Official title:

Effect of the resistance-cognitive dual-task training on frailty status and cognitive function in frail community-dwelling older adults with chronic musculoskeletal pain: A pilot randomized controlled trial

NCT number: NCT07035327

Document date: 30 July 2025

Effect of the resistance-cognitive dual-task training on frailty status and cognitive function in frail community-dwelling older adults with chronic musculoskeletal pain: A pilot randomized controlled trial

Abstract

Background: The increasing prevalence of frailty among the ageing population poses significant health challenges, including heightened vulnerability to stressors and adverse outcomes such as falls, hospitalization, and chronic musculoskeletal pain (CMP). CMP significantly contributes to functional disability. Studies indicate a strong association between pain severity and frailty, with a high prevalence of chronic pain among older adults. Cognitive decline correlates with frailty and CMP, affecting perception speed, memory, and verbal fluency.

While physical activity is effective in improving physical functions and reducing pain, hence it may improve physical frailty, its impact on cognitive improvement is limited. Current research lacks comprehensive interventions targeting cognitive frailty. Dual-task training (DTT), which integrates motor and cognitive tasks, has shown promise in enhancing physical and cognitive functions in populations with neurological conditions and cognitive impairments. This study explores the potential of DTT to improve cognitive functions and frailty status in frail individuals with CMP.

Methods: This is a pilot randomized controlled trial of around 38 community-dwelling older adults with chronic musculoskeletal pain and frailty. They will be randomly assigned to either the intervention (n=19) or control group (n=19). The intervention group will receive resistance training and cognitive tasks simultaneously, while the control group will perform resistance exercises only. Both groups will perform exercises (twice/week) under supervision for 10 weeks.

Outcome measures and data analysis: Feasibility and acceptability of the programme will be assessed at the end of the training programme. Outcome measures of frailty status, cognitive function, pain level, and health-related quality of life will be assessed at the initial and the last sessions. To examine preliminary efficacy, within-group and between-group changes in pain and functional measures will be analysed.

Expected results: We expect DTT will be feasible and well-accepted, and participants receiving DTT will gain greater improvement in frailty status, physical and cognitive performances, reduction in pain, and enhancement in health-related quality of life when compared to conventional resistance training.

Keywords: Frailty, Chronic musculoskeletal pain, Exercise, Dual-task training

Introduction

Frailty is a state shown by a regression in ageing individuals' reserves and the chief reason for the vulnerability to various stressors (Cesari et al., 2017). With the rising trend of the ageing population, the prevalence of frailty is expected to grow simultaneously. This brings about the increased risk of unfavourable outcomes like falls, hospitalization, disability, or comorbidity (Pandey et al., 2019). With deterioration in multiple physiological systems, frail individuals may suffer from negative health-related effects, and chronic musculoskeletal pain (CMP) is a major one. On the other hand, CMP may also be a leading cause of frailty since the severity of musculoskeletal pain has a direct effect on individual functions, like mobility (Blyth & Noguchi, 2017). Therefore, managing both frailty and CMP with interventions aimed at slowing down the deterioration is the key. CMP is a chief culprit for the functional disability. It has a large impact on older people's physical activity level, depression, cognitive impairment, and even frailty level (Blyth & Noguchi, 2017). Study shows that pain severity was associated with frailty, with 99% of frail individuals (n=176), classified using the FRAIL questionnaire, having moderate or severe CMP (i.e. ≥4 on the pain numeric rating scale [NRS]) (Chaplin et al., 2023). In the same study, people who transited from non-frail to frail status had greater baseline pain levels (mean NRS: 6.4) than those who remained non-frail (mean NRS: 4.7). This shows that CMP has a positive correlation to frailty. A systematic review of 23 studies showed that approximately 45% of frail community-dwelling older adults had chronic pain, and its prevalence could reach as high as 70% in prefrail or frail older people (Otones Reyes et al., 2019). Frailty could lead to the degeneration of the peripheral and central nervous system, causing nociceptive issues, pain modulation and expression (Blyth & Noguchi, 2017).

In addition to physical deterioration, the rise of cognitive problems is prevalent in frail individuals. A cross-sectional study shows that among the community-dwelling older people over 65 years old, 39% of the frail ones showed cognitive impairment compared to 22% and 16% of pre-frail and normal elderly, respectively (Macuco et al., 2012). The cognitive functions of perception speed, episodic and semantic memory, and verbal fluency showed declined performance in frail elderly (Brigola et al., 2015). Another review also found that there was a strong correlation between CMP and cognitive decline (Alcon et al., 2023). These show that cognitive impairment is a subject of concern in the older population with frailty and CMP.

Physical activity has been the main intervention in treating the frail elderly, and it has been proven effective in reducing physical frailty. Additionally, physical exercise can induce endogenous analgesia, which supports the use of exercise therapy in subjects with CMP (Daenen et al., 2015). However, a meta-analysis showed that physical activity alone had no significant effect on improving cognition (Negm et al., 2019). There are still limited studies about the effect of intervention specifically targeting cognitive frailty, and not a clear flow from the comprehensive assessment to the multimodal interventions to counter cognitive frailty (Sugimoto et al., 2021). Dual-task training (DTT), which combines motor tasks and cognitive tasks, is an intervention that has been proven effective in enhancing the physical capabilities like gait speed and postural stability (Ghai et al., 2017) of older adults in general and those with neurological diseases, like stroke or Parkinson's disease (Varela-Vásquez et al., 2020). General cognitive functions like memory and attention can also be improved by DTT in cognitively healthy populations, or patients with cognitive impairment and Alzheimer's disease (AD) (Pereira Oliva et al., 2020). Since cognitive deficits are present in older people with frailty and CMP as mentioned, DTT may be one of the feasible interventions to improve both physical and cognitive functions, targeting this group of people with physical deficits and cognitive impairment effectively. We would like to see whether a similar effect will be obtained on frail individuals with CMP. The study aims to provide insight into how we provide intervention to enhance cognitive and physical functions, which may possibly pave the way for how we treat the problems of frailty clinically.

Objectives

1. To assess the feasibility and acceptability, and investigate the effect of a 10-week resistance-cognitive DTT program on frailty status in community-dwelling older adults with frailty and CMP compared to conventional resistance training.
2. To investigate the effect of the resistance-cognitive DTT program on cognitive function, pain levels and health-related quality of life in community-dwelling older adults with frailty and CMP compared to conventional resistance training.

We hypothesize that

1. The 10-week resistance-cognitive DTT program is feasible and well accepted, and can improve frailty status greater in community-dwelling older adults with frailty and CMP compared to conventional resistance training.
2. Resistance-cognitive DTT program can improve cognitive function, pain levels and health-related quality of life in community-dwelling older adults with frailty and CMP to a greater extent, compared to conventional resistance training.

Research Plan and Methodology

Study design and setting

It will be a pilot randomized controlled trial on a 10-week resistance-cognitive DTT programme. 38 subjects will be recruited from the general public in Hong Kong. Potential participants will also be identified from another ongoing cross-sectional study (ChiCTR2400089069) that investigates the prevalence of frailty in community-dwelling older adults with CMP. The program will last for 10 weeks with assessments conducted at the initial and final sessions. The assessment overview and overall flow of the study can be found in Appendices 1 and 2. Subjects will receive assessments and training in the Hong Kong Polytechnic University under supervision.

Methods

Recruitment

To recruit subjects with frailty, recruitment posters will be posted on the notice boards of the Hong Kong Polytechnic University. Invitation posts and stories will also be posted on social media like Facebook and Instagram. Potential subjects will also be identified from another cross-sectional study (ChiCTR2400089069) with a similar target population. Eligibility criteria will be screened by online questionnaires. Eligible subjects will undergo face-to-face objective assessments after getting the written consent for participation. Participants will be randomized into the intervention and control groups after the initial assessment.

Randomization and allocation

Randomization and group assignment will be performed by an investigator not involved in recruitment or assessment. After participants' eligibility for enrolment is confirmed, a researcher will use a computer to automatically generate a random sequence using Excel software (Microsoft Corporation, Redmond, USA) to generate random integers, with odd numbers being the experimental group and even numbers being the control group. The grouping information will be stored in a separate folder. Participants will undergo the corresponding exercise program which will be supervised by the researcher.

Treatment

The entire program will be scheduled to span 10 weeks, with exercise sessions occurring twice per week on non-consecutive days. The exercise frequency will be established based on the American College of Sports Medicine's guidelines (Liguori et al. 2022), in which resistance exercise is recommended for at least two days per week.

(i) Intervention group

Participants in the intervention group will engage in a DTT training program, in which resistance training will be incorporated with cognitive tasks. Ten-minute warm-up and cool-down sessions will precede and follow each exercise session.

- Resistance training:
  Participants will be instructed to perform the following exercises with proper form: (1) squat to chair, (2) seated unilateral hip flexion, (3) seated unilateral knee extension, (4) standing unilateral knee flexion and (5) bilateral calf raise. The lower limb exercises will be followed by four upper limb exercises: (6) seated elbow flexion, (7) twisting a towel, (8) seated horizontal opening of arms and elbow, (9) seated diagonal opening of arm and elbow. The procedures of these exercises are described in Appendix 3. The modified BorgCR-10 scale will be adopted to determine the intensity of exercise (Borg, 1998). During the initial two-week familiarization period, one set of 10-15 repetitions at an intensity of 4-5 will be performed. From the third to the twelfth week, participants will perform two sets of 8-12 repetitions at an intensity of 5-6 for each exercise (Liguori et al., 2022). A two-minute rest period will be allowed between sets. Participants will be instructed to execute the concentric and eccentric phases over approximately 2.5 seconds to enhance muscle strength and power. Loads will be adjusted using ankle and wrist weights for exercises (1) to (6), and elastic bands with different resistance for exercises (8) and (9). A standard towel will be used for exercise (7), and subjects will be asked to twist and squeeze the towel with maximal force for 10 repetitions if the pain level is not increased (Izquierdo et al., 2017; Coelho-Júnior & Uchida, 2021).

  In normal situations, exercising painful muscles will not change pain sensitivity either in the exercising muscle or at distant locations. However, in some patients with dysfunctional endogenous analgesia and the presence of central sensitization, there may be a risk that participants may experience an increase in pain during the initial weeks of the program (Daenen et al., 2015). If participants experience an increase in pain that surpasses their usual levels during resistance training, they will switch to alternative non-painful resistance exercises before resuming the exercise that initially causes discomfort. They will also be reminded to ensure adequate rest following the exercise session (Daenen et al., 2015). In subsequent sessions, these participants will be instructed to perform the resistance exercises at a reduced volume and intensity, with their pain levels closely monitored.

- Cognitive task:
  Among different aspects of cognitive functions, verbal fluency has been chosen as a cognitive task in the training since it can serve as a predictor of cognitive decline, providing valuable insight into the potential need for early intervention (Frankenberg et al., 2021). Additionally, working memory has been selected owing to its critical role in cognitively demanding daily activities, such as problem-solving and reading comprehension (Matysiak et al., 2019).

  Subjects will be asked to perform a verbal fluency task simultaneously with the resistance training exercises. The verbal fluency task will require participants, during the concentric action of the exercise, to say aloud as many words as possible within a given category for each exercise set. Each month, the task's difficulty will be increased by altering the word categories, progressing from general to specific, while semantic categories (such as animals and colours) will be varied in each exercise set. Participants will be asked to avoid repeating words and generate new ones (Castaño et al., 2022).

  Apart from the verbal fluency task, subjects will also be asked to perform mental arithmetic tasks which require sufficient working memory (Nascimbeni et al., 2015). This task requires subjects to count backwards from a certain integer. Subjects will initially start by counting backwards by one beginning with two pre-determined numbers: 378 or 283. Subjects will then progress to counting backwards by four and seven **(**Winser et al., 2019). They will progress once they are managed to complete the

task without making mistakes in one session. A three-digit odd number will be randomly generated by the computer as a starting number to ensure participants will not rely on the memorized sequence but actively process each number.

There will be no specific combination of cognitive tasks and resistance exercises, it will be selected randomly upon each resistance exercise. However, each participant should perform each cognitive task for a similar number of times in one session.

(ii) Control group:

Subjects in the control group will perform the resistance exercises only without receiving any cognitive training. Ten-minute warm-up and cool-down sessions will precede and follow each exercise session. Subjects will be instructed to maintain their usual physical activity level throughout the program.

Inclusion and exclusion criteria

Adults, of either sex, aged 60 years or above, living in Hong Kong, being able to read and communicate verbally, screened frail using the Tilburg Frailty Indicator (TFI) (total score ≥5) with report of memory problems (question 9) (Gobbens et al., 2010), experiencing any CMP with a pain level higher or equal to 4 in the numerical pain rating scale over a consecutive 3-month period will be recruited.

Any individuals with either of the following will be excluded: absence of frailty; surgical procedure in the lower limbs or the vertebral column; wheelchair bound or inability to walk for five minutes; severe balance impairment; uncompensated cardiac or vascular condition; acute inflammatory musculoskeletal conditions; ongoing cancer; dementia; neurological diseases such as stroke, Parkinson's disease, cerebellar disease, myelopathy, and peripheral neuropathy; mental illnesses such as schizophrenia, bipolar, psychosis, borderline personality disorder; illiteracy.

Sample size consideration

As this is a pilot study, the study has been designed to generate data that will be used for setting up future larger randomised controlled trials. The sample size has been selected to evaluate the feasibility, safety and preliminary efficacy of the intervention. An exploratory sample size of 30 participants will be recruited in this study, in which 15 of them will be randomly allocated to the intervention group performing DTT, and the control group. To anticipate a 20% loss, the sample size will increase to 38. All results from the pilot study will be helpful in sample size calculations for the future large study.

Outcome measures

(i) Primary outcome

- Feasibility and acceptability

  Feasibility will be evaluated through recruitment and compliance rates of the program. Recruitment rate will be defined as the total number of participants recruited out of the total number of participants screened. Treatment compliance will be defined as the proportion of scheduled sessions attended in each group. Acceptability will be assessed by a six-question post-program questionnaire based on the barriers to engaging in physical activity (Tiecker et al., 2024). Participants will be asked about (1) their perceived importance of physical exercise, (2) their acceptability and satisfaction of the exercises, (3) the pain or discomfort during the exercises, (4) how challenging it was to perform the exercises, (5) exercise duration, (6) whether the exercises could assist in activities of daily living. All questions will be asked to rate from a 5-point Likert scale from 'Strongly disagree' to 'Strongly agree' (Appendix 4). Participants will be asked to justify all questions to let the researchers understand their difficulties. The questionnaire will be administered at the last session of this program. For descriptive interpretation, these thresholds (≥70% of participants attending ≥70% of supervised sessions and ≥70%

reporting satisfaction) will be regarded as indicative of good feasibility and acceptability.

- Frailty status:

To assess the frailty status of participants, three assessment tools will be used since there is currently no gold standard in assessing frailty (Dent et al., 2017): the Tilburg Frailty Indicator (TFI) (Gobbens et al., 2010), the Fried Frailty Phenotype (FFP) (Fried et al., 2001) and the Short Physical Performance Battery (SPPB) (Ramírez-Vélez et al., 2021). TFI consists of 4 parts, including physical, social and psychological components, and determinants of frailty (not scored and not subjected to change in this study), which provide us with information on the multifaceted nature of frailty other than physical deficits (Gobbens et al., 2010). Other than frailty determinants that are not scored, there are 15 items in total, with a score of 0 or 1 on each item. A total score of ≥5 has a validity of 0.86 to determine the frailty status of the community-dwelling older Chinese population (Dong et al., 2017). FFP consists of 5 components in assessing the severity of fraily, including weight loss, weakness, exhaustion, slowness and low physical activity (Fried et al., 2001). The frailty score is calculated and the status is categorized into robust (0), pre-frail (1-2) and frail (3-5) (Auyeung et al., 2014; Fried et al. 2001). The SPPB is an assessment tool for participants' physical function. It includes 3 components: standing balance, 4-m gait speed, and five-repetition sit-to-stand motion (Ramírez-Vélez et al., 2021). Each component has a score of 0-4. It can be used to show the physical frailty of the participants. A total score of <9 is regarded as frail, with a high sensitivity (79.7-92%) and specificity (73.8-80%) (da Câmara et al., 2013; Perracini et al., 2020; Ramírez-Vélez et al., 2021).

(ii) Secondary outcome

There are four secondary outcome measures: a) cognitive function, b) pain level, c) quality of life, and d) acceptability towards the programme

- Cognitive function

To assess the cognitive status of participants, three assessment tools will be used: the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 1995), the forward digit span test (Wechsler, 2008) and the Cognitive Failures Questionnaire (CFQ) (Broadbent et al., 1982). The MoCA is a well-established 30-point test that assesses various aspects, like attention, memory and fluency. The Hong Kong version (HK-MoCA) will be used (Wong et al., 2009). A higher score indicates better cognitive function. A score of 25 or below may indicate the presence of mild cognitive impairment (Nasreddine et al., 1995). The digit span test is a measure of working memory. Participants will be presented with a random series of digits and be asked to repeat them in the order presented (Wechsler, 2008). If the participant responds correctly, the next trial presents a longer sequence. The task will terminate when participants respond incorrectly on three occasions. The participant's span will be the longest number of sequential digits that can be accurately remembered. A longer span indicates better working memory with high internal reliability (70-90%) (Conway et al., 2005). The CFQ is a self-report measure to assess individual forgetfulness, distractibility, and false triggering in everyday life (Rast et al., 2009). It has 25 items (0-4 points) scored by the client or significant other (Broadbent et al., 1982). The total score is 100 points. A higher point indicates fewer cognitive difficulties in daily life, with a high test-retest reliability of 0.71 (Bridger, 2013). A valid and reliable Chinese version of the CFQ will be used in this study (Zhou et al.,2016).

- Pain score

The average pain score will be assessed by the numerical pain rating scale (NPRS). Participants will be asked to rate the average pain level on a scale from 0 (no pain) to 10

(maximal pain). It has a high test-retest reliability of 0.95 (Ferraz et al., 1990).

- Health-related quality of life
  The health-related quality of life will be assessed by the EQ-5D-5L questionnaire. It has a validated Hong Kong Chinese version (Wong et al., 2019). The questionnaire consists of 5 dimensions of health, including mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension will be rated from 1 (no problem) to 5 (extreme problems). It also has an EQ-VAS scale to self-rate the overall health perception from 0 (worst health) to 100 (best health). The questionnaire will be administered before and after the intervention programme.

Sociodemographic data will also be collected, including age, gender, body mass index, marital status, living status, mobility status, educational level, employment status, lifestyle variables (exercise habit, smoking, alcohol intake), number of self-reported comorbidities, and any presence of polypharmacy (i.e. concurrent use of ≥5 drugs) in the baseline assessment.

Statistical analysis
Descriptive statistics with means (SDs) or medians (IQRs) for continuous variables, and counts (percentages) for categorical variables will be reported for the demographics of the participants. Shapiro-Wilk test will be used to check data for normality. The recruitment, compliance and acceptability rates will be presented as percentages with 95% confidence intervals (95% CIs) to describe the feasibility and acceptability of the program. For the first and second objectives, independent t-tests for parametric statistics or Mann-Whitney U Test for non-parametric statistics will be used to compare baseline statistics between the intervention and control groups. Mixed ANOVA will be used to show the differences of change in outcome measures between both groups, and post-hoc tests will be used to check for differences in the outcomes between pre- and post-intervention in both groups. Statistical analyses will be performed using SPSS software version 29 (IBM, New York, USA). The level of significance will be set at $p<0.05$.

Ethical considerations

The researcher will explain the risks and benefits of the study to the participants. Written informed consent will be obtained from the participants. Participants may withdraw from the project without prejudice. Data will be kept confidential in secure offices of the Department of Rehabilitation Sciences. Only group data will be published. Approval for the project will be obtained from The Hong Kong Polytechnic University Institutional Review Board. The study will adhere to the local laws, the Declaration of Helsinki, and institutional policies. This study will be registered with the Chinese Clinical Trials Registry before the first participant is recruited.

References

Alcon, C., Bergman, E., Galli, F., Humphrey, J., Patel, R. M., & Wang-Price, S. (2023). The relationship between pain catastrophizing and cognitive function in chronic musculoskeletal pain: A scoping review. *Pain Research & Management*, *2023*, 5851450. https://doi.org/10.1155/2023/5851450

Auyeung, T. W., Lee, J. S., Leung, J., Kwok, T., & Woo, J. (2014). The selection of a screening test for frailty identification in community-dwelling older adults. *The Journal of Nutrition, Health & Aging*, *18*(2), 199–203. https://doi.org/10.1007/s12603-013-0365-4

Blyth, F. M., & Noguchi, N. (2017). Chronic musculoskeletal pain and its impact on older people. *Best Practice & Research Clinical Rheumatology*, *31*(2), 160–168. https://doi.org/10.1016/j.berh.2017.10.004

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics.

Bridger, R. S., Johnsen, S. Å., & Brasher, K. (2013). Psychometric Properties of the cognitive failures questionnaire†. *Ergonomics*, *56*(10), 1515–1524. https://doi.org/10.1080/00140139.2013.821172

Brigola, A. G., Rossetti, E. S., Santos, B. R., Neri, A. L., Zazzetta, M. S., Inouye, K., & Pavarini, S. C. (2015). Relationship between cognition and frailty in elderly: A systematic review. *Dementia & Neuropsychologia*, *9*(2), 110–119. https://doi.org/10.1590/1980-57642015dn92000005

Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, *21*(1), 1–16. https://doi.org/10.1111/j.2044-8260.1982.tb01421.x

Castaño, L. A. A., Castillo de Lima, V., Barbieri, J. F., de Lucena, E. G. P., Gáspari, A. F., Arai, H., Teixeira, C. V. L., Coelho-Júnior, H. J., & Uchida, M. C. (2022). Resistance Training Combined With Cognitive Training Increases Brain Derived Neurotrophic Factor and Improves Cognitive Function in Healthy Older Adults. *Frontiers in psychology*, *13*, 870561. https://doi.org/10.3389/fpsyg.2022.870561

Cesari, M., Calvani, R., & Marzetti, E. (2017). Frailty in older persons. *Clinics in Geriatric Medicine*, *33*(3), 293–303. https://doi.org/10.1016/j.cger.2017.02.002

Chaplin, W. J., McWilliams, D. F., Millar, B. S., Gladman, J. R., & Walsh, D. A. (2023). The bidirectional relationship between chronic joint pain and frailty: Data from the investigating Musculoskeletal Health and Wellbeing cohort. *BMC Geriatrics*, 23(1). https://doi.org/10.1186/s12877-023-03949-4

Coelho-Júnior, H. J., & Uchida, M. C. (2021). Effects of Low-Speed and High-Speed Resistance Training Programs on Frailty Status, Physical Performance, Cognitive Function, and Blood Pressure in Prefrail and Frail Older Adults. *Frontiers in medicine*, *8*, 702436. https://doi.org/10.3389/fmed.2021.702436

Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769–786. https://doi.org/10.3758/bf03196772

Daenen, L., Varkey, E., Kellmann, M., & Nijs, J. (2015). Exercise, not to exercise, or how to exercise in patients with chronic pain? Applying science to practice. *The Clinical journal of pain*, *31*(2), 108-114.

da Câmara, S.M.A., Alvarado, B.E., Guralnik, J.M., Guerra, R.O. and Maciel, Á.C.C. (2013), Using the Short Physical Performance Battery to screen for frailty in young-old adults with distinct socioeconomic conditions. Geriatrics & Gerontology International, *13*, 421-428. https://doi.org/10.1111/j.1447-0594.2012.00920.x

Dent, E., Lien, C., Lim, W. S., Wong, W. C., Wong, C. H., Ng, T. P., Woo, J., Dong, B., de la Vega, S., Hua Poi, P. J., Kamaruzzaman, S. B., Won, C., Chen, L.-K., Rockwood, K., Arai, H., Rodriguez-Mañas, L., Cao, L., Cesari, M., Chan, P., … Flicker, L. (2017). The asia-pacific clinical practice guidelines for the management of frailty. *Journal of the American Medical Directors Association*, *18*(7), 564–575. https://doi.org/10.1016/j.jamda.2017.04.018

Dong, L., Liu, N., Tian, X., Qiao, X., Gobbens, R. J. J., Kane, R. L., & Wang, C. (2017). Reliability and validity of the Tilburg Frailty Indicator (TFI) among Chinese community-dwelling older people. *Archives of Gerontology and Geriatrics*, *73*, 21–28. https://doi.org/10.1016/j.archger.2017.07.001

Ferraz, M. B., Quaresma, M. R., Aquino, L. R., Atra, E., Tugwell, P., & Goldsmith, C. H. (1990). Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis. *The Journal of Rheumatology*, *17*(8), 1022–1024.

Frankenberg, C., Weiner, J., Knebel, M., Abulimiti, A., Toro, P., Herold, C. J., Schultz, T., & Schröder, J. (2021). Verbal fluency in normal aging and cognitive decline: Results of a longitudinal study. *Computer Speech & Language*, *68*, 101195-. https://doi.org/10.1016/j.csl.2021.101195

Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., McBurnie, M. A., & Cardiovascular Health Study Collaborative Research Group (2001). Frailty in older adults: evidence for a phenotype. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 56(3), M146–M156. https://doi.org/10.1093/gerona/56.3.m146

Ghai, I., Ghai, S., & Effenberg, A. O. (2017). Effects of dual tasks and dual-task training on postural stability: A systematic review and meta-analysis. *Clinical Interventions in Aging*, *12*, 557–577. https://doi.org/10.2147/CIA.S125201

Gobbens, R. J. J., van Assen, M. A. L. M., Luijkx, K. G., Wijnen-Sponselee, M. Th., & Schols, J. M. G. A. (2010). The Tilburg Frailty Indicator: Psychometric properties. *Journal of the American Medical Directors Association*, *11*(5), 344–355. https://doi.org/10.1016/j.jamda.2009.11.003

Izquierdo, M., Casas-Herrero, A., Zambom-Ferraresi, F., Martínez-Velilla, N., Alonso-Bouzón, C., & Rodriguez-Mañas, L. (2017). *A practical guide for prescribing a multi-component physical training program to prevent weakness and falls in people over 70. Multi-component physical exercise program VIVIFRAIL*. https://vivifrail.com/wp-content/uploads/2019/11/VIVIFRAIL-ENG-Interactivo.pdf

Liguori, G., Feito, Y., Fountaine, C. (Charles J., & Roy, B. (Eds.). (2022). *ACSM's guidelines for exercise testing and prescription* (Eleventh edition.). Wolters Kluwer.

Macuco, C. R., Batistoni, S. S., Lopes, A., Cachioni, M., da Silva Falcão, D. V., Neri, A. L., & Yassuda, M. S. (2012). Mini-mental state examination performance in frail, pre-frail,

and non-frail community dwelling older adults in Ermelino Matarazzo, São Paulo, Brazil. *International Psychogeriatrics, 24*(11), 1725–1731. https://doi.org/10.1017/s1041610212000907

Matysiak, O., Kroemeke, A., & Brzezicka, A. (2019). Working Memory Capacity as a Predictor of Cognitive Training Efficacy in the Elderly Population. *Frontiers in Aging Neuroscience*, *11*, 126–126. https://doi.org/10.3389/fnagi.2019.00126

Nascimbeni, A., Caruso, S., Salatino, A., Carenza, M., Rigano, M., Raviolo, A., & Ricci, R. (2015). Dual task-related gait changes in patients with mild cognitive impairment. *Functional Neurology*, *30*(1), 59–65. https://doi.org/10.11138/FNeur/2015.30.1.059

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MOCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Negm, A. M., Kennedy, C. C., Thabane, L., Veroniki, A.-A., Adachi, J. D., Richardson, J., Cameron, I. D., Giangregorio, A., Petropoulou, M., Alsaad, S. M., Alzahrani, J., Maaz, M., Ahmed, M. M., Kim, E., Tehfe, H., Dima, R., Sabanayagam, K., Hewston, P., Abu Alrob, H., & Papaioannou, A. (2019). Management of Frailty: A systematic review and network meta-analysis of randomized controlled trials. *Journal of the American Medical Directors Association*, *20*(10), 1190–1198. https://doi.org/10.1016/j.jamda.2019.08.009

Otones Reyes, P., García Perea, E., & Pedraz Marcos, A. (2019). Chronic pain and frailty in community-dwelling older adults: A systematic review. *Pain Management Nursing*, *20*(4), 309–315. https://doi.org/10.1016/j.pmn.2019.01.003

Pandey, A., Kitzman, D., & Reeves, G. (2019). Frailty is intertwined with heart failure. *JACC: Heart Failure*, *7*(12), 1001–1011. https://doi.org/10.1016/j.jchf.2019.10.005

Pereira Oliva, H. N., Mansur Machado, F. S., Rodrigues, V. D., Leão, L. L., & Monteiro-Júnior, R. S. (2020). The effect of dual-task training on cognition of people with different clinical conditions: An overview of systematic reviews. *IBRO Reports*, *9*, 24–31. https://doi.org/10.1016/j.ibror.2020.06.005

Perracini, M. R., Mello, M., de Oliveira Máximo, R., Bilton, T. L., Ferriolli, E., Lustosa, L. P., & da Silva Alexandre, T. (2020). Diagnostic accuracy of the short physical performance battery for detecting frailty in older people. *Physical Therapy*, *100*(1), 90–98. https://doi.org/10.1093/ptj/pzz154

Ramírez-Vélez, R., López Sáez De Asteasu, M., Morley, J. E., Cano-Gutierrez, C. A., & Izquierdo, M. (2021). Performance of the short physical performance battery in identifying the frailty phenotype and predicting geriatric syndromes in community-dwelling elderly. *The Journal of Nutrition, Health and Aging*, *25*(2), 209–217. https://doi.org/10.1007/s12603-020-1484-3

Rast, P., Zimprich, D., Van Boxtel, M., & Jolles, J. (2008). Factor structure and measurement invariance of the cognitive failures questionnaire across the adult life span. *Assessment*, *16*(2), 145–158. https://doi.org/10.1177/1073191108324440

Salse-Batán, J., González-Devesa, D., Duñabeitia, I., Bidaurrazaga-Letona, I., Ayán-Pérez, C., & Sanchez-Lastra, M. A. (2025). Effects of stretching exercise on walking performance and balance in older adults: A systematic review and meta-analysis. *Geriatric Nursing (New York)*, *61*, 479–490. https://doi.org/10.1016/j.gerinurse.2024.12.018

Simão, R., Lemos, A., Salles, B., Leite, T., Oliveira, É., Rhea, M., & Reis, V. M. (2011). The Influence of Strength, Flexibility, and Simultaneous Training on Flexibility and Strength Gains. *Journal of Strength and Conditioning Research*, *25*(5), 1333–1338. https://doi.org/10.1519/JSC.0b013e3181da85bf

Sugimoto, T., Arai, H., & Sakurai, T. (2021). An update on cognitive frailty: Its definition, impact, associated factors and underlying mechanisms, and interventions. *Geriatrics & Gerontology International*, *22*(2), 99–109. https://doi.org/10.1111/ggi.14322

Tiecker, A. P., Cadore, E. L., Izquierdo, M., Zmuda, G. G. O., Aguirre, F. B., & Bós, Â. J. G. (2024). Acceptability of a home-based multicomponent exercise program (Vivifrail®) for the oldest-old via videoconferencing during the Covid-19 pandemic. *Revista Brasileira de Geriatria e Gerontologia.*, *27*. https://doi.org/10.1590/1981-22562024027.230089.en

Varela-Vásquez, L. A., Minobes-Molina, E., & Jerez-Roig, J. (2020). Dual-task exercises in older adults: A structured review of current literature. *Journal of Frailty, Sarcopenia and Falls*, *05*(02), 31–37. https://doi.org/10.22540/jfsf-05-031

Wechsler, D. (2008). Wechsler Adult Intelligence Scale--fourth edition. *PsycTESTS Dataset*. https://doi.org/10.1037/t15169-000

Winser, S., Pang, M. Y. C., Rauszen, J. S., Chan, A. Y. Y., Chen, C. H., & Whitney, S. L. (2019). Does integrated cognitive and balance (dual-task) training improve balance and reduce falls risk in individuals with cerebellar ataxia? *Medical Hypotheses*, *126*, 149–153. https://doi.org/10.1016/j.mehy.2019.03.001

Wong, A., Xiong, Y. Y., Kwan, P. W., Chan, A. Y., Lam, W. W., Wang, K., Chu, W. C., Nyenhuis, D. L., Nasreddine, Z., Wong, L. K., & Mok, V. C. (2009). The validity, reliability and clinical utility of the Hong Kong Montreal Cognitive Assessment (HK-MoCA) in patients with cerebral small vessel disease. *Dementia and geriatric cognitive disorders*, *28*(1), 81–87. https://doi.org/10.1159/000232589

Wong, E. L., Cheung, A. W., Wong, A. Y., Xu, R. H., Ramos-Goñi, J. M., & Rivero-Arias, O. (2019). Normative Profile of Health-Related Quality of Life for Hong Kong General Population using Preference-Based Instrument EQ-5D-5L. Value in Health, *22*(8), 916–924. https://doi.org/10.1016/j.jval.2019.02.014

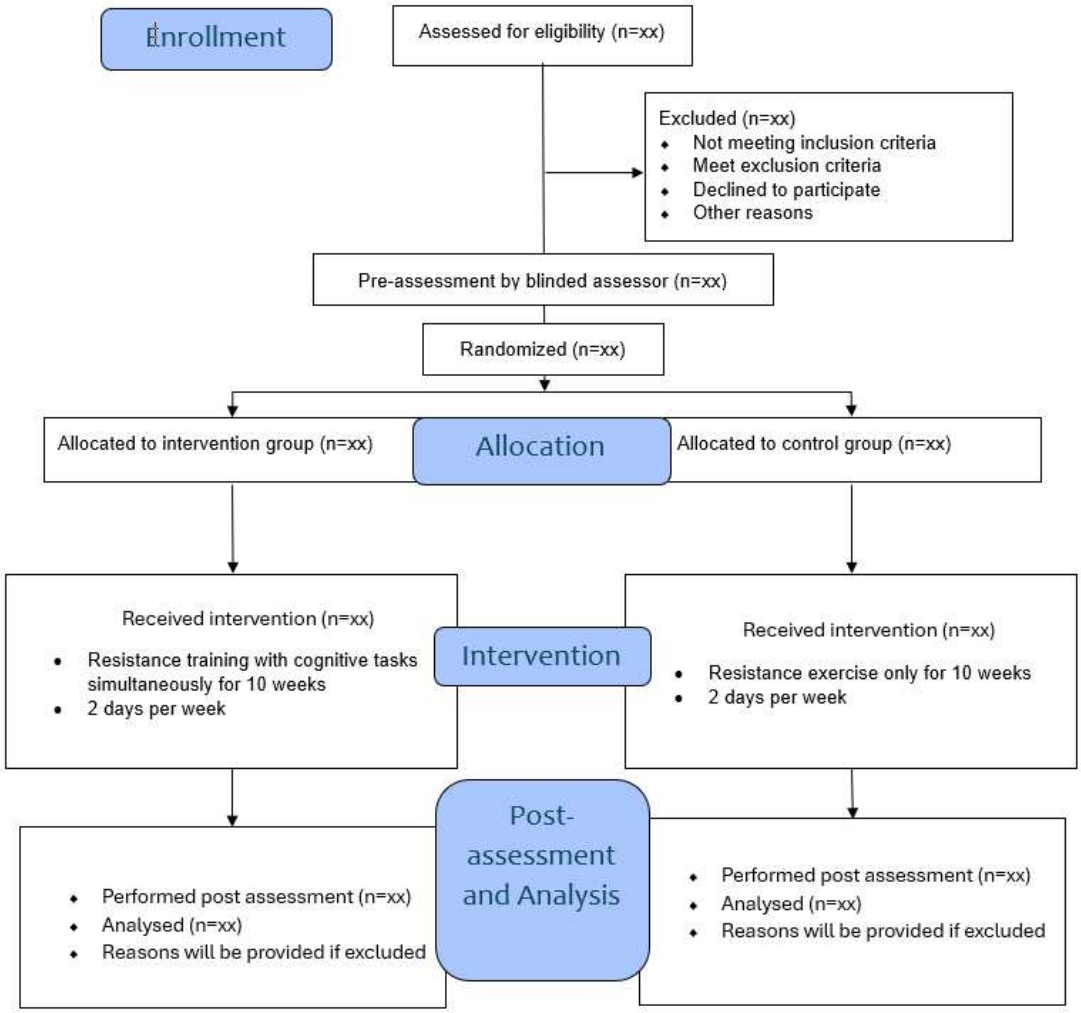
Zhou, Y., Chen, J., Liu, Y., Wang, P., Zhu, L., & Yan, T. (2016). 认知失败问卷中文版测评大学生样本的效度和信度[Validity and Reliability of the Chinese Version of the Cognitive Failures Questionnaire in a University Student Sample]. Chinese and reliability of the Chinese version of the cognitive failure questionnaire in a sample of college students, *24*(3), 438-443.

Appendix 1. Assessments overview and sample of outcome measures

Assessment	Baseline (Day 0)	Intervention period	End of intervention
Enrolment			
Eligibility screen	X		
Informed consent	X		
Demographic data	X		
Comorbidity data	X		
Treatment			
Intervention group: resistance training, cognitive tasks		X	
Control group: resistance exercise		X	
Outcomes			
Feasibility and acceptability			X
Frailty level			
- TFI	X		X
- FFP	X		X
- SPPB	X		X
Cognitive function			
- MoCA	X		X
- Forward digit span test	X		X
- CFQ	X		X
Pain intensity: NPRS	X		X
Health-related quality of life: EQ-5D-5L	X		X

TFI, Tilburg Frailty Indicator; FFP, Fried Frailty Phenotype; SPPB, Short Physical Performance Battery; MoCA, Montreal Cognitive Assessment; CFQ, Cognitive Failures Questionnaire; NPRS, Numerical Pain Rating Scale

Appendix 2. CONSORT Flow Diagram



Appendix 3. Description of exercises

Resistance exercises	
(1) Squat to chair	Subjects sit in a firm chair with arms, supporting their feet well on the ground, and stand up without using the arms of the chair. In the standing position, subjects lower their body down until their buttocks touch the chair and immediately return to standing.
(2) Seated unilateral hip flexion	Subjects sit in a firm chair with arms and slowly lift one knee towards their chest as high as is comfortable with the knee bent, keeping the foot off the ground. They then lower the foot back to the floor, returning to the starting position.
(3) Seated unilateral knee extension	Subjects horizontally extend one leg, trying to keep it as straight as possible, and repeat with the other leg once they have finished the recommended sets.
(4) Standing unilateral knee flexion	Subjects stand up and, if necessary, support their arms on a firm chair or table. With their back straight, they flex the knee, keeping the foot back, and return to the initial position. They repeat with the other leg once the sets indicated have been finished.
(5) Bilateral calf raise	Subjects stand in front of a table or chair back with their feet separated and aligned with their shoulders. They get on their tiptoes until they are as high as possible, then go down gradually until their heels are on the floor. If they lose balance, they support themselves on the table or chair; they do not do so if they can keep their balance well.
(6) Seated elbow flexion	Subjects sit with their arms stretched across their body with a weight in each hand. They bend the elbows towards the chest, moving the weights towards the shoulders.
(7) Twisting a towel	Subjects roll up a small towel into the shape of a tube, grab the towel by the ends, and use both hands to make a movement similar to wringing out a soaking towel. They tighten gradually but as strong as they can.
(8) Seated horizontal opening of arms and elbow	Subjects hold an elastic band by the ends and roll it appropriately to prevent injury. They stretch the band at the height of their chest and separate the arms to fully extend the elbows.
(9) Seated diagonal opening of arm and elbow	Subjects hold an elastic band by the ends and roll it appropriately to prevent injury. They begin to separate the arms diagonally to extend the elbows at the height of the knees.

Appendix 4. Acceptability Questionnaire

Criteria	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Importance of engaging in the proposed exercises					
Acceptability and satisfaction of the exercises					
Discomfort felt when performing the exercises					
Difficulty in performing the exercises					
Duration of exercises					
Can the exercises help with activities of daily living?					

(Adpoted from Tiecker et al., 2024)