LUND UNIVERSITY
Faculty of Medicine
Master Programme in Medical Science

Thesis
2018-05-31
16-30 higher education credits

The role of exercise intensity on stride time variability and executive function in patients with mild cognitive impairment - A pilot study

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Introduction to the master’s thesis prior to the part of the thesis that is written in the format of an article.

In writing this master’s thesis I have followed the authors instructions of International Journal of Physical Therapy and Rehabilitation since that journal was deemed the most relevant for publication regarding both topic and quality of the project.

International Journal of Physical Therapy and Rehabilitation - Authors instructions:

The Abstract of the manuscript should be approximately 300 words long and present a short description of the study. It should be clearly written, well informative and briefly state the scope of the research. Abbreviations should be avoided as much as possible in the abstract.

> **Background:** The purpose of the study.
>
> **Methods:** How the study was performed and what statistical tests were used.
>
> **Results:** The main findings.
>
> **Conclusion:** A brief summary and potential implications.
>
> **Keywords** A list of keywords in alphabetical order not exceeding ten words or short phrases, excluding words used in the title. (E.g. keyword 1, keyword 2, keyword 3...)

No maximum number of words given for the article in its entirety.

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The role of exercise intensity on stride time variability and executive function in patients with mild cognitive impairment – a pilot study

Abstract

Background The increase in stride time variability (STV) in people with mild cognitive impairment (MCI) has been shown to precede further cognitive decline. It is not fully understood to what extent these changes in STV can benefit from physical exercise, if intensity of exercise matters and if a positive effect on STV could also benefit cognition.

Objectives The primary objectives of the study were 1/ to investigate if different intensities of physical exercise would have a different influence on STV and executive function in a group of patients with MCI after an exercise intervention, and 2/ to refine the protocol in preparation for a full-scale RCT. The secondary objective was to investigate if there was a correlation between changes in STV and changes in executive function.

Participants and Methods Participants with MCI (N=33) completed a 12-week exercise program with 1 hour, twice a week, of combined aerobic and endurance strength group training, with either moderate intensity (n=13) or high intensity (n=12). A control group (n=8) received no intervention. Velocity, stride time and STV of gait were tested at baseline and after 3 months by having participants walk on an electronic walkway during normal and dual task conditions. Executive function was measured with a computerised version of the Stroop Colour Word test (SCWT).

Results There was an increase (worsening) of STV (p=0.040) from baseline to retest in one of the dual tasks (walking at self-selected pace whilst carrying a tray with a glass of water on) for the high intensity group. No other statistically significant differences between baseline tests and retests were found for velocity, stride time, STV for either normal gait or dual task conditions or the SCWT test in any group.

Conclusion 12 weeks of combined aerobic and anaerobic training did not have an influence on STV or the SCWT. With minor modifications the test-method is applicable for a larger RCT.

Keywords Dementia, dual task, Stroop, gait speed, gait variability, stride time variability.

1. Introduction

Mild cognitive impairment (MCI) is a stage prior to the onset of dementia. The term refers to cognitive limitations in cognitive capacity, specifically memory function, beyond those of normal ageing (1, 2). There is no specific test used to diagnose MCI but the recommended clinical criteria for the diagnosis of MCI is as follows (3):

- Concern shown regarding a change in cognition – preferably confirmed by someone who knows the patient.
- Impairment in one or more cognitive domains – typically assessed through test of mental performance such as the Mini-Mental State Examination (MMSE).
- Preservation of independence in functional abilities – even if activities take more time and more mistakes are made, the patient with MCI is more independent than a patient with Alzheimer's Disease (AD).
- Not demented, in other words, the absence of a dementia diagnosis.

A systematic review of conversion studies concluded that the numbers vary in different studies but overall, the conversion rate from MCI to AD is 10 % annually compared to 1-2 % in the elderly in general (4).

In non-demented, ambulatory older adults, tests of cognition have previously been able to show a link between executive function and some of the measures of gait. For instance, a higher (better) score on the Stroop colour-word test (SCWT) of executive function correlates with lower (better) stride time variability (STV) (5) and lower scores on tests of executive function have also proved to be able to predict falls in a five-year prospective study (6).

In terms of measuring cognitive function, the effect of dual task tests on gait can be quantified through the variability in the spatio-temporal parameters (7, 8). As previously mentioned, STV has also been linked specifically to tests of executive function.

It has been shown that gait variability, and the risk and rate of falls, can be improved in different populations through means of physical exercise (9-12). Gait can also be improved with anti-dementia drugs (13), which indicates that cognitive status can have a direct effect on gait variability even when there has been no attempt directed at manipulating motor skills or gait.

As an example of the influence of physical activity on gait variability, a number of trials (9, 14, 15) have shown that 12 weeks of physical exercise or task specific training can significantly improve gait variability in elderly people with and without dementia. In one of the mentioned trials (14) the training performed by the intervention group would be classified as high-intensity according to the American College of Sports Medicine (2014) but since intensity was not the focus of that particular study, there was no comparison with a group exercising at a lower intensity.

Gait characteristics of people with MCI have been studied before with the conclusion being that MCI participants walk slower than healthy participants and faster than patients with Alzheimer's disease (14), the authors did however also conclude that further research appear necessary to make data more reliable by enlarging the study cohort. Two recent RCTs have shown that for gait variability in older adults without MCI improvements are greater with task-oriented motor learning than with standard exercise (9, 16). To the best of our knowledge, no study so far has investigated what role intensity has on the effect of physical activity on gait variability.

1.1 Objectives

The primary objectives of the study were 1/ to investigate if different intensities of physical exercise would have a different influence on STV and executive function in a group of patients with MCI after an exercise intervention, and 2/ to refine the protocol in preparation for a full-scale RCT. The secondary objective was to investigate if there was a correlation between changes in STV and changes in executive function.

2. Participants and Method

The present study was a part of a larger pilot that investigated the influence of intensity of exercise on physiological and psychological aspects of an exercise intervention. Parts of the following method section (participants and exercise intervention) have been previously published (17).

2.1 Design

Experimental pilot study to allow for an investigation of the viability of a future RCT.

2.2 Participants

The inclusion criteria were; 60-80 years of age, cognitive function measured with Mini Mental Test (MMT) to be ≤ 24, and a medical investigation during the last 12 months or consecutive new patients. The exclusion criteria were: dementia, other known brain disease or brain injury explaining the cognitive decline, serious psychological disturbance (a cognitive or psychological condition without adequate medication that would have impeded the carrying out of the intervention), insufficient knowledge of the Swedish language or medical or orthopaedic problems that would have contraindicated following the training regimen used in this study.

The recruitment process started with identifying 135 patients with mild cognitive impairment (MCI) diagnosed at a memory clinic in the south of Sweden who had visited the clinic at any point during a two-year timespan from July 1st, 2013. Later, from January 1st, 2014, to increase the number of participants, an additional 99 patients from the memory clinic in a nearby city were invited to participate in the study. Letters were sent out offering participation in the present study and informing patients that participating or not participating would not affect their care at the memory clinic. Letters were sent out by the principal investigators (AW and SV).

70 of the invited 234 patients accepted to participate. 2 participants gave additional information that they were going abroad during the time of the study and were thus excluded. 2 more participants did not want to participate when they understood that tests and exercise were going to be held somewhere that caused inconvenience with transport.

In order to meet the inclusion and exclusion criteria, 66 medical journals were checked by a medical doctor working at one of the memory clinics, and this led to the exclusion of 20 participants.

46 patients were invited to participate out of which 42 accepted to be included in the project. 6 of the invitees declined participation before the initial test session, 3 due to transport difficulties and 3 due to joint problems (back, knee, and foot).
The remaining 36 participants were randomised into a control group (CG) (n=8), a moderate intensity group (MITG) (n=13) and a high intensity group (HITG) (n=15).
Randomisation was done in SPSS following a method described by Arifin (18).

1 participant in the MITG performed the initial tests but did not show up to the exercise sessions due to a longer vacation abroad. 2 participants in the HITG had to drop-out from exercise, 1 after 2 sessions due to pain related to osteoarthritis of the hip and 1 after 3 sessions due to extreme tiredness. 25 participants completed the exercise intervention and the pre- and post-tests (12 in the MITG and 13 in the HITG). Analyses of the actual exercise intensities were performed using the recorded heart rate (HR) and showed that 3 participants in the MITG had performed exercise with higher heart rate than prescribed whilst 4 in the HITG had an actual exercise intensity lower than prescribed. Thus, a shift of these 7 participants were made so that analyses could be performed based on the actual exercise intensities instead of the intended intensities. This new grouping of participants to their actual intensity level led to 13 participants in the MITG and 12 in the HITG, see figure 1.

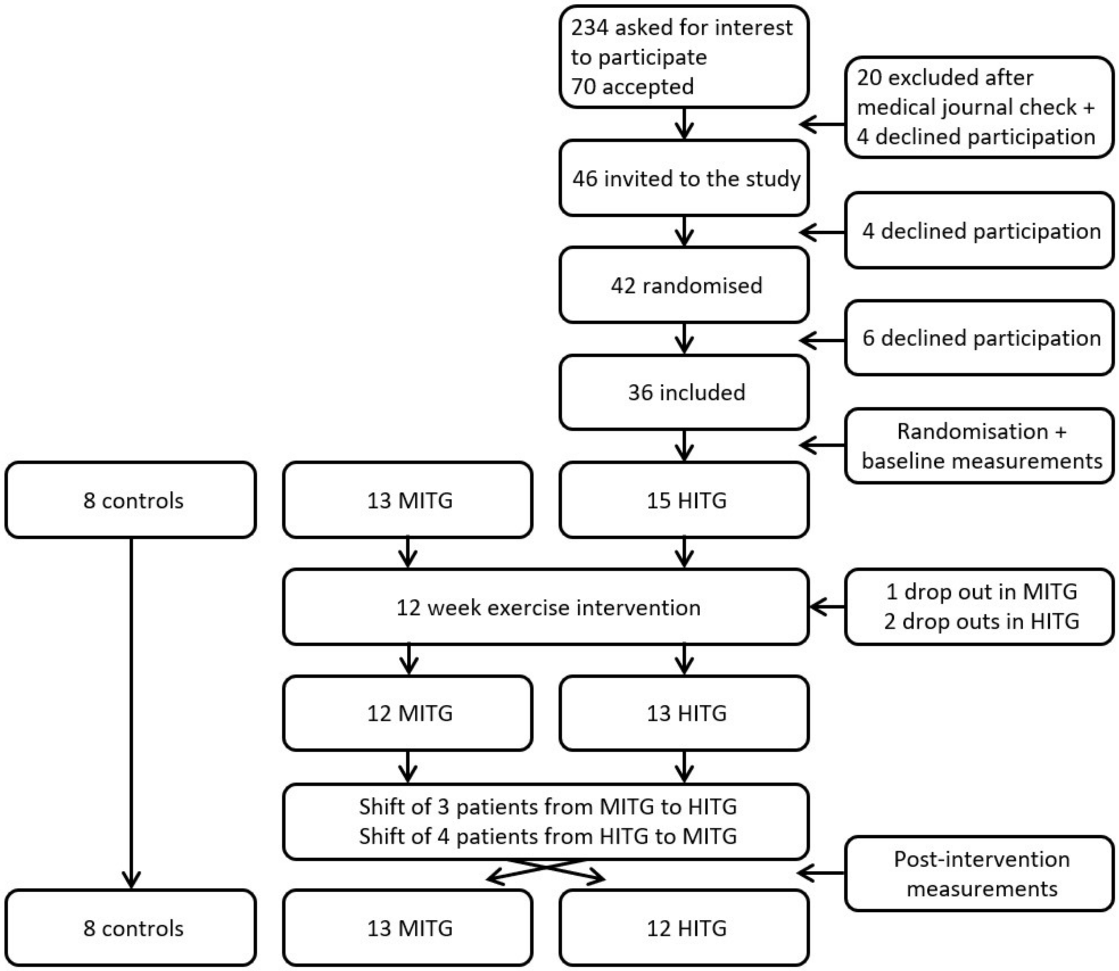

Figure 1. Flow-chart describing the recruitment, randomisation to the control group, moderate (MITG) and high intensity (HITG) training groups as well as the shift of participants post training for analyses.

2.3 Gait measurements

Participants were asked to perform 3 tasks of walking. All 3 tasks had participants walk at a comfortable, self-selected pace back and forth 6 times (3 times in each direction) over a 5m/16ft GAITRite™ electronic walkway (CIR systems, INC). 8 strides per leg is the standard minimum of gait cycles that need to be observed to obtain a mean that is representative of an individual's gait pattern (19). 3 trials per task (nine walks in each direction) secures that the required minimum will be reached and that the collected data should be reliable (20). In order to collect data only on steady-state walking and to avoid outliers, e.g. due to turns, participants were instructed to turn at a line on the floor 2 meters from each end of the mat (21).

The tasks were:

1/ Self-selected pace - walking at self-selected speed.

2/ Working memory - walking at self-selected speed with the added dual-task of loudly counting down from 100 in steps of 2 (100, 98, 96, 94 and so forth).

3/ Motor task - walking at self-selected speed with the added dual-task of carrying a tray with a nearly full glass of water on without spilling.

The tests and the protocol were chosen based on what has been previously used to study the relation between gait and cognition (5, 22-27) and recommendations on testing protocols (28). Data was exported from the GAITRite™ software to Microsoft Excel and then analysed with SPSS. To assess the STV we used the coefficient of variability (CV). Gait velocity was measured in centimetres per second (cm/s). The coefficient of variability was calculated as outlined below:

$$\text{Coefficient of variability (\%)} = SD / mean * 100$$

Variability of gait speed has been shown to correlate with executive function measured in different ways, one of them being the SCWT (5). Variability of gait may also be useful when trying to predict risk of falling making it a relevant outcome measure (29).

2.4 Executive function – the Stroop colour-word test (SCWT)

Participants were instructed to perform a computerised version of the SCWT (Inquisit 4™, Millisecond software). The participants were sat in front of a screen that showed 1 question, or task, at a time. The objective was to name the colour that the word or symbol was written or shown in. Participants answered by pressing a key for each corresponding colour on the keyboard. Keys were D for green, F or red, J for blue and K for black. These specific keys were chosen because they are easily reached with the middle and index fingers of a person's hands when seated with hands resting on the keyboard. This was deemed to be the position that required the least time and effort to find the correct key. The test had participants answer 90 questions divided into 3 categories: control, congruent and incongruent.

1/ Control - a rectangle and no word.
2/ Congruent - the meaning of the word and the colour it is written in are the same.
3/ Incongruent - the meaning of the word and the colour it is written in differ.

The 3 types of questions appeared at random to avoid the confounding factor of participants getting better at the test as the test went along, thus potentially answering the last questions faster than the first. Data collected was reaction time (average delay in response time in milliseconds) and accuracy (percentage of correct answers given per category). Furthermore, a composite score was calculated (100 x accuracy / reaction time) for two reasons, one to allow comparisons with previous research (2) and the other to help illustrate the data and the findings.

2.5 Exercise intervention

Exercise was performed for 1 hour, 2 times a week for 12 weeks for both the moderate intensity training group (MITG) and the high intensity training group (HITG) in accordance with Norton’s intensity classification (30). Each individual was given a range of heart rate (HR) as well as a range of perceived exertion, based on an initial maximal exercise test (17), as an exercise recommendation for guidance during the exercise bouts. Those in the HITG were given a range of HR of 70-90 % HR max with the corresponding perceived exertion between 7 and 17 on the RPE-scale and those in the MITG were given a range of HR of 55-70 % HR max with the corresponding perceived exertion between 6 and 13 on the RPE-scale.

The exercise was performed at an exercise centre with the supervision of an experienced trainer. Aerobic exercise was performed on stationary bicycles and syncro-machines, using interval training. Endurance strength exercise was performed using different weight training machines. Each session had the same layout, starting with a warm up standing freely in the room during 6 min, followed by 5 min aerobic on bicycle, four different exercises of 2 min strength endurance, 10 min aerobic on bicycle, three different exercises of 2 min strength endurance, 10 min aerobics on bicycle, 4 min of cooling down and additional 4 min of stretching standing freely in the room. During each exercise session heart rates were monitored by using Polar 300 chest belts in combination with a wrist unit. Everyone used the same wrist unit during all exercise sessions. Each participant had their own diary with clear instructions of intensity and after each exercise part they were asked to manually write down the heart rate as well as their perceived exertion. After the exercise period all the registrations of HR from the Polar equipment were transferred to a computer to be analysed to ensure that the exercise intensities performed were in accordance with the prescribed intensity.

2.6 Statistical analysis

Data was analysed using IBM SPSS Statistics 22 for Windows (IBM Corporation, Armonk, NY, U.S.). A P-value of less than 0.05 % was used for statistical significance. Based on normal distributions, data were presented as mean (SD) for the measurements of baseline characteristics of participants, measurements of gait and the SCWT. The mean differences (SD) between post exercise and baseline were calculated for gait and SCWT. Analysis of the influence of the intervention for these parameters were performed using 2-way ANOVA with post hoc Scheffe test, for repeated measures within groups.

2.7 Ethical approval

The study was approved by the Regional Ethical Review Board in Lund, Sweden (2014/6). Each participant signed a written informed consent after written and oral information. In order for the study to be in compliance with the declaration of Helsinki (31), written informed consent needed to be obtained by an "appropriately qualified individual who is completely independent of this relationship" and to meet this demand the task of handing out and collecting the papers was done by one of the researchers in the study who did not work at either of the two memory clinics.

3. Results

3.1 Participants

The characteristics of the participants who completed the intervention and testing are shown in Table 1. In total, 33 participants were included and tested at baseline and post-intervention. Randomisation placed 8 in the control group and the remaining 25 were randomised into either the high intensity training group (HITG, n=12) or the medium intensity training group (MITG, n=13). There were more men than female participants for all groups. There were no differences between the three groups regarding age, body weight, body height or BMI.

Table 1: Characteristics of the 33 participants shown for all participants prior to randomisation and for the three different groups.

PARTICIPANTS	All (n=33)	CG (n=8)	MITG (n=13)	HITG (n=12)
Male	21	5	9	7
Female	12	3	4	5
Age (years)	71 (61-79)	71 (63-77)	70 (61-79)	72 (64-79)
Body weight (kg)	76 (58-98)	76 (62-93)	76 (61-93)	75 (58-98)
Body height (m)	1.74 (1.58-1.98)	1.74 (1.63-1.84)	1.75 (1.68-1 98)	1.73 (1.58-1.84)

3.2 Gait

The effect of the intervention on gait performance is shown in Table 2. The only change in a group from baseline to post-intervention that was statistically significant was an increase (worsening) of STV during walking in the working memory dual task in the HITG (p=0.040). No statistically significant changes were found in the self-selected pace and motor task between baseline and post-intervention tests for the HITG, MITG or the CG in any of the three tested variables velocity, stride time or STV.

Table 2: effects of the intervention on gait performance shown as the mean ± SD.

GAIT TESTS		All (n=33)	CG (n=8)	MITG (n=13)	HITG (n=12)
SELF SELECTED PACE					
Velocity (cm/s)	Baseline	106 (23)	120 (23)	107 (17)	95 (26)
	After	-	109 (16)	106 (19)	94 (18)
	Significance	-	Ns.	Ns.	Ns.
Stride time (s)	Baseline	1.15 (0.15)	1.06 (0.13)	1.18 (0.11)	1.19 (0.18)
	After	-	1.11 (0.06)	1.15 (0.08)	1.17 (0.12)
	Significance	-	Ns.	Ns.	Ns.
Variability (%)	Baseline	2.89 (1.14)	2.35 (0.63)	2.94 (1.16)	3.18 (1.33)
	After	-	3.06 (0.68)	3.25 (2.41)	2.17 (1.17)
	Significance	-	Ns.	Ns.	Ns.
WORKING MEMORY					
Velocity (cm/s)	Baseline	78 (25)	81 (24)	84 (31)	69 (18)
	After	-	73 (17)	86 (31)	61 (19)
	Significance	-	Ns.	Ns.	Ns.
Stride time (s)	Baseline	1.71 (0.93)	1.61 (0.32)	1.81 (1.47)	1.67 (0.45)
	After	-	1.63 (0.30)	1.79 (1.52)	1.88 (0.68)
	Significance	-	Ns.	Ns.	Ns.
Variability (%)	Baseline	11.78 (9.53)	14.29 (6.14)	10.02 (12.14)	11.70 (8.94)
	After	-	13.33 (9.21)	10.59 (14.72)	20.77 (14.98)
	Significance	-	Ns.	Ns.	0.040
MOTOR TASK					
Velocity (cm/s)	Baseline	86 (35)	88 (29)	90 (26)	79 (22)
	After	-	86 (15)	80 (20)	82 (16)
	Significance	-	Ns.	Ns.	Ns.
Stride time (s)	Baseline	1.23 (0.19)	1.23 (0.26)	1.21 (0.16)	1.26 (0.16)
	After	-	1.21 (0.11)	1.24 (0.14)	1.22 (0.15)
	Significance	-	Ns.	Ns.	Ns.
Variability (%)	Baseline	63.74 (91.76)	5.69 (4.54)	54.04 (100.52)	121.82 (88.86)
	After	-	6.54 (4.77)	65.95 (129.61)	115.42 (84.68)
	Significance	-	Ns.	Ns.	Ns.

3.3 Executive function

The difference on performance in the SCWT before and after the intervention is shown in Table 2. No statistically significant changes were found in the SCWT between baseline and post-intervention tests for the HITG, MITG or the CG in any of the three tested variables accuracy, response time or the composite index.

Table 3: influence of the intervention on performance in the stroop colour word test shown as the mean ± SD.

STROOP TEST		All (n=33)	CG (n=8)	MITG (n=13)	HITG (n=12)
Accuracy (%)	Baseline	89.2 (9.9)	85.6 (11.8)	91.8 (10.4)	88.6 (8.1)
	After	-	89.0 (14.5)	92.8 (14.0)	86.8 (12.2)
	Significance	-	Ns.	Ns.	Ns.
Response time (ms)	Baseline	3201 (1450)	2894 (857)	2769 (1358)	3868 (1688)
	After	-	2547 (827)	2845 (1149)	4658 (1927)
	Significance	-	Ns.	Ns.	Ns.
Composite index	Baseline	3.6 (2.0)	3.2 (1.0)	4.3 (2.5)	3.0 (1.99)
	After	-	3.9 (1.6)	4.0 (2.2)	2.3 (1.4)
	Significance	-	Ns.	Ns.	Ns.

4. Discussion

4.1 Primary objectives

We hypothesized that STV and the SCWT would benefit from the exercise intervention at both medium and high intensity, and that high intensity would yield better results. We found no difference on STV or performance on the SCWT before and after the intervention for any group. According to the method used in this study, the influence of physical exercise on STV and the SCWT does not differ depending on the intensity of exercise in a group of patients with MCI. There was a significant post-intervention worsening of STV in the high intensity group for one of the dual task (walking and counting backwards) and this worsening contradicts findings in other studies (9, 14, 16) where improvements, or status quo, is the typical finding on gait variability after an exercise intervention. Another possible explanation is that this type of dual task walking is not suitable for this population. Walking while counting backwards did not lead to reliable information because participants could compensate to different degrees and in different ways for the difficulty of the task. Some participants focused heavily on the counting task and almost completely neglected the walking task, leading to a freezing of gait. Some participants did the opposite and focused on the walking, neglecting the counting task. This compensation occurred in some cases the first time the test was carried out, in some cases on both occasions and in some cases only the second time the test was performed. Some participants did not compensate at all. We cannot be sure that walking when counting backwards measures what we intend to measure and therefore the validity of that specific test is compromised.

The lack of significant changes on the SCWT after intervention is in line with a recently published systematic review done on effectiveness of physical exercise on cognitive and physiological outcomes for patients with MCI (32) where one finding was that exercise in general has no significant influence on executive function or memory but on global cognition for persons with MCI.

One valuable finding that can improve upon the protocol was participants failing to comply with the prescribed intensity level, meaning that results had to be analysed depending on the actual training intensity and not the prescribed one. This change from prescribed to actual training intensity was interpreted as it making more sense to simply have participants train at self-selected intensities and then analyse the results according to what intensities they trained at. However, not prescribing participants an intensity level might add the confounding factor of not being able to control for what participants would be more inclined to train at a certain level than another, but this should be compensated for by studying the changes on a group and individual level. If not prescribing participants an intensity level it would probably be necessary to try to control for physical activity level prior to participation. The next challenge would be to find a good way to help MCI patients adhere to the intensity level deemed more beneficial for them, that is, if future research can show with more certainty that one intensity level is superior.

In a recent systematic review (32) on exercise and cognition for people with MCI it was concluded that the few studies done point in the direction of medium intensity aerobic exercise being the better exercise modality, whilst resistance training had issues with low adherence rates and as for multi-modal exercise interventions there were doubts about the compatibility with the population because of the complexity of such programmes. It was concluded that the elderly with MCI respond better to simple, single-component physical exercise than a multi-component programme. These new findings, that were not available when this study was designed, might influence and could improve the exercise intervention if a larger RCT is carried out in the future.

Another valuable experience was that many participants found it difficult to use the Polar heart rate monitor. Guided help was often needed during the course of a work-out and prescribed training intensities was, as previously mentioned, not followed by all participants. A simpler system would be preferred.

4.2 Secondary objective

The secondary objective was to investigate whether there is a correlation between changes in gait and changes in executive function. The data shows no changes in gait or executive function with this intervention. Therefore, we cannot establish whether there is a correlation between changes gait and changes in executive function. This objective does however remain relevant for a future RCT if changes have been made to the exercise intervention and other results can be expected.

4.3 Limitations and strengths

First, the deliberate inclusion of confounding factors in the intervention, including but not limited to a new environment, new people for participants to interact with and a combination of aerobic and anaerobic exercise. The exercise intervention was chosen to allow for a more pragmatic investigation. Rather than isolating physiological effects the intervention was aimed at reflecting a real clinical situation meaning one that would resemble an intervention that could be prescribed to this patient group as part of usual care. Second, the small sample size, from which we believe the lack of significant changes partly stem from. The sample size was small because this was a pilot and as such, the overall aim was to study and improve upon the protocol and the method to allow for a larger RCT, in which the effects of the intervention could then be more reliably concluded thanks to the greater sample size. It is possible that non-parametric test would have been better, given the sample size. The choice to use parametric test (2-way ANOVA) was based on the data being normally distributed.

In the present study the purpose was first to see if the chosen exercise intervention would bring about statistically significant changes within a group from baseline to post-intervention. Measurements between groups could be relevant with a larger sample and a different research question.

Adherence to the intervention in this study was outstanding with an average of 21 out of 24 (87.5 %) sessions, compared to the highest reported adherence being 78.2 % out of all studies included in the abovementioned systematic review (32).

Gait velocity and STV have been identified as predictors of falls for the elderly in general (26, 33) which is what made them relevant outcome measures in this study even though falling was not investigated.

4.4 Ethical considerations

The major ethical consideration was the risk of falls. The risk of falls was an inevitable risk due to the nature of dual tasks and the participants in the study; walking and simultaneously performing dual tasks is likely to negatively affect gait and motor control in general, especially in a population suffering from MCI. Therefore, according to the Swedish law of ethics (Etikprövningslagen 4 §, punkt 2), the study needed to go through ethical review in order to be legally carried out. In order for the study to be in compliance with the declaration of Helsinki (31), written informed consent needed to be obtained by an "appropriately qualified individual who is completely independent of this relationship" and to meet this demand the task of handing out and collecting the papers was done by one of the researchers in the study who did not work at the memory clinic. Another ethical consideration was the participant's potential inability to fully comprehend what it would mean to enter the study since the participant's suffered from a cognitive impairment. The last mentioned is, however, not something that requires an ethical review if the participants are not considered incapable of taking decisions on their own, as might be the case with participants suffering from more severe cognitive impairments such as might be associated with for example traumatic brain injury. The study was approved by the Regional Ethical Review Board in Lund, Sweden (2014/6).

4.5 Implications for further research

For future studies a larger patient group would be beneficial, as would a revision of the exercise intervention according to new information that has emerged in the field since this study was carried out.

5. Conclusion

12 weeks of combined aerobic and endurance strength training for one hour two days a week did not influence stride time variability or executive function for any of the three groups (high intensity, medium intensity and control group).

With minor modifications the test-methods are applicable for a larger RCT. No changes need to be made to the testing of gait characteristics although removing or replacing the current dual-tasks could provide more reliable and useful information. The SCWT could benefit from being performed in the more traditional analogue manner to increase reproducibility of the study.

6. Competing interests

The authors declare that they have no competing interests regarding the publication of this article.

7. Author's contributions

Devised the study: AW (Anita Wisén) and SV (Susanne Vestberg).

Design of the exercise intervention and research leader: AW.

Design of the test protocol for gait and executive function: KL (Kristoffer Lidengren).

Collected the data clinically: AW, ÅT (Åsa Tornberg) and KL.

Analysed the data: AW, ÅT and KL.

Wrote the manuscript: KL.

Critically reviewed and contributed to the writing of the manuscript: AW.

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