Cycling: how can we activate care-dependent older adults with a mild cognitive impairment?

Peer-reviewed author version

MARINUS, Nastasia; HANSEN, Dominique; FEYS, Peter; MEESEN, Raf; TIMMERMANS, Annick & SPILDOOREN, Joke (2023) Cycling: how can we activate care-dependent older adults with a mild cognitive impairment?. In: Disability and rehabilitation. Assistive technology (Print), 18 (6), p. 896-903.

DOI: 10.1080/17483107.2021.1936665
Handle: http://hdl.handle.net/1942/34267

Cycling: How Can We Activate Care-dependent Older Adults With A Mild Cognitive Impairment?

Nastasia Marinus[a,b*#], Dominique Hansen[a,b,c#], Peter Feys[a,b], Raf Meesen[a], Annick Timmermans[a], Joke Spildooren[a].

[a]*REVAL - Rehabilitation Research Center, Faculty of Rehabilitation Sciences, Hasselt University, Diepenbeek, Belgium;* [b]*BIOMED - Biomedical Research Center, Hasselt University, Diepenbeek, Belgium;* [c]*Heart Centre Hasselt, Jessa Hospital, Hasselt, Belgium*

#Shared authors
*Corresponding author:
Nastasia Marinus
Hasselt University, Faculty of Rehabilitation Sciences
Agoralaan, Building A, 3590 Diepenbeek, Belgium
E-mail: nastasia.marinus@uhasselt.be
Tel 0032 (0)11 269203
Twitter: https://twitter.com/MarinusNastasia
Researchgate: https://www.researchgate.net/profile/Nastasia_Marinus
ORCID: https://orcid.org/0000-0002-4903-2439

Short biographical notes: Nastasia Marinus is a PhD student at Hasselt University. Her doctoral program is focussed on all aspects of frailty in older adults with cardiovascular diseases. Prof. dr. Dominique Hansen is Professor of Rehabilitation and Exercise Physiology in Internal Diseases and Vice Dean of the Faculty of Rehabilitation Sciences at Hasselt University. The research focus of Prof. dr. Annick Timmermans is situated in "technology-supported assessment" and "motor learning during/after technology-supported rehabilitation" in musculoskeletal disorders. The area of specialization of Prof. dr. Raf Meesen is situated in motor control, motor learning, ergonomics, behavioural/cognitive neuroscience and neuroplasticity. Prof. dr. Peter Feys is Professor in Rehabilitation Sciences and Physiotherapy at Hasselt University, and dean of the faculty of Rehabilitation Sciences. His inter-disciplinary research is focused on the assessment and rehabilitation for gait and upper limb

function in predominantly persons with neurological conditions (MS and secondary stroke). It comprises investigations of motor fatigability, music-based entrainment and sonification, upper limb training, cognitive-motor interference, technology-supported training, and community self-directed training. Prof. dr. Joke Spildooren is an assistant professor at Hasselt University. Her main research focus is situated in the field of geriatric rehabilitation.

Full text word count: 5729

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Cycling: How Can We Activate Care-dependent Older Adults With A Mild Cognitive Impairment?

Purpose: In residential care, 50% of older adults are sedentary in most of their time, regardless of the positive impact of physical exercise on health. This study analysed whether television images positively impact the motivation and exercise intensity of cycling exercises of older adults in residential care. Methods: In this randomised controlled cross-over study, 10 residential older adults (mean age 85.0±5.7 years) with Mild Cognitive Impairment (MCI) participated in 3 different cycling exercise interventions (TV off, TV turned on the National Geographic channel (NG) and TV with MemoRide software (Activ84Health®, Leuven, Belgium) (MR) (cybercycling)) compared with a rest condition. Results: The participants cycled significantly more distance during NG compared with TVoff ($p=0.024$). In comparison to the rest condition, the mean heart rate was significantly higher in all exercise conditions while the maximal heart rate was only higher during NG ($p=0.022$). There was no difference in the Borg scale between the different exercise interventions. Interest and enjoyment scored significantly higher during NG ($p=0.014$) and MR ($p=0.047$) compared to the rest condition and in the NG versus TVoff ($p=0.018$). No significant differences were observed in the emotions of the participants. Conclusions: This study has shown indications that the addition of television images may increase the exercise intensity and motivation to exercise in residential older adults with MCI. However, the overall levels of physical activity were insufficient to meet the recommendations for moderate-intense aerobic exercise according to the International Association of Gerontology and Geriatrics and Global Aging Research Network.

Keywords: older adults; frailty; residential care, cyber cycling, physical activity, motivation

Introduction

Sedentary behaviour is a serious problem in older adults, especially in residential care centres, in which 85% to 97% of the time is spent sedentary. [1, 2] Residential older adults have on average a walking time of 0.5 hours a day [3] and only 5 minutes a day are spent for moderate-to-vigorous intense physical activity. [1] However, to counteract the risk of cardiovascular mortality, sarcopenia and osteopenia, physical exercise is of vital importance.[4]

According to the current recommendations of the International Association of Gerontology and Geriatrics and Global Aging Research Network (IAGG-GARN), [5] residential older adults have to enhance their overall level of physical activity. Moreover, participation in moderate-intense multicomponent training (especially muscle strength and aerobic exercise), twice a week, for 35 to 45 minutes per session is recommended. However, a big gap is currently present between these recommendations and daily practice in residential care. To increase the levels of physical activity in residential care, it is important to encourage older adults with interesting exercise modalities and exciting exercise facilities.[6]

Research has shown that low self-efficacy and a lack of motivation are important barriers for older adults to participate in exercise. [7] This low intrinsic motivation, in combination with memory problems and confusion restricts exercise in older adults with Mild Cognitive Impairment (MCI) or early dementia even more. [8] Therefore, alternative and novel, virtual reality-enhanced exercises are explored. These 'exergames', defined as videogames that combine gameplay with physical exercise, [9] could play a promising role in the motivation to exercise [9, 10] and consequently self-

reported physical activity, postural control, gait [11] , quality of life [12] and mood [13] in older adults, living in assisted living facilities [9] or in residential care centers. [12] Considering the importance of the cardiovascular benefits of physical exercise, especially in (pre)frail older adults, [14] preservation of the aerobic exercise volume (duration/intensity) is crucial too. However, 72,6% of institutionalized older adults are not able to stand independent. [15] Therefore, cycling on a stationary bike is the main source of aerobic exercise in (pre)frail institutionalised older adults. **Moreover, this kind of exercise is preferable for subjects with poor balance, poor neuromotor coordination, impaired vision, impaired gait patterns, weight-bearing limitations, and/or foot problems [16], which are frequently present in (pre)frail older adults.** However, cycling on a stationary bike can be very monotonous. [16] From that point of view, virtual reality-enhanced cycling or "cybercycling" has promising results in independent living older adults [17]. Moreover, even TV viewing alone has the potential to increase the enjoyment of physical activity in sedentary middle-aged adults. [18] At last, cybercycling can even have a 23% relative risk reduction in the clinical progression to MCI in independent older adults. [19]
The promising results in independent living older adults can be taken into account to examine the potential of television-based exercise modalities to increase both the exercise intensity and motivation to exercise in residential (pre)frail older adults with MCI. [18] Isbel et al. showed that virtual cycling was an overall positive experience for institutionalized older adults with cognitive impairments. [20]

To our knowledge, this is the first study which examines, in a randomised controlled cross-over design, whether residential older adults with MCI will be intrinsically motivated to exercise at a higher exercise intensity when television images, by means of cybercycling or a television program, are added to the cycling exercises.

It is hypothesized that cycling exercises with television images will both increase the motivation as well as the exercise intensity, and, as such, the cardiovascular health, in residential pre(frail) older adults with MCI compared with cycling exercises without these visual stimuli. It is hypothesized that cybercycling will increase the exercise intensity and motivation to exercise more, relative to TV viewing alone, to meet the recommendations for moderate-intense aerobic exercise according to the IAGG-GARN. [5]

Materials and methods

Subjects

For this feasibility study, participants were recruited at WZC Sint-Elisabeth, a residential care setting for 115 care-dependent older adults in Hasselt, Belgium. The inclusion criteria were: 75 years or older; MCI (a score between 18 and 25 on the Montreal assessment scale (MoCA)), slowness and/or muscle weakness according to the frailty phenotype of Fried; living at least 1 month in the residential care center (to exclude improvements or deterioration as a result of adaptation to the residential care); able to understand simple instructions (based on the first contact of the assessor with the older adult); able to participate in the study during 4 consecutive weeks and able to actively exercise on an exercise bike (eventually seated from their wheelchair) during at least 5 minutes. Subjects were excluded (i.) if they suffered any neurological or orthopedic disease from which progression (e.g. active recovery or decline) due to the disease process could be expected on short term (1-2 months) (e.g. acute stroke, ALS, MS); (ii.) when they were blind or had an uncorrected visual impairment (and consequently not able to see the visual TV-images). These in- and exclusion criteria were checked one week before the start of the study.

In collaboration with the medical staff of the residential care setting, the assessor selected 66 older adults who possibly fulfilled the inclusion criteria. Afterwards, the assessor contacted these older adults and/or their legal guardians and, if willing to participate, screened them for fulfilling the inclusion criteria. Nine out of the 66 older adults were excluded because they had no signs of slowness or muscle weakness according to the Fried criteria. Moreover, Forty seven older adults were not able to participate during 4 consecutive weeks, resulting in 10 older adults participating in the study (figure 1). Informed consent was obtained from all individual participants or their legal guardians. The study was executed between April 2018 and May 2018.

--- insert figure 1----

Study Design And Exercise Interventions

This study was approved by the ethical committee of Hasselt University (CME2018/O15) and registered in ClinicalTrials.gov (NCT03526653). It was a randomised controlled cross-over design in which each participant performed 3 different cycling exercise interventions (30 minutes) compared with a rest condition (no exercise = control) over a period of 4 weeks (one intervention per week). Each cycling exercise was performed in front of a 54-inch flat screen TV which was (i) turned off (TVoff), (ii) turned on the National Geographic channel (NG) and (iii) with MemoRide software (MR). In the rest condition, participants rested for 30 minutes, seated in the chair or in their wheelchair (Rest).

The cycling exercise interventions as well as the rest conditions were all conducted by the assessor. The exercise interventions were performed on a Thera-Trainer Tigo, which made it possible for the wheelchair-bound participants to exercise seated from their wheelchair. Participants who were not wheelchair-bound, exercised from a chair with armrests. Motor support of the Thera-Trainer Tigo was turned off and participants had to exercise actively.

Participants were stimulated to exercise as long (maximum 30 minutes) and as fast as possible, but were allowed to (verbally) indicate whether they preferred to stop exercise**/to rest** in case of fatigue. **They thus always had the possibility, during these 30 minutes, to start the cycling exercise again after a period of rest. After 30 minutes, the cycling exercise was terminated definitively.**

MemoRide (Activ84Health®, Leuven, Belgium) (figure 2) is a technology that combines an exercise bike (in this case the Thera-Trainer Tigo) with a software program with Google Street View images. The exercise bike, provided with a pedalling sensor secured to the pedalling (Wahoo RPM Cadence sensor) is connected to a tablet (Samsung Galaxy Tab A)

via bluetooth. As a result, when the sensor detects movement, it signals the software and the Google Street View images are moving synchronized with the pedal frequency called "cybercycling". When the participant stops cycling, the Google Street View images will also stop. To receive this visual feedback from the MemoRide route, the minimal detection threshold of the pedalling sensor of 30 rpm has to be reached.

--- insert figure 2----

The National Geographic channel and MemoRide route were the same for all participants. For the National Geographic channel, a documentary about rare and exotic animals was used. For the MemoRide software, a road across Alpe d'Huez in France was used. Both the National Geographic channel as the MemoRide route were unknown for all the participants and the sound was turned off to avoid distraction and to standardize the study design. Moreover, the specific cycling route of Alpe d'Huez was chosen because of the absence of possible confounding factors in this route (e.g. traffic (lights), crossings). The National Geographic documentary was a random chosen documentary of 30 minutes minimally to make a comparison between a television program on the one hand and the interactive MemoRide software on the other hand.

Randomisation

The order in which the 4 different interventions were completed, was randomised by the therapist for each participant by sealed opaque envelopes.

Baseline Characteristics

One week before the start of the study the following subject characteristics were measured: Age, body mass, height, BMI (Body Mass Index), slowness of movement, muscle weakness and cognitive status (table 1).

Cognitive status was measured with the Montreal Cognitive Assessment (MoCA) (Version 7.1 Dutch)[21, 22]. This is a valid and reliable brief cognitive screening tool for mild cognitive impairment and measures the cognitive functioning of the participant in 8 domains: Visuospatial/executive, naming, memory, attention, language, abstraction, delayed recall and orientation. The maximum score is 30 points. A score between 18 and 25 refers to MCI whereas a score between 10-17 or less than 10 refers to moderate cognitive impairment or severe cognitive impairment respectively. [21]

The presence of slowness was calculated according to the frailty phenotype of Fried. Participants were asked to walk 4,6m as fast as possible. Males with a body length of ≤173 cm or >173 cm were considered slow when they needed ≥7 sec or ≥6 sec respectively. Females with a body length of ≤159 cm or >159 cm were considered slow when they needed ≥7 sec or ≥6 sec respectively. [23]

The presence of muscle weakness, measured with a hand held dynamometer, was also calculated according to the frailty phenotype of Fried. Muscle weakness in males was defined as ≤29 kg, ≤30 kg or ≤32 kg when males had a BMI of ≤24, 24.1-28 or > 28 respectively. Muscle weakness in females was defined as ≤17 kg, ≤17.3 kg, ≤18 kg or ≤21 kg when females had a BMI of ≤23, 23.1-26, 26.1-29 or > 29 respectively. [23]

Outcome Measures

The exercise parameters were: distance, heart rate, blood pressure and blood lactate.
The distance in kilometres (km) covered with the Thera-Trainer Tigo, was read from the exercise bike, directly after the end of the exercise intervention.

Heart rate in beats per minute (bpm) was measured during each intervention, with a Polar® A300 heart rate monitor by wearing a chest strap with a heart rate sensor and a wrist watch. The data from the heart rate monitor were analysed with the tool Polar Flow Web Service and an average heart rate was calculated. The Polar Flow Web Service was also used to extract the maximal heart rate (HR_{max}) which was defined as the highest heart rate value measured during the exercise intervention.

Blood pressure (in mmHg) was measured with a blood pressure monitor (Omron® M2), before and after each intervention, after a resting period of 2 minutes, seated in a chair with arm rests. Blood pressure was measured 3 times (one-minute rest intervals and the average blood pressure was calculated. To compare these data, the blood pressure difference (post minus pre) was calculated (Δblood pressure). As a result, a post-intervention blood pressure which was respectively lower or higher compared with the pre-intervention blood pressure, resulted in a respectively negative or positive value.

Blood lactate (in mmol/l) was measured within 1 minute after the end of each intervention with a finger prick, while the participant was seated in a chair with arm rests. The capillary blood drop was received with a BM-Lactate test strip and the strip was analysed with the Accutrend Plus® blood lactate meter.

The motivational parameters were: Perceived exertion, motivation and emotions regarding and during the exercise interventions and rest condition. At the start of each exercise intervention and immediately after each exercise intervention, rate of perceived exertion was evaluated by completing the Borg scale [24]. Participants had to score their perceived exertion ranging from 0 (no exertion at all) to 10 (maximal exertion).

The motivation of the participants was examined by using 2 questionnaires, the Intrinsic Motivation Inventory (IMI) and the Credibility/Expectancy Questionnaire (CEQ) which were completed directly after the end of each exercise intervention and rest condition.

The IMI [25] is a valid and reliable, multidimensional questionnaire to assess the subjective experience of the participants to a target activity and has been frequently used in older adults with a chronic stroke [26], traumatic brain injury [27], MCI [28]or dementia [29]. It contains 7 subscales from which 3 subscales were used in this study: Interest/enjoyment (7 statements), effort/importance (5 statements) and pressure/tension (5 statements). The participant had to answer how true each statement was for him/her by giving a score from 1 to 7, ranging from not at all true to very true. An average score was calculated for each subscale.

The CEQ [30] is a valid and reliable questionnaire which examines the beliefs of the participant and has also been used in older adults with dementia [29] or Parkinson's Disease. [31] Only 1 question was used, to examine how confident the participants would be to recommend the exercise intervention or rest condition to other (older) persons. The participants had to give a score from 1 to 9, ranging from "not at all confident" to "very confident".

The emotions of the participants were observed with the Observed Emotion Rating Scale (OERS).[32] The OERS was administered as persons with cognitive impairments have a diminished ability to articulate verbally their feelings. With this observation scale, the presence of 5 different emotions (pleasure, anger, anxiety/fear, sadness and general alertness) is evaluated during 10 minutes, by giving a score to each emotion, ranging from 1 (never) to 5 (more than 5 minutes). In this study, the participants were continuously filmed with a video camera during each exercise intervention and rest condition. Afterwards, each emotion was analysed by using the video images of the first and last 5 minutes of each intervention and rest condition.

Statistical Analysis

Statistical analyses were implemented in JMP® Pro 14.1.0 (SAS Institute Inc.). Since this was a feasibility study and the first study which implemented this study design to examine the

potential of television images (television program or cybercycling) in care-dependent older adults with MCI, it was not possible to execute a power calculation. According to Shapiro-Wilk tests, data regarding mean heart rate, HR_{max}, IMI (effort/importance and pressure/tension subscale) and CEQ were not normally distributed. To make comparisons between all of the interventions, Wilcoxon Signed Rank Tests (non-normal distribution) or paired t-tests (normal distribution) were used. Results were expressed as mean±SD. A p-value <0.05 (2-tailed) was considered as statistically significant.

Results

Ten older adults (4 men and 6 women) with a mean age of 85.0±6.0 years participated in the study. All participants completed the study. Subject characteristics are displayed in table 1.

--- insert table 1----

Exercise Parameters

The participants cycled significantly more distance in the National Geographic intervention compared with the TVoff intervention (7.61±3.03 km vs 6.83±3.19 km; p=0.024).
During exercise, mean heart rate (TVoff p=0.002, NG p=0.002 and MR p=0.004) was significantly higher in all exercise conditions in comparison to the rest condition. However, only in the National Geographic intervention, HR_{max} was significantly higher (p=0.022) in comparison to the rest condition. Δblood pressure (systolic and diastolic) and lactate were not significantly different between the 4 conditions (table 2).

---insert table 2---

Motivational Parameters

According to the Borg scale, participants perceived significantly more exertion after exercise compared to the rest condition (TVoff versus Rest p<0.0001, NG versus Rest p=0.0003 and MR versus Rest p=0.0001). The average Borg scale ranged between 3.6 (MR) and 4.5

(TVoff) during exercise, which corresponds to low intense aerobic exercise. No difference in the Borg scale between the different exercise interventions was seen.

The score of the interest/enjoyment subscale of the IMI was significantly higher for the National Geographic (p=0.014) and MemoRide intervention (p=0.047) versus the rest condition. This was in contrast to the TVoff condition in which no significant difference in comparison to the rest condition was seen. Moreover, interest and enjoyment of the older adults were significantly higher in the National Geographic intervention compared with the TVoff intervention (p=0.018).

The score of the pressure/tension subscale was significantly lower during MemoRide versus TVoff (p=0.031).

When the exercise interventions were compared with the rest condition, there was a significant difference in the score of the CEQ (TVoff versus Rest p=0.039, NG versus Rest p=0.043 and MR versus Rest p=0.016) implicating that regardless of the type of cycling, the older adults are willing to advise other people to exercise instead of staying sedentary (table 3).

---insert table 3---

No significant differences were observed in the emotions of the participants during the different interventions. General alertness was observed most of the time.

Discussion

This was the first study which examined, in a randomised controlled cross-over design, the impact of a television program and cybercycling on the exercise intensity of cycling exercises and motivation in residential pre(frail) older adults with MCI.

Previous studies already emphasized the potential of cybercycling [17, 19, 33-35] to increase the enjoyment of exercising. [34] However, in comparison with this study, some previous studies were non-randomised designs [34] without a rest condition [17, 19, 34, 35] and had a

shorter session duration (< 30 minutes) [33, 34] or studied only motivation. [20] Moreover, the included participants were younger (<75 years),[35] robust (non-frail), [17, 19, 34, 35] ambulatory [17, 19, 34, 35] or community-dwelling. [17, 19, 34, 35]

To positively impact the cardiovascular health of residential older adults, moderate-intense aerobic exercise interventions, twice a week are preferred. [5] According to these recommendations, moderate-intense aerobic exercise is defined as exercise that noticeably increases heart rate and respiration, without generating breathlessness or undue fatigue, eventually self-reported as a score of 5 or 6 on a 10-point Borg-scale. Cardiovascular responses, as a result of central command, are closely related to the intensity of exercise. [36] However, in this study, the increase in heart rate during exercise was relatively small which can be explained by the medication intake (especially beta-blockers) of the participants. [37] Also, there was no significant difference in blood pressure at the end of the exercise intervention compared with the baseline values at the start of the intervention. Further, no significant differences in blood lactate concentrations were found, nor between the exercise interventions, nor in comparison to the rest condition even though increases in blood lactate can be expected after low- to moderate- intense exercise. [38]

Finally, as also the Borg scale did not reach a score of 5 or 6, the addition of television images was not sufficient to meet the recommendations for moderate-intense aerobic exercise despite the stimulation to exercise as long and as fast as possible during maximally 30 minutes.

Besides the objective exercise parameters to examine the exercise intensity, it was important to examine the intrinsic motivation of the participants. When subjectively asking the participants which exercise interventions they preferred, they chose the MemoRide intervention and National Geographic Intervention. They reported to like the beautiful landscapes/roads (MemoRide) and animals (National Geographic).

Moreover, the interest for the exercise intervention was significantly higher in the National Geograpic versus TVoff intervention and participants felt more relaxed (according to pressure/tension scale of IMI) in de MemoRide intervention compared with the TVoff intervention. These results confirm the hypothesis of an increased motivation to exercise when television images were added to the exercise intervention.

Further, we expected an additional motivation and exercise volume during cybercycling. However, only the exercise volume during National Geographic was significantly higher than during the TVoff intervention. Even with an exercise effort comparable to traditional stationary cycling, BDNF and executive functions increases in independent older adults during cybercycling, resulting in a risk reduction on MCI. [19] This suggest that a combination of cognitive and physical exercise has a higher potential for the prevention of cognitive decline [19] and as such should be preferred in older adults.

Therefore, we suggest the following modifications for cybercycling to improve exercise volume and motivation. 1) To develop a standardized study design and to exclude possible confounders, the chosen MemoRide route was unknown and the same for all the participants. However, to motivate older adults to exercise, it could be important to choose a recognisable route. From this point of view, the MemoRide software has the possibilities to exercise with routes from all over the world. 2) The pedalling sensor had a minimal detection threshold of 30 rpm. However, due to physical weakness, 2 participants were sometimes not able to reach this threshold. As a consequence, they did not constantly receive the visual feedback from the MemoRide route. To increase the motivation during an exercise intervention by means of the MemoRide software in (pre)frail residents, it should be connected with a pedalling sensor with a minimal detection threshold of 1 rpm. 3) One of the facilitators for exercise among older adults with MCI is social engagement with others. This can be accomplished by cybercycling with an audience in the nursing home. The older adults

can then cycle through the neighbourhood from each other and reminiscent about cycling earlier in life [20] and their previous homes. 4) Finally, the addition of a competition element in the MemoRide software may also increase the motivation and thereby the exercise volume. Promising results were already evidenced in independently living older adults exercising with comparable cybercycling software programs. [17] However, this effect is mainly visible in more competitive participants. [17]

To conclude, older adults in residential care are very sedentary. [2] This study has shown indications that the addition of television images may increase the exercise volume and motivation to exercise in residential (pre)frail older adults with MCI. However, they did not meet the recommendations for moderate-intense aerobic exercise for residential older adults according to the IAGG-GARN. [5] Further research is warranted to increase the exercise volume of the (pre)frail older adults with MCI in residential care and to adapt the MemoRide system to the very specific needs of this population.

Lat, Long 50.9285329,5.3929204

Acknowledgements: We thank the collaborators of MemoRide (Activ84Health®), WZC Sint-Elisabeth and the study participants for their engagement in this study.

Disclosure of interest: The authors report no conflict of interest.

References

1. Parry, S., et al., *Physical activity and sedentary behaviour in a residential aged care facility.* Australas J Ageing, 2019. **38**(1): p. E12-e18.
2. Sackley C, L.S., Cardoso K, Hoppitt T, *Observations of activity levels and social interaction in a residential care setting.* International Journal of Therapy and Rehabilitation, 2006. **13**(8): p. 370-373.
3. Bootsman, N.J.M., et al., *The relationship between physical activity, and physical performance and psycho-cognitive functioning in older adults living in residential aged care facilities.* J Sci Med Sport, 2018. **21**(2): p. 173-178.
4. Mendonca, G.V., et al., *Impact of Exercise Training on Physiological Measures of Physical Fitness in the Elderly.* Curr Aging Sci, 2016. **9**(4): p. 240-259.
5. de Souto Barreto, P., et al., *Recommendations on Physical Activity and Exercise for Older Adults Living in Long-Term Care Facilities: A Taskforce Report.* J Am Med Dir Assoc, 2016. **17**(5): p. 381-92.
6. Aro, A.A., S. Agbo, and O.B. Omole, *Factors influencing regular physical exercise among the elderly in residential care facilities in a South African health district.* Afr J Prim Health Care Fam Med, 2018. **10**(1): p. e1-e6.
7. Buman, M.P., L. Daphna Yasova, and P.R. Giacobbi, *Descriptive and narrative reports of barriers and motivators to physical activity in sedentary older adults.* Psychology of Sport and Exercise, 2010. **11**(3): p. 223-230.
8. Hobson, N., et al., *Perceived Facilitators and Barriers to Exercise Among Older Adults With Mild Cognitive Impairment and Early Dementia.* J Aging Phys Act, 2020. **28**(2): p. 208-218.
9. Meekes, W. and E.K. Stanmore, *Motivational Determinants of Exergame Participation for Older People in Assisted Living Facilities: Mixed-Methods Study.* J Med Internet Res, 2017. **19**(7): p. e238.
10. Costa, M.T.S., et al., *Virtual Reality-Based Exercise with Exergames as Medicine in Different Contexts: A Short Review.* Clin Pract Epidemiol Ment Health, 2019. **15**: p. 15-20.
11. Gomes, G.C.V., et al., *Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit Plus(TM) for frail older adults: A randomized feasibility clinical trial.* Maturitas, 2018. **118**: p. 20-28.
12. Keogh, J.W., et al., *Physical and psychosocial function in residential aged-care elders: effect of Nintendo Wii Sports games.* J Aging Phys Act, 2014. **22**(2): p. 235-44.
13. Van Schaik, P., et al., *Virtual augmented exercise gaming for older adults.* Cyberpsychol Behav, 2008. **11**(1): p. 103-6.
14. de Labra, C., et al., *Effects of physical exercise interventions in frail older adults: a systematic review of randomized controlled trials.* BMC Geriatr, 2015. **15**: p. 154.
15. Thapa, P.B., et al., *Comparison of clinical and biomechanical measures of balance and mobility in elderly nursing home residents.* J Am Geriatr Soc, 1994. **42**(5): p. 493-500.
16. Medicine, A.C.o.S., in *ACSM's guidelines for exercise testing and prescription*, 9, Editor. 2013.
17. Anderson-Hanley, C., et al., *Social facilitation in virtual reality-enhanced exercise: competitiveness moderates exercise effort of older adults.* Clin Interv Aging, 2011. **6**: p. 275-80.
18. Steeves, J.A., et al., *Physical Activity With and Without TV Viewing: Effects on Enjoyment of Physical Activity and TV, Exercise Self-Efficacy, and Barriers to Being Active in Overweight Adults.* J Phys Act Health, 2016. **13**(4): p. 385-91.
19. Anderson-Hanley, C., et al., *Exergaming and older adult cognition: a cluster randomized clinical trial.* Am J Prev Med, 2012. **42**(2): p. 109-19.
20. D'Cunha, N.M., et al., *Effects of a virtual group cycling experience on people living with dementia: A mixed method pilot study.* Dementia (London), 2020: p. 1471301220951328.
21. Nasreddine, Z.S., et al., *The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment.* J Am Geriatr Soc, 2005. **53**(4): p. 695-9.

22. *MoCA*. 19 June 2019]; Available from: https://www.mocatest.org/moca-clinic-data/.
23. Fried, L.P., et al., *Frailty in older adults: evidence for a phenotype.* J Gerontol A Biol Sci Med Sci, 2001. **56**(3): p. M146-56.
24. Borg, G., *Psychophysical scaling with applications in physical work and the perception of exertion.* Scand J Work Environ Health, 1990. **16 Suppl 1**: p. 55-8.
25. McAuley, E., T. Duncan, and V.V. Tammen, *Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: a confirmatory factor analysis.* Res Q Exerc Sport, 1989. **60**(1): p. 48-58.
26. Bessa, N., et al., *Effects of exergames training on postural balance in patients who had a chronic stroke: study protocol for a randomised controlled trial.* BMJ Open, 2020. **10**(11): p. e038593.
27. De Luca, R., et al., *Can patients with severe traumatic brain injury be trained with cognitive telerehabilitation? An inpatient feasibility and usability study.* J Clin Neurosci, 2020. **79**: p. 246-250.
28. Delbroek, T., W. Vermeylen, and J. Spildooren, *The effect of cognitive-motor dual task training with the biorescue force platform on cognition, balance and dual task performance in institutionalized older adults: a randomized controlled trial.* J Phys Ther Sci, 2017. **29**(7): p. 1137-1143.
29. Spildooren, J., et al., *A physical exercise program using music-supported video-based training in older adults in nursing homes suffering from dementia: a feasibility study.* Aging Clin Exp Res, 2019. **31**(2): p. 279-285.
30. Devilly, G.J. and T.D. Borkovec, *Psychometric properties of the credibility/expectancy questionnaire.* J Behav Ther Exp Psychiatry, 2000. **31**(2): p. 73-86.
31. Goedeken, S., et al., *Encoding strategy training and self-reported everyday prospective memory in people with Parkinson disease: a randomized-controlled trial.* Clin Neuropsychol, 2018. **32**(7): p. 1282-1302.
32. Lawton, M.P., Van Haitsma, K., Klapper, J.A. , *Observed Emotion Rating Scale.* . 1999.
33. Arlati, S., et al., *A Social Virtual Reality-Based Application for the Physical and Cognitive Training of the Elderly at Home.* Sensors (Basel), 2019. **19**(2).
34. Pedroli, E., et al., *Characteristics, Usability, and Users Experience of a System Combining Cognitive and Physical Therapy in a Virtual Environment: Positive Bike.* Sensors (Basel), 2018. **18**(7).
35. Anderson-Hanley, C., et al., *Neuropsychological benefits of stationary bike exercise and a cybercycle exergame for older adults with diabetes: an exploratory analysis.* J Diabetes Sci Technol, 2012. **6**(4): p. 849-57.
36. Williamson, J.W., P.J. Fadel, and J.H. Mitchell, *New insights into central cardiovascular control during exercise in humans: a central command update.* Exp Physiol, 2006. **91**(1): p. 51-8.
37. Hansen, D., et al., *Endurance exercise intensity determination in the rehabilitation of coronary artery disease patients: a critical re-appraisal of current evidence.* Sports Med, 2012. **42**(1): p. 11-30.
38. Hansen, D., et al., *Adipose tissue lipolytic inhibition enhances the glucoregulatory properties of exercise in type 2 diabetes patients.* Eur J Sport Sci, 2018. **18**(9): p. 1245-1254.

Table 1 Subject characteristics

	Older adults
Number	10
Age (years)	85.0±6.0
Gender (Male/Female)	4/6
Gait velocity (m/s)	0.5±2.4
Muscle weakness (kg)	15.9±7.0
BMI (kg/m^2)	29.5±6.6
MoCA	20.8±4.5

Results are expressed as mean±SD

Table 2 Exercise parameters in the four experimental conditions

	Rest (n=10)	TVoff (n=10)	National Geographic (n=10)	MemoRide (n=10)	p-value	Effect size
ΔBlood pressure (mmHg)						
Systolic	-4.2±12.3	-4.3±9.3	-5.6±14.7	-1.1±16.3	NS	-
Diastolic	-2.0±5.9	1.1±5.7	0.6±5.6	-2.8±7.5	NS	-
Borg scale	-	4.5±2.1	4.0±2.3	3.6±1.8	<0.0001° 0.0003$^{\circ\circ}$ 0.0001$^{\circ\circ\circ}$	- - -
Distance (km)	-	6.8±3.2	7.6±3.0	7.1±2.6	<0.0001°, $^{\circ\circ}$, $^{\circ\circ\circ}$ 0.024$^{\#}$	- 0.25
Heart rate (bpm)						
mean	68.6±12.9	77.3±17.2	80.8±21.2	77.8±19.2	0.002° 0.002$^{\circ\circ}$ 0.004$^{\circ\circ\circ}$	0.67 0.95 0.71
max	80.3±16.7	86.2±24.5	88.7±24.4	85.9±23.4	0.022$^{\circ\circ}$	0.50
Δheart rate	-1.1±3.2	0.4±2.6	-0.9±4.0	0.0±3.0	NS	-
Lactate (mmol/l)	3.2±1.1	3.1±0.7	3.2±1.0	3.4±1.0	NS	-

Results are expressed as mean±SD °TVoff versus Rest, °°NG versus Rest, °°°MR versus Rest, $^{\#}$NG versus TVoff

ΔBlood pressure Post-intervention minus pre-intervention blood pressure

Effect size (mean intervention minus mean control group (TVoff or rest)) divided by SD control group

NS Not significant, SD Standard deviation

Table 3 Motivational parameters

	Rest (n=10)	TVoff (n=10)	National Geographic (n=10)	MemoRide (n=10)	p-value	Effect size
IMI						
Interest/Enjoyment	25.0±12.1	34.1±9.4	39.9±7.9	37.9±7.8	0.014°° 0.047°°° 0.018#	1.23 1.07 0.62
Effort/Importance	33.3±1.5	31.9±3.0	32.0±2.6	31.0±3.3	0.031°°°	-1.5
Pressure/Tension	6.6±1.5	7.8±2.9	6.6±1.9	5.7±1.1	0.031##	-0.72
CEQ	3.4±2.8	6.1±2.3	6.3±2.2	7.3±0.5	0.039° 0.043°° 0.016°°°	0.96 1.04 1.39

Results are expressed as mean±SD °TVoff versus Rest, °°NG versus Rest, °°°MR versus Rest, #NG versus TVoff, ##MR versus TVoff

Effect size (mean intervention minus mean control group (TVoff or rest)) divided by SD control group

Figure 1 Flow chart of the selection process

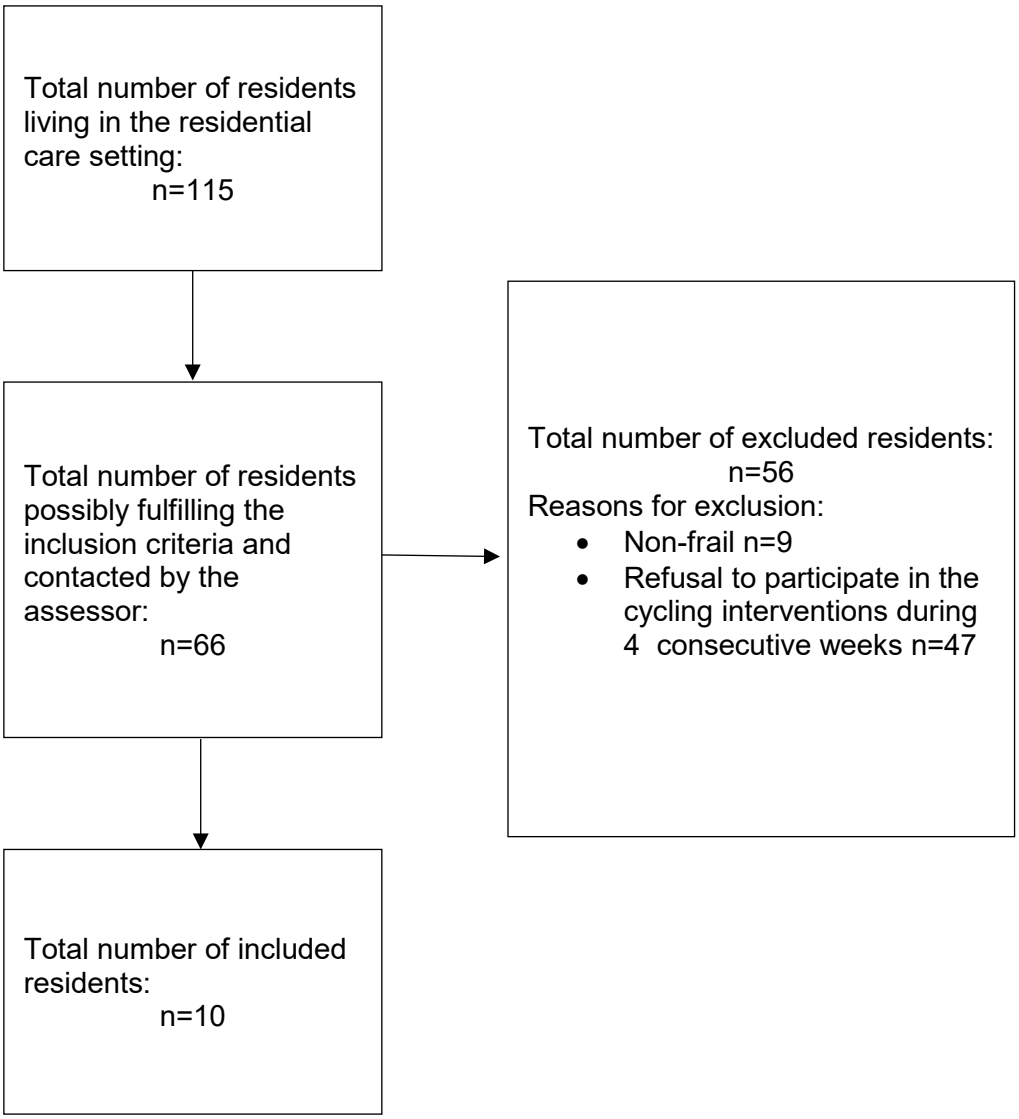

Figure 2

Alpe d'Huez route from MemoRide software during cybercycling

Figure captions

Figure 1 Flow chart of the selection process

Figure 2 Alpe d'Huez route from MemoRide software during cybercycling