoid risks to the user's health and minimise costs.[67]

Regarding the effect of PRI on depression, our meta-analysis of six RTCs found no benefit, which is in line with other studies. A review identified nine studies focusing on animal-assisted and pet-robot interventions (AAI and PRI) in psychological symptoms of dementia.[68] Their results showed no effect of AAI and PRI on agitation, depression, and QoL.[24] Conversely, another review in PRI comprising eight studies in patients with dementia, meta-analysis evidenced significant effects on agitation levels and depression symptoms.[24] On the other hand, another review examined the use of robotic animals as animal surrogates for the treatment of psychiatric disorders in dementia patients and suggested that robotic surrogates may have the same effects as human-animal therapy.[65]

In terms of the potential of PRI for mental health, PRI can help to create a positive social space; it stimulates increased oxytocin levels, lowers blood pressure levels and thus produces a positive human response to stress.[40] PRI is based on the hypothesis that interaction with pet-robots reduces stress levels, leading to a reduction in depressive and anxiety symptoms.[43,51] However, due to methodological limitations of previous clinical trials, it is unclear what effect PRIs have on depressive symptoms. Therefore, future studies investigating the efficacy of PRIs are warranted, taking into account the need for more robust methods, large sample sizes and adequate reporting of results according to international standards.

### 4.4. Implications for clinical practice

Healthcare systems could implement this type of intervention as an adjunct to usual care or in their complementary therapy programmes, working with qualified external agencies. For the implementation of AAT, the recommendations take into account that the intervention should be carried out in large open spaces, and consider a qualified team, consisting mainly of a handler, trained and tested in violent behaviour.[62,64]

In terms of implementation costs, AAT is very expensive compared to other traditional interventions (i.e., psychotherapy and pharmacotherapy). Some studies report that the cost of implementing DAT, one of the most commonly used AAT interventions, is around USD 8000, as it includes animal care and training, food and veterinary care.[69] However, AAT in nursing homes or community spaces with older people may be beneficial in the long term because it involves participation in recreational activities that improve the physical, mental and social state of the older adult. In turn, these interventions may also benefit the carers. By improving the health and quality of life of the patient, they may reduce disruptive behaviour, while also influencing staff satisfaction.

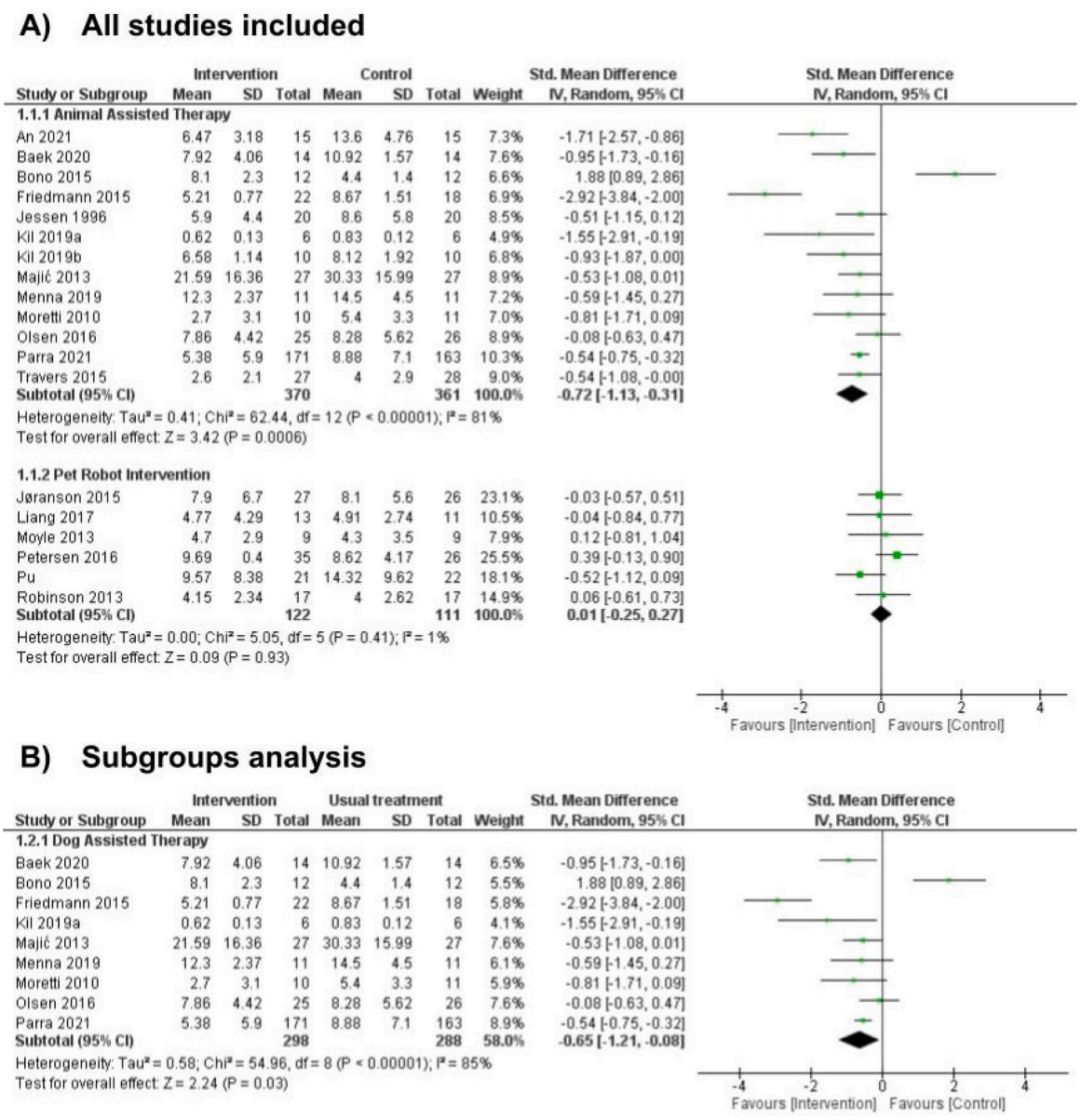


**Fig. 3.** Forest plot of meta-analysis of all studies and meta-analysis by subgroups (dog-assisted therapy only and sea-like interactive robot only) for the outcome of depression at post-intervention.

### *4.5. Strengths and limitations*

Our main strengths were that we used a comprehensive search strategy in different databases and that we only included RCTs, which allowed us to evaluate articles with a robust method and theoretically with a lower risk of bias. On the other hand, the limitations of the study must also be acknowledged. First, the small number of participants in all included trials makes it difficult to assess the strength of the evidence and limits the generalisability of the results, as shown in the meta-analysis. Second, almost half of the studies found were of "fair" or "poor" methodological quality. Overall, the studies included in this review had a high risk of bias, a factor that should be carefully considered when applying these findings in public health settings. However, it is worth noting that there have been criticisms of the validity and internal consistency of the Cochrane risk of bias tool, particularly about other mental disorders.[70] Therefore, future research should focus on evaluating and possibly refining the psychometric properties of this tool to ensure more accurate assessments.

### *4.6. Conclusions*

Our study concluded that AAT and DAT had a moderate and statistically significant effect as interventions to reduce depressive symptoms in older adults. On the other hand, PRI did not show a significant effect in reducing depressive symptoms. We can include that the clinical implications of these findings allow us to consider AAT and DAT as complementary elements to therapy that would generate better assistance for the geriatric population manifesting symptoms of depression.

## Ethics approval and consent to participate

Not applicable.

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## CRediT authorship contribution statement

**Mayo-Puchoc Nikol:** Formal analysis, Methodology, Software, Visualization, Writing – review & editing. **Malaquias-Obregon Sofía:** Data curation, Investigation, Methodology, Validation. **Dámaso-Román Andrea:** Data curation, Investigation, Methodology, Validation. **Villarreal-Zegarra David:** Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Validation, Writing – review & editing. **Yllescas-Panta Teodoro:** Conceptualization, Data curation, Investigation, Methodology, Validation, Writing – original draft.

## Declaration of generative AI and AI-assisted technologies in the writing process

We used DeepL to translate specific sections of the manuscript and Grammarly to improve the wording of certain sections. The final version of the manuscript was reviewed and approved by all authors.

## Declaration of Competing Interest

The authors report no conflict of interest when conducting the study, analyzing the data, or writing the manuscript. TYP developed the first version of the study for his thesis. However, their involvement in the next steps of publication was limited. NIM and DVZ wrote the final version of the manuscript restructured the analysis and updated the search.

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*Consent for publication*

Not applicable.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2024.103023.

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