Effects of multicomponent training and detraining on fitness of older adults with or at risk of frailty: results of a 10-month quasi-experimental study

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Abstract

The aims of this study were: 1) to analyse the effects of a 6-month multicomponent training (MCT)on physical fitness of older adults with or at risk of frailty; 2) to study the consequences of a 4-month detraining period; 3) to analyse the influence of frailty status on the training and detraining adaptations. A total of 102 robust, frail and pre-frail older adults (80.1±6.1 y) were divided into an intervention (TRAIN) and control group (CON). The TRAIN performed a 6-month MCT, while the CON continued with their usual lifestyle. Fitness assessment was mainly based on the Senior Fitness Test. Four evaluations were carried out; at baseline, and at three, six and ten months from baseline. Linear mixed models were performed to analyze group by time interactions and to compare differences in changes within groups between different time points. After 6-month MCT, TRAIN showed greater improvements for all fitness variables (group effects $p<0.05$, except for flexibility) when compared to the CON. During the 4-month detraining period, TRAIN significantly decreased their balance, upper-limb flexibility and upper and lower limb strength (all $p<0.05$). CON only decreased upper-limb flexibility. When accounting for frailty status in the TRAIN, the frail-prefrail showed lower adaptations to the training and were more affected by detraining than the robust. The presented MCT is a good strategy to improve fitness in this population, but its positive effects are limited in time. It is therefore critical to avoid detraining periods.

Keywords: ageing; health; exercise; strength, endurance.

HIGHLIGHTS

- Our 6-month MCT-program improves the physical fitness of robust, frail and prefrail older adults
- A detraining period of four months, partially deteriorate the physical fitness of robust, frail and prefrail older adults, so it is recommended to promote ongoing exercise programs or smaller break periods
- It seems that those older adults with a more advanced frailty status, may not benefit from exercise to the same degree and will be more affected by detraining. Therefore, trainers may need to individualize training protocols to obtain the greatest exercise benefits.

1. INTRODUCTION

Worldwide demographic changes, characterized by an increase in life expectancy have imposed new health challenges[1]. Although the prolongation of life remains an important public health goal, living longer does not entail an improved quality of life (QoL). Therefore, preserving the capacities to live independently, is of even greater significance[2].

Aging is characterized by multiple changes, among which are a decline of physical functioning and the loss of autonomy to perform activities of daily living (ADL). These factors are strongly associated with QoL and the risk for several adverse outcomes[3], which could trigger a stage of vulnerability called frailty. It can be defined as an age-associated biological syndrome that precedes disability[4] and it is a highly prevalent condition across the world in older adults (>60y). While frailty has an incidence of 12%, the pre-frailty status affects 47% of older adults[5].

However, frailty can be reversed through specific interventions, especially at early stages of the process[6]. Given the negative consequences of frailty, its prevention and treatment have become major public health challenges. In this way, scientific evidence supports regular exercise as a tool to improve health-related factors[7], QoL [8] and frailty[9]. Nonetheless, it should be highlighted that not all types of exercise interventions have the same effects[10]. Based on current literature, multicomponent training (MCT), which consists of a combination of aerobic training, muscle strengthening, balance exercises, stretching (i.e. flexibility training) and/or coordination training[11], seems to be one of the best strategies with older individuals[9,10]. MCT have demonstrated positive effects upon falls, gait ability, balance, aerobic endurance and strength[9].

Nevertheless, despite the fact that there are many studies analysing the effects of training on physical fitness in older adults[11], many of them are difficult to replicate, since their training protocols are not usually described with enough accuracy[12]. Moreover, due to the large differences in functional capacity and physical performance between robust and frail older adults[13] it is important to analyse how they respond to exercise according to their frailty status. This will allow to advance towards the optimal individual dose to achieve the greatest adaptations.

Moreover, some events such as disease, holiday periods or the COVID-19 pandemic, can temporarily interrupt the exercise activities. In this way, little is known about the effects caused by detraining in older adults. It is difficult to establish clear conclusions, although it seems that fitness improvements achieved with training may not be maintained for too long in older population, since previous studies have observed a worsening after six weeks of detraining[14]. Furthermore, it is not clear whether all components of fitness decline equally or whether some are more affected by detraining. Additionally, to our knowledge, this is one of the first attempts to investigate whether frailty status might influence the deterioration of fitness during periods of detraining, which could lead to more efficient and precise training programs.

Therefore, the aims of this study were: 1) to analyse the partial and overall effects of a 6-month MCT on physical fitness of frail and prefrail older adults (screened by the Short Physical Performance Battery (SPPB)), 2) to study the consequences of a 4-month detraining period on physical fitness; 3) to analyse the influence of frailty status (diagnosed by the Fried criteria: robust vs. frail-prefrail) on these adaptations

2. METHODS

2.1 Study design and participants

Participants received detailed information about their participation in the study. All participants that voluntarily agreed to participate signed an informed consent. The study was in accordance with the Helsinki Declaration of 1961 revised in Fortaleza (2013)[15] and the current legislation of human clinical research of X (Law X). The protocol was submitted to and approved by the ethics committee of the X and it was registered in the electronic repository *clinicaltrials.gov* (reference number: X).

This study was carried out on the framework of the X project. It was a 10-month, non-randomized controlled trial. Participants were recruited from four health-care centres and three nursing homes from X, X. People above 65 years, and classified as frail or prefrail according to the cut-off points of the Short Physical Performance Battery (SPPB), were included (SPPB<10 points)[16,17]. Those who had cancer and/or dementia were excluded. Sample size calculation was performed for a power of 80% and 5% alpha level and to reject the null hypothesis H0: m1=m2. Assuming a medium-large effect size (f=0.30) and a correlation among repeated measures of 0.5, a sample size of 68 (34 per group) would be needed. The sample was increased by 20% to consider the possible loses during follow-up. Therefore, the final sample size was 86 (43 per group). Of the 110 participants who met the inclusion criteria and agreed to participate, 102 completed at least two of the four evaluations and were included in the study. Personal information and health outcomes were collected with a structured questionnaire.

Participants were allocated by convenience into a control group (CON) and an intervention group (TRAIN). Those elders who were unable or unwilling to attend training sessions regularly for 6 months, were directly included in the CON. The TRAIN performed a supervised 6-month MCT followed by a 4-month detraining period, while the CON followed their usual lifestyle for 10 months.

Both groups were assessed in four time-points: the first was at baseline (*M0*), whereas the second and third were in the middle (3-month: *M3*) and at the end (6-month: *M6*) of the MCT to analyse the partial and total effects of the program. Finally, the fourth (*M10*) was done 10 months after the first assessment to determine the effects of a 4-month detraining period.

Additionally, during the project, all participants received three 1h-talks related to healthy habits to reduce the possible drop-off caused by multiple evaluation periods, especially of the CON. The topics were "functional capacity and frailty", "nutritional recommendations for older adults" and "physical exercise recommendations for older adults". They were delivered by a certified nurse, nutritionist and sport scientist respectively.

2.1 Multicomponent training program: Eelder-fit

The technical content of the Eelder-fit is based on a specific literature[7,8,10] and its protocol has been published elsewhere[18].

Summarizing, this intervention consisted of a 6-month MCT of three supervised sessions per week of 1-hour duration. The first and third weekly sessions, called "Strength and Functional sessions" were used to perform strength, power, static balance exercises and tasks that simulate ADL. On the second weekly session, named "Endurance sessions", participants carried out aerobic basic exercises such as walking, steps and stationary cycle in addition to agility, coordination and motor skill tasks. Each session was adapted according to participants characteristics and functional capacity at baseline, as recommended by previous studies[19]. Training periodization and methodology is shown in table 1.

Trainers registered the attendance of TRAIN participants. To improve participation, those three elders of each TRAIN group who attended the highest percentage of sessions, received sports equipment as an award.

2.2 Health-related evaluations, Body Composition and Physical Activity

The complete set of studied variables is available elsewhere[18] and the batteries and questionnaires included in this study are shown in table 2. Physical activity (PA) was assessed in three time-points: at baseline, just after the end of the MCT-program and after the detraining period. It was monitored with wrist-worn triaxial accelerometers (GENEActiv, Activinsights Ltd., Cambridge, UK) following the methodology used in previous studies of the same project[20]. Summarizing, participants wore the device on the non-dominant wrist for 7 consecutive days. Only participants with a minimum of 4 valid days, including at least 480min/day of wearing time, were included in the analysis. Non-wear time detection was evaluated in blocks of 30 consecutive minutes, following the criteria of Van Hees et al.[21]

Height was assessed by a portable stadiometer with 2.10m maximum capacity and 1mm error margin (Seca, Hamburg, Germany). A body composition analyser based on Bio-Electrical Impedance

Analysis (TANITA BC-418MA, Tanita Corp., Tokyo, Japan) was used to measure the body mass (kg) and to estimate the percentage of body fat. Body mass index (BMI) was calculated dividing weight (kg) by squared height (m^2).

2.3 Fitness Evaluation

Physical fitness assessment was mainly based on the Senior Fitness Test Battery[22], although other complementary tests were also used and are presented in table 3. Although all participants were screened as frail or prefrail with the SPPB battery[17], a further subclassification was performed using Fried criteria[23] in the TRAIN. This classification divided participants into robust, frail and prefrail and was used to analyse the effect of frailty status on training and detraining adaptations.

2.4 Statistical analysis

The statistical analyses were performed using IBM SPSS Statistics (v.25.0 for Windows; IBM Corporation, Chicago IL). Descriptive data are reported as mean and standard deviation or number of participants and percentage, according to the nature of each variable. Student's t-test and Chi-square test were used to analyse differences between groups at baseline for continuous and categorical data respectively (table 2).

Three Linear mixed-effect models were performed to evaluate the main effects of the group during training (M0-M3 and M0-M6) and detraining periods (M6-M10) and to analyse the residual effects of training (M0-M10). The models combine both, within group and between-group changes comparisons. The outcomes were registered as the absolute changes noted during the different periods of the study. The same analyses were also conducted to evaluate the main effects of frailty status in the fitness adaptations after training and detraining periods of the TRAIN participants. TRAIN was divided into two subgroups according with their frailty status[23] (frails-prefrails [FRA-PRE] vs. robust [ROB]: frail and prefrail were pooled together given the small sample size [n=4] of frails). Bonferroni corrections were applied to explore significant differences along training subperiods (M0-M3 and M0-M6).

The models considered the maximum likelihood estimation and the best-fitting covariance structure. For comparisons, group (TRAIN vs CON) or frailty status-condition (ROB vs FRA-PRE), period and sex were included as a fixed factors, participants as a random factor and baseline values and age as covariates. Statistical significance was set at $p<0.05$ in all tests. Given that no differences were observed in baseline between groups in age and sex, the analyses were carried out with men and women as a whole group.

3. RESULTS

3.1 Descriptive characteristics of the sample

Baseline characteristics are shown in table 2. TRAIN and CON obtained greater performance in grip strength and balance respectively (both p<0.05). The attendance of TRAIN participants along the program was 80.0±17.4% and there were no adverse events.

3.2 Physical activity and sedentary behaviour

When comparing baseline values to those obtained just after the end of the MCT-program, TRAIN increased their moderate-to-vigorous physical activity (MVPA) (7.1±2.2 min/day), while CON decreased their light-intensity physical activity (LPA) (-17.6±8.0 min/day) (all p<0.05). Group effects were found in the ST&SB and LPA (both p<0.05). Moreover, when comparing PA levels of the two last time-points (just after the training period vs. just after the detraining period), TRAIN decreased their MVPA (-6.6±2.1 min/day) (p<0.05) while no changes were found for the CON.

3.2 Effects of the MCT-program on physical fitness components

The Eelder-fit triggered improvements (all p<0.05) in all fitness variables in the TRAIN (Panel A of figure 1). Upper and lower limb strength suffered a greater performance increase after the 6-month MCT, than during the first 3 months. Regarding to the CON, all the variables remained constant, except grip strength and flexibility, which enhanced (both p<0.05).

After the MCT, a group effect favourable to TRAIN was found in the whole set of fitness variables (p<0.05), except in the flexibility. Besides, the post hoc analysis (M0-M3 and M0-M6) showed the same results with a statistical trend for usual walking (p=0.052) and excepting the balance in the first 3-month.

3.3 Effects of the detraining period and residual effects of Eelder-fit on physical fitness components

Panel A of figure 1 shown the detraining effects (M6-M10). While the TRAIN deteriorated in balance, strength of upper and lower limbs, both groups decreased in upper limb flexibility. There was no group effect on any of the variables.

Despite the previous declines, the performance of the TRAIN was still higher when compared to the baseline levels in all the variables (M0-M10) except for balance, upper-limbs flexibility and aerobic endurance. The CON also shown improvements in strength of lower limb and grip strength after the 10-month period (all p<0.05). Along the whole study, group effects were found for agility, lower limb flexibility and in strength of the upper and lower, favouring the TRAIN (all p<0.05). Besides, a trend was observed in usual walking speed (p=0.051).

3.4 Effects of frailty status during training

Changes obtained by different TRAIN subgroups according to their frailty status (FRA-PRE (mean age 82.±5.8y) vs. ROB (mean age 77.1±6.1y); p<0.05) are shown in panel B of figure 1.

Although training effects were similar in both subgroups, a frailty status effect was observed in balance favourable to ROB. Furthermore, the post hoc tests revealed a frailty status by period effect in upper limb strength during the 6-month training period also favourable to ROB (both p<0.05).

Both subgroups improved in almost all variables assessed. However, grip strength and aerobic endurance did not improve during Eelder-fit for the FRA-PRE, and balance neither increased for the FRA-PRE. Moreover, while the lower limb strength and flexibility of the ROB did not enhance during the first half of the program, FRA-PRE did not show improvements in upper limb flexibility in the same period. In addition, the improvements achieved by both subgroups in upper and lower limb strength during the whole program, was greater than the obtained in its first half.

3.5 Effects of frailty status on the detraining period and on the residual effects of training

With respect to detraining period (panel B of figure 1), frailty status effect was found for upper limb flexibility and grip strength (p<0.05). Additionally, a trend was also observed in usual walking speed in 6-m (p=0.051). Regarding to the ROB, they deteriorated in upper limb flexibility and walking speed in 30-m, whereas they improved their grip strength and usual walking speed in 6-m. Regarding FRA-PRE, they also deteriorated in upper limb flexibility, although the performance drop was greater than in the ROB. Moreover, they decreased their upper and lower limb strength (all p<0.05).

4. DISCUSSION

The main findings were: 1) the 6-month Eelder-fit improves all fitness variables tested in frail and prefrail older adults screened by SPPB; 2) a 4-month detraining period was enough to impair upper and lower limb strength, balance and upper limb flexibility, of the TRAIN; 3) the ROB obtained slightly higher benefits after training and were less affected by detraining period

The Eelder-fit was highly successful as it significantly improved performance for all the measured physical fitness components. All the variables, except aerobic endurance, presented higher improvements after 6-month training regarding the first 3 months. Nevertheless, the strength tests were the only ones that presented greater significant improvements (p<0.05). Additionally, flexibility tests were also the only ones in which a group effects were not observed. The above could be partially explained by the characteristics of the Eelder-fit. While strength was the component in which the program was more focused, with two sessions per week; flexibility was only trained during the cool-down of the sessions.

The improvements achieved by Eelder-fit are in line with previous research[24] and have been previously linked with better health status, greater ability to perform ADL and better QoL[25]. In this regard, gait speed, strength, and dynamic-balance can predict accelerated functional declines, ADL difficulties, falls, disability, and mortality in older adults[26,27]. For these reasons, the early identification of frail older adults or those at risk of frailty is of great importance, because they are the ideal target population for preventive exercise interventions against disability and negative health outcomes, and consequently reduce associated health care costs[8]. In contrast to our positive findings, other reports with MCT-programs did not obtain significant changes in balance[9,28], agility[29,30], gait speed[9], grip strength, flexibility or aerobic endurance[28,30]. This fact could be partially explained because these exercise prescriptions underestimated the workload ability of frail older adults[10].

Regarding the CON, previous studies with frail participants and shorter training periods, have shown performance declines in strength, agility[24,30] or gait speed[9]. Nevertheless, our CON did not worsen at the end of the 6-month MCT, and even improved their flexibility and grip strength ($p<0.05$). The absence of variations along the study may be multifactorial but could partially be explained by the positive effect of the health-related talks performed, or the increase in performance produced by the cumulative repetition of the tests.

Moreover, this is the first study performed with robust, frail and prefrail older frail adults in which the effects of detraining on fitness were also studied. This is a critical issue as it underlines the importance of temporarily stopping exercise in those older adults with or at risk of frailty (common due to holiday periods, surgical operations, home-confinements due to COVID-19, or others), since it is detrimental in this population. Our results have shown that detraining affected balance, upper-limb flexibility, and strength of the TRAIN. Ansai et al.[29] did not find a decrease in balance after 16 weeks of detraining following 16-week MCT, although the participants were not frail. Nevertheless, it is partially in line with our study, since while the ROB did not decrease in this variable, whereas FRA-PRE worsened. Regarding agility, our results agree with the study of Coetse et al.[31], in which no changes were obtained, although the participants were younger (55-75y). However, in other reports with community-dwelling older adults[32] the performance suffered a decline with 3-month detraining after 9-month MCT.

Regarding strength, TRAIN showed a performance drop in upper and lower limb during the detraining period, which is in line with studies with similar detraining periods[31,33]. In this sense, Carvalho et al.[33] concluded that strength was the fitness component most affected by detraining. Contrary, Esain et al.[32], who performed a 9-month training intervention followed by a 3-month detraining period, did not find declines in the Chair-stand and arm-curl tests. However, in the aforementioned study, the training period was longer and the detraining shorter than in the current research, which may help to maintain performance gains along detraining. Furthermore, participants were aged usual exercisers and therefore could have presented an active lifestyle during the detraining. Meanwhile, grip strength was not affected by detraining in our study in accordance with previous research[34].

In relation to aerobic endurance, our results are in agreement with previous research in which the performance was maintained after 12-week detraining period in older adults who regularly exercise[32], and 16-week period in healthy elderly[35]. Nevertheless, these results are in contrast with other reports where a decline was found after short (6-week) and long term (52-week) detraining periods[36]. One possible explanation of these conflicting results could be the PA adherence created by Eelder-fit. Nevertheless, this should be studied in depth, since while the TRAIN increased their MVPA just after the Eelder-fit ended when compared to baseline (M0-M6), it decreased with regard the end of the detraining (M6-M10). Consequently, it is unknown how long the effect of adhesion lasts.

With respect to gait velocity, neither of the two tests showed a significant decline. To our knowledge, only one study has analyzed detraining effects in maximum gait velocity, showing a decline after one year detraining[37].

Based on our detraining results, there could be a relationship between the fitness variables most affected by detraining and those that are less commonly practiced in the ADL, that require specific exercises to be improved as balance, flexibility or strength. Hence, discontinuous supervised exercise programs must include an unsupervised training prescription, which should focus on these specific components. Moreover, as stated above, long detraining periods should be avoided as they will induce fitness impairments which in turn will increase the number of adverse health outcomes, including disability and mortality[26,27].

Although detraining partially worsened the fitness variables assessed in TRAIN participants, the main part of the achieved improvements with the MCT-program, remained significantly better when compared to baseline values. In our study, only balance, upper-limb flexibility and aerobic endurance gains, were reversed to baseline levels. Thus, it seems that long-term exercise programs could offer a protection against activity cessation, maintaining training gains for longer periods. Nonetheless, futures studies should analyze different combinations of MCT training-detraining periods. Regarding CON, they improved at the 10-month assessment compared to baseline values in lower-limb strength and grip strength. These findings were unexpected, although as previously mentioned, the performed health-related talks, or the learning effect of the cumulative repetition of the tests, could have improved these variables along the study.

Focusing on the effects of frailty status on exercise, although our results did not show great differences between subgroups, the ROB got slightly more training benefits and were less affected by detraining. A previous systematic review concluded that exercise seems to be more effective in the earlier stages of frailty, since those older adults with higher degree of frailty could not be able to train as hard with respect those at an earlier stages[6]. In this regard, another study showed that older adults with worst functional status, have more possibilities to be a non-responder to the exercise[38]. However, exercise adaptations could probably change by modifying training variables[39], so it may be possible that participants with higher frailty, need a longer exercise program and/or shorter break periods. Based on this scenario, more studies are needed to identify and characterize those older adults with greater difficulties responding to the effects of training to provide them alternative treatment strategies with the optimal exercise dose.

Some limitations of this study should be mentioned. Firstly, although the sample size was calculated a priori and respected for the main comparison of the study, the secondary analysis of TRAIN subgroups, presented a small and unbalanced sample (15 ROB vs 45 FRA-PRE), avoiding the establishment of three subgroups (robust, prefrail and frail), which led to a low statistical power in this comparison. Secondly, a randomization of the sample was not performed for pragmatic and ethical reasons, since not prescribing exercise to older adults may be considered unethical[40]. However, there were only two differences at baseline in physical fitness between CON and TRAIN (balance and grip strength), one favorable for each group. Thus, the sample was divided according to the volunteers' availability to maximize training attendance and simulate the benefits of real-life conditions, where motivated people do exercise and unmotivated do not.

The present study has several strengths as it is the first study to evaluate the detraining effects on physical fitness in frail and prefrail older adults. Additionally, to date, no research has focused neither on analyzing the effectiveness of a MCT and the consequences of detraining considering frailty status, which could help to develop tailored and individualized protocols. In this way, this study detailed with accuracy the training methodology and protocol, so it can be easily performed by trainers to improve the physical fitness of robust, frail and prefrail older adults. Moreover, the program was individualized and adapted depending on the functional capacity and individual abilities of the participants, ensuring a progressive and safe adaptation.

5. CONCLUSIONS

To sum up, the Eelder-fit has proved to be feasible and beneficial in older adults, since no adverse events were observed, and it has improved their physical fitness. Therefore, it could contribute to a better health status and help maintain independence in this population. Moreover, a 4-month detraining period negatively affected balance, flexibility of upper-limb and strength. Promote ongoing exercise programs, set smaller break periods or implement them with an unsupervised exercise prescription could mitigate fitness impairment due to detraining. It seems that frailty status has a mild effect on training adaptations, since the ROB benefited slightly more from the training. Additionally, they were less affected by detraining. Our findings will contribute to developing efficacious and more precise exercise interventions in frail older adults or those at risk of frailty.

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Table 1. Eelder-fit training periodization

Strength & Power Sessions

Phase	PHASE 1. Familiarization				PHASE 2. Strength										PHASE 3. Coordination and power							PHASE 4. Functional and power		
Goals	Cause training adaptations				Increase strength levels										Enhance intermuscular coordination				Increase power			Improve performance DLA		
	Learn technical executions				Increase muscle endurance										Increase muscle endurance and strength level				Increase strength levels			Increase power and coordination		
Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Type of session	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST	PW	PW	PW	PW	PW	PW	PW
Sessions/week	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
Nº Ex*	6(2)	6(2)	7(2)	7(2)	7●(2)	7(2)	7(2)	8‡(2)	8●(2)	8(2)	8‡(2)	8●(2)	8(2)	8‡(2)	7●(2)	7	7●	7	6●(6)	6‡(6)	7(7)	6●(6)	6‡(6)	6(6)
Sets	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
Rep & Speed	8↓	8↓	10↓	10↓	10→	12→	15→	12→	12→	15→	12→	12→	15→	12→	12→	15→	12→	15→	12↑	12↑	15↑	12↑	12↑	15↑
Balance ex (s)	15	15	20	20	30	30	30	30	30	30	30	30	30	30	30	-	-	-	20	20	20	30	30	30
Set Rest time (s)	90	90	90	90	60	60	60	60	60	60	60	60	60	60	75	75	75	75	90 (20_a)	90 (20_a)	90 (20_a)	90 (30_a)	90 (30_a)	90 (30_a)

Aerobic Endurance & Functional Sessions

Phase	PHASE 1. Familiarization				PHASE 2. Development										PHASE 3. Maintenance							PHASE 4# Functional and power		
Goals	Increase aerobic capacity (VO_2 max)				Increase aerobic capacity (VO_2 max)										Increase aerobic capacity (VO_2 max)							Improve performance DLA		
	Improve coordination and functional performance				Improve coordination and functional performance										Improve coordination and functional performance							Increase power and coordination		
	Enhance motor skills and dynamic balance				Enhance motor skills and dynamic balance										Enhance motor skills and dynamic balance									
Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Type of session	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	AE	FUN	FUN	FUN
Sessions/week	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
Nº Ex	7	7	7	7	7●	7	7	7‡	7●	7	7	7‡	7●	7	7	7‡	7●	7	7	7‡	7	6	6	6
Sets	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Set time (s)	30	30	45	45	60	60	60	60	75	75	75	75	90	90	90	90	90	90	90	90	90	60	75	90
Set Rest time (s)	60	60	90	90	90	90	75	75	75	75	60	60	60	60	90 (30_b)	90 (30_b)	90 (45_b)	90 (45_b)	90 (60_b)	90 (60_b)	90 (60_b)	60 (30_a)	75 (45_a)	90 (60_a)
Total WTs	7	7	10.5	10.5	14	14	14	14	17.5	17.5	17.5	17.5	21	21	28	28	31.5	31.5	35	35	35	18	24	30
Ratio (WT:RT) (s)	1:2	1:2	1:2	1:2	1:1.5	1:1.5	1:1.25	1:1.25	1:1	1:1	1.25:1	1.25:1	1.5:1	1.5:1	2:1	2:1	2.25:1	2.25:1	2.5:1	2.5:1	2.5:1	1.5:1	2:1	2.5:1

Note: ↓: low speed execution (concentric and eccentric phase in approximately 4s); →: moderate speed execution (concentric and eccentric phase in approximately 2s); ↑: high speed execution (executed as fast as possible during the concentric phase, followed by a controlled eccentric phase of approximately 2 s); ●: exercises change; ‡: overload. *: number of balance exercises are between brackets; $_a$: balance exercises performed during the active rest of power and functional session; $_b$: static and dynamic balance exercises and coordination tasks using ball and balloon handling performed during the active rest of aerobic endurance sessions; #: this phase correspond to the 4th phase of strength periodization; AE: Aerobic endurance sessions; ADL: activities of daily living; Ex: exercises; FUN: functional sessions; Rep & Speed: repetitions and speed execution; PW: power sessions; ST: strength sessions; WTs: Total Work time session excluding 10-15min warm up (joint mobility, balance and cardiorespiratory exercises were performed), and a 10–15 min cool down (flexibility exercises and cognitive tasks).

Table 2. Participant characteristics at baseline

Characteristics	**WHOLE SAMPLE (n=87-110)**	**CON (n=40-51)**	**TRAIN (n=47-60)**	**TRAIN ROB (n = 14-15)**	**TRAIN FRA-PRE (n = 34-45)**
Age (years)	80.1 ± 6.1	79.2 ± 5.8	80.8 ± 6.2	77.1 ± 6.1	**82.1 ± 5.8†**
Sex					
Males	28 (25.5%)	9 (18.0%)	19 (31.7%)	7 (46.7)	12 (26.7)
Females	82 (74.5%)	41 (82.0%)	41 (68.3%)	8 (53.3)	33 (73.3)
Body Composition					
BMI	29.7 ± 5.1	29.6 ± 5.1	29.8 ± 5.1	29.5 ± 5.1	30.0 ± 5.2
Weight (kg)	72.9 ± 13.8	70.2 ± 12.5	74.9 ± 14.5	78.5 ± 13.0	73.7 ± 15.0
Height (cm)	155.9 ± 10.5	153.5 ± 11.4	158.0 ± 9.3	164.0 ± 5.8	**156.0 ± 9.4†**
BF%	38.8 ± 6.5	38.7 ± 6.0	37.0 ± 6.8	34.6 ± 5.4	37.9 ± 7.1
Physical Fitness					
Flamingo Test (s.)	9.0 ± 11.2	**11.4 ± 12.9***	7.0 ± 9.1	7.6 ± 5.7	6.7 ± 10.0
2.45-m Up and Go Test (s.)		8.5 ± 2.3	9.7 ± 4.4	7.5 ± 1.3	**10.5 ± 4.9†**
Chair Sit and Reach Test (cm)	-13.0 ± 11.1	-11.5 ± 12.5	-14.2 ± 9.8	-16.5 ± 7.1	-13.5 ± 10.5
Back Scratch Test (cm)	-13.8 ± 11.1	-14.7 ± 12.5	-13.0 ± 9.7	-11.3 ± 10.6	-13.6 ± 9.4
Chair Stand Test (rep)	10.7 ± 3.3	10.9 ± 3.0	10.5 ± 3.5	12.5 ± 2.3	**9.8 ± 3.6†**
Arm Curl Test (rep)	13.8 ± 3.9	13.8 ± 4.6	13.7 ± 3.5	14.7 ± 5.1	13.4 ± 2.8
Handgrip Test (kg)	21.4 ± 8.0	**19.7 ± 6.2***	22.9 ± 9.0	30.7 ± 9.6	**20.2 ± 7.2†**
6-min Walk Test (m)	368.7 ± 108.2	376.0 ± 106.5	362.7 ± 110.1	446.0 ± 45.7	**334.9 ± 111.5†**
30-m Walk test (s.)	25.5 ± 9.2	24.9 ± 8.5	26.1 ± 9.7	20.9 ± 3.0	**27.8 ± 10.6†**
6-m Usual Walking test (s.)	7.2 ± 4.8	6.7 ± 2.1	7.6 ± 6.1	5.8 ± 1.1	8.1 ± 6.9
Functional capacity & ADL performance					
SPPB (p)	7.8 ± 1.7	8.1 ± 1.6	7.5 ± 1.8	8.6 ± 1.1	**7.2 ± 1.8†**
IADL scale score	10.1 ± 4.0	10.1 ± 3.6	10.1 ± 4.2	8.8 ± 2.2	10.6 ± 4.7
Barthel Index score	95.7 ± 7.2	95.4 ± 8.0	96.1 ± 6.5	98.7 ± 2.3	**95.1 ± 7.2†**
Frailty					
Fried (p)	1.5 ± 1.2	1.4 ± 1.2	1.5 ± 1.2	0.0 ± 0.0	**2.0 ± 1.0†**
Physical Activity and Sedentary Behaviour ᵝ					
ST & SB (min/day)	1330.7 ± 67.0	1326.2 ± 72.4	1333.6 ± 63.5	1324.9 ± 46.5	1336.3 ± 68.2
LIPA (min/day)	91.5 ± 51.7	93.9 ± 52.1	89.9 ± 51.8	95.5 ± 36.4	88.1 ± 56.0
MVPA (min/day)	17.9 ± 21.3	19.8 ± 23.7	16.5 ± 19.7	19.6 ± 14.0	15.6 ± 21.2
Cognitive impairment					
Mini Mental state score	26.0 ± 4.1	26.3 ± 3.5	25.8 ± 4.5	27.1 ± 2.4	25.3 ± 4.9
Malnutrition					
MNA	24.7 ± 3.3	24.7 ± 3.5	24.6 ± 3.1	25.9 ± 2.7	24.1 ± 3.1

Note: Number of participants of the sample and % per group for categorical variables; mean ± standard deviation for continuous variables; CON: control group; TRAIN: training group; BMI: Body Mass Index; % BF: body fat percentage; s: seconds; cm: centimetres; rep: repetitions.; kg: kilograms; m: meters; ROB: training subgroup with robust participants; FRA-PRE: training subgroup with frail and pre-frail participants; SPPB: Short Physical Performance Battery; p: points; IADL: instrumental activities of daily living; MNA: Mini Nutritional Assessment; =: Range of the minimum and maximum number of participants. e.g: for the CON all tests were completed by 40 participants, and some were completed by 51; ᵝ: adjusted by 24 valid hours; ST & SB: Sleep time and Sedentary behaviour; LPA: Light physical activity; MVPA: Moderate-to-vigorous physical activity; ***:** significant differences between CON vs. TRAIN; †: significant differences between TRAIN subgroups (ROB vs. FRA-PRE); #: Differences obtained by T-test analysis for independent samples

Table 3. Physical fitness components evaluated, and tests performed

Physical fitness components and tests	Definition (number of attempts)	Battery or test
Balance		
Static balance		
Flamingo test	Time (s.) holding balance on one foot (2 el)	Flamingo test
Agility		
2.45-m Up-&-go test	Time spent (s.) to rise from a chair, walk 2.45 m, turn, come back and sit (2)	SFT
Flexibility		
Char sit-&-reach test	Distance (cm) from the tips of the middle fingers to the toe end of the shoe performed from a sitting position with one leg extended (1 el)	SFT
Back Stratch test	Distance (cm) of overlap or the distance between the tips of the middle fingers of both arms (1 el)	SFT
Strength		
Dynamic strength		
Chair stand test	Number of stands (reps.) from a chair performed in 30 s. (1)	SFT
Arm curl test	Number of curl lifts (reps.) performed in 30 s. (1)	SFT
Isometric strength		
Handgrip test	Maximal contractile grip force (kg) (2 el)	Frailty phenotype Frailty Index
Aerobic endurance		
6-min walk test	Maximum distance (m) covered in 6-min time limit (2) in a rectangular route of 46 m	SFT
Walking speed		
Maximum gait speed		
30-m walk test	Time spent (s.) in covered 30-m by walking as fast as possible (2)	30-m walk test
Usual gait speed		
6-m usual walking test	Time spent (s.) in covered 6 meters by walking as usual gait speed (1)	Gait speed test

Note: SFT: Senior Fitness Test; reps: repetitions; el: each limb; (1): one attempt; (2): two attempts.

PANEL A

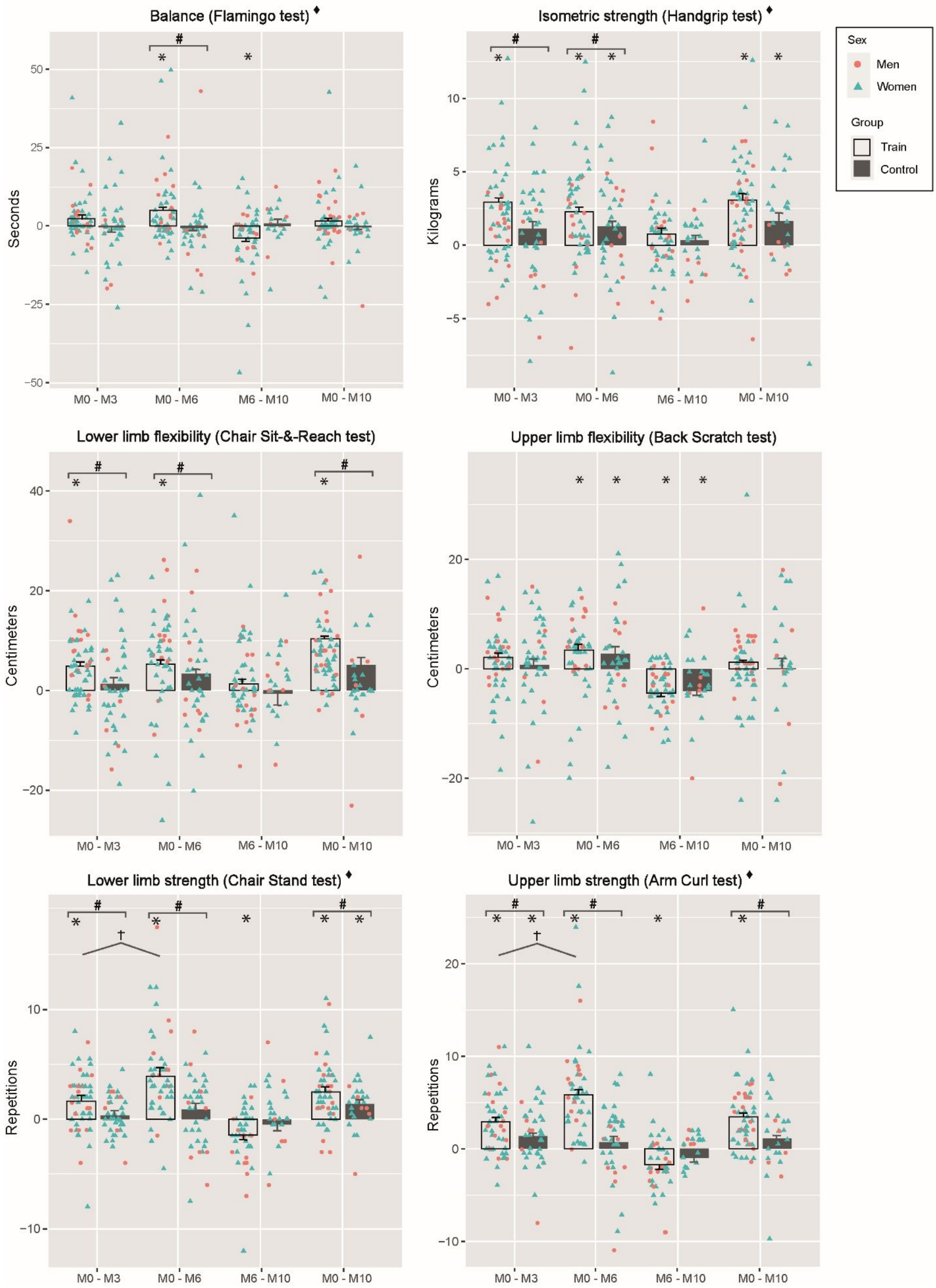

Figure 1-Panel A. Changes in physical fitness between different time points

M0-M3: changes between baseline and 3rd month: M0-M6: changes between baseline and 6th month; M6-M10: changes between 6th and 10th month; M0-M10: changes between baseline and 10th month; CON: Control Group; TRAIN: Training Group; *: differences within groups changes ($p<0.05$); ♦: group effects for 6-month training period; #: group-by-period-interaction (for M0-M3 and M0-M6) and group effects (for M6-M10 and M0-M10); †: within group differences between changes obtained in different periods (all $p<0.05$)

PANEL A (continuation)

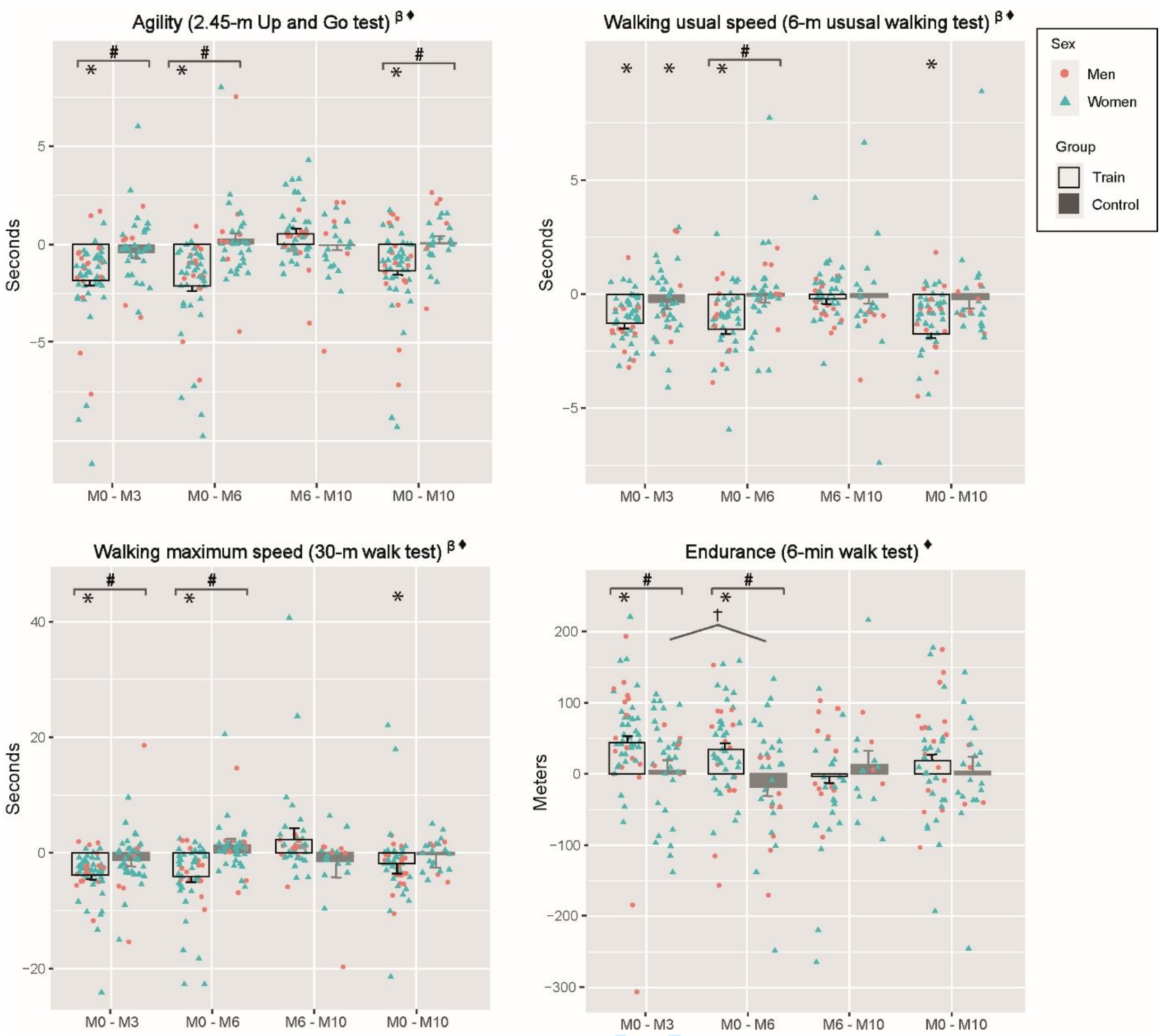

Figure 1-Panel A (continuation). Changes in physical fitness between different time points

M0-M3: changes between baseline and 3rd month: M0-M6: changes between baseline and 6th month; M6-M10: changes between 6th and 10th month; M0-M10: changes between baseline and 10th month; CON: Control Group; TRAIN: Training Group; β: negative changes represent performance improvement; *: differences within groups changes (p<0.05); ♦: group effects for 6-month training period; #: group-by-period-interaction (for M0-M3 and M0-M6) and group effects (for M6-M10 and M0-M10); †: within group differences between changes obtained in different periods (all p<0.05)

PANEL B

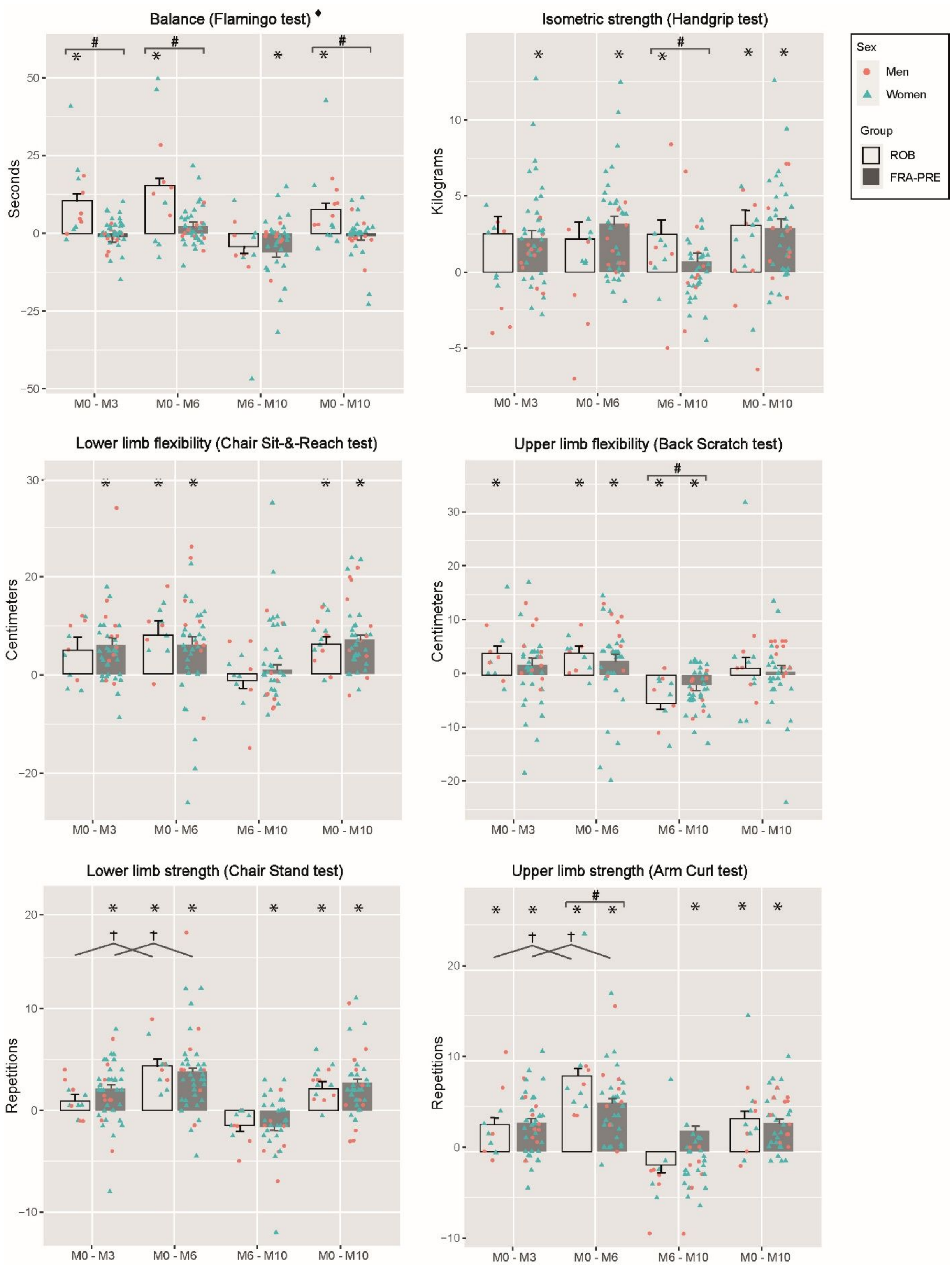

Figure 1-Panel B. Physical fitness changes along different time points in training subgroups according to their frailty status

M0-M3: changes between baseline and 3rd month: M0-M6: changes between baseline and 6th month; M6-M10: changes between 6th and 10th month; M0-M10: changes between baseline and 10th month; ROB: Robust participants of intervention group; FRA-PRE: Frail and prefrail participants of intervention group; *: differences within subgroups changes (p<0.05); ♦: subgroup effects for 6-month training period; #: group-by-period-interaction (for M0-M3 and M0-M6) and group effects (for M6-M10 and M0-M10) between frailty status subgroups; †: within subgroup differences between changes obtained in different periods (all p<0.05)

PANEL B (continuation)

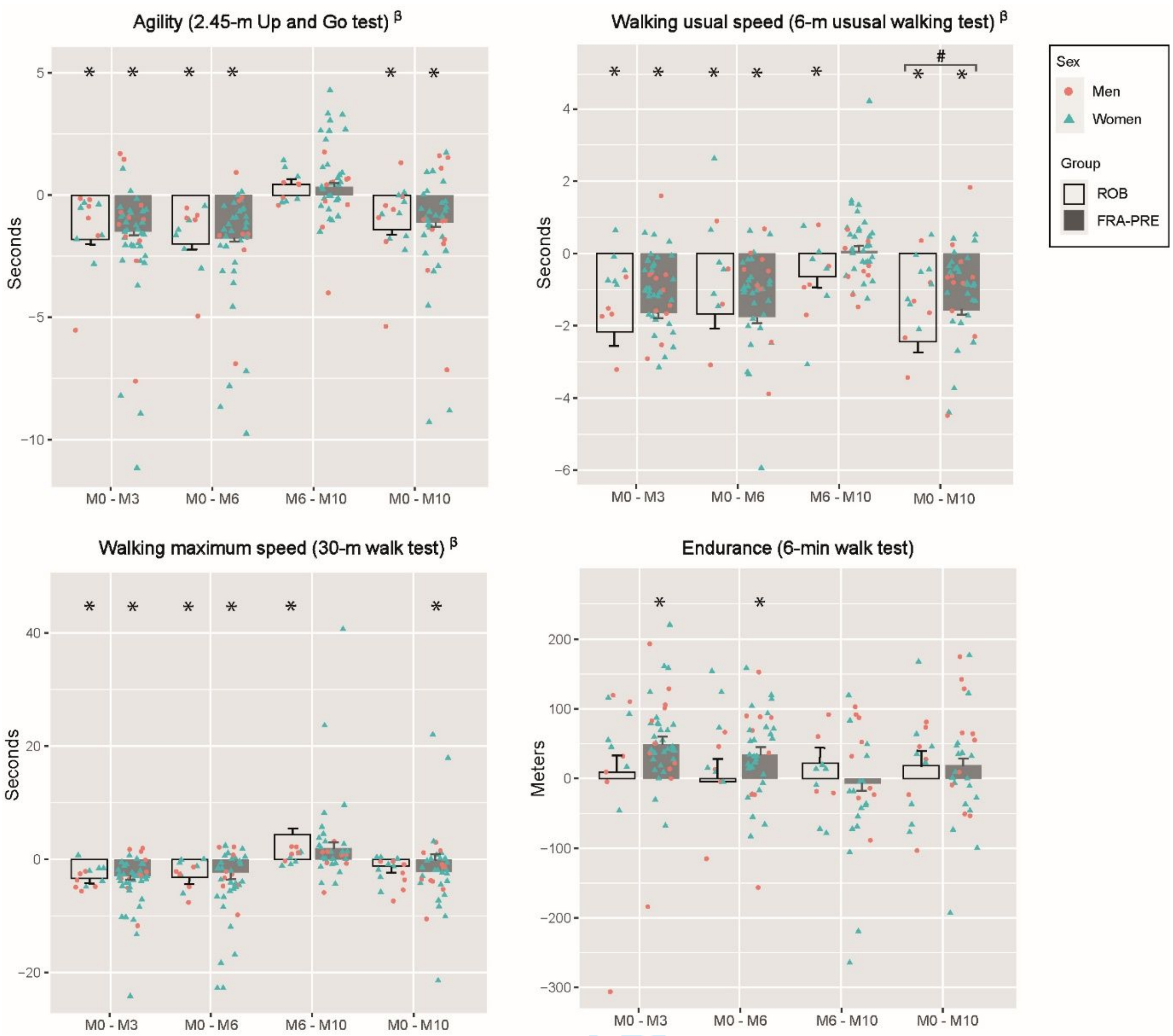

Figure 1-Panel B (continuation). Physical fitness changes along different time points in training subgroups according to their frailty status

M0-M3: changes between baseline and 3rd month: M0-M6: changes between baseline and 6th month; M6-M10: changes between 6th and 10th month; M0-M10: changes between baseline and 10th month; ROB: Robust participants of intervention group; FRA-PRE: Frail and prefrail participants of intervention group; β: negative changes represent performance improvement; *: differences within subgroups changes ($p<0.05$); ♦: subgroup effects for 6-month training period; #: group-by-period-interaction (for M0-M3 and M0-M6) and group effects (for M6-M10 and M0-M10) between frailty status subgroups; (all $p<0.05$)