BMC Geriatrics

https://doi.org/10.1186/s12877-026-07999-2

Article in Press

Effects of a combined diet and physical activity intervention (the ALAPAGE program) on dietary diversity and lower-limb muscle strength in community-dwelling older people: a pragmatic randomized controlled trial

Received: 12 September 2025

Accepted: 13 July 2026

Published online: 22 July 2026

Cite this article as: Jacquemot A., Cogordan C., Fressard L. *et al.* Effects of a combined diet and physical activity intervention (the ALAPAGE program) on dietary diversity and lower-limb muscle strength in community-dwelling older people: a pragmatic randomized controlled trial. *BMC Geriatr* (2026). https://doi.org/10.1186/s12877-026-07999-2

Anne-Fleur Jacquemot, Chloé Cogordan, Lisa Fressard, Gwenaelle Maradan, Cheraz Riabi, Aurélie Bocquier, Hélène Tréhard, Victor Hervieu, Christophe Dubois, Sarah Danthony, Pierre Verger, Nicole Darmon & Agnès Vinet

Title: Effects of a combined diet and physical activity intervention (the ALAPAGE program) on dietary diversity and lower-limb muscle strength in community-dwelling older people: a pragmatic randomized controlled trial.

Authors

Anne-Fleur Jacquemot[1, 2*]; Chloé Cogordan[1 *]; Lisa Fressard[1]; Gwenaelle Maradan[1], Cheraz Riabi[1], Aurélie Bocquier[1,3], Hélène Tréhard[1], Victor Hervieu[1]; Christophe Dubois[3]; Sarah Danthony[5]; Pierre Verger[1,6]; Nicole Darmon[7], Agnès Vinet[8] on behalf of the ALAPAGE study group†

*These two authors contribute equally to this work

Affiliations

1 Observatoire Régional de la Santé - PACA, Marseille, France;

2 Université de Bordeaux - Campus Carreire, Bordeaux, France;

3 Université de Lorraine, Inserm, INSPIIRE, F-54000, Nancy, France

4 Trophis, Marseille, France;

5 Laboratoire Sens, Université Grenoble Alpes, Saint-Martin-d'Hères, France;

6 Unité des Virus Émergents (UVE: Aix-Marseille Univ, Università di Corsica, IRD 190, Inserm 1207, IRBA), Marseille, France

7 Moisa, Univ Montpellier, Cirad, Ciheam-Iamm, Inrae, Institut agro, Ird, Inrae - Centre Occitanie-Montpellier, Montpellier, France;

8 Avignon Université, LAPEC, UPR4278, Avignon, France

***Correspondence:** agnes.vinet@univ-avignon.fr

ABSTRACT

Background: Diet and physical activity are key components of healthy aging. We aimed to evaluate the effectiveness of a combined diet and physical activity intervention (the ALAPAGE program) in improving dietary diversity (proxy for the nutritional quality of individual diets) and lower-limb muscle strength

(LLMS, a predictor of the ability to perform activities of daily living) among community-dwelling adults aged ≥ 60 years in France.

Methods: The ALAPAGE program comprised a 7-week intervention period with weekly collective sessions supervised by a dietician and/or a qualified physical activity professional, followed by 12 weeks of unsupervised activity. Its effectiveness was assessed through a cluster-randomized controlled trial conducted in 2022-2024. Clusters of groups of approximately 10 participants were allocated to either an intervention arm or a control arm (2:1 ratio). Primary outcomes were 1) dietary diversity assessed with the ORCHID score (each assessment based on two 24-hour dietary recalls and a simplified food frequency questionnaire), and 2) LLMS, assessed by the 30-second chair stand test. Assessments were conducted at baseline (T0), 7 weeks (T1, dietary diversity only), and 3 months (T2). A difference-in-difference (D-I-D) analysis, adjusted for covariables, was used to evaluate the specific impact of the intervention over time, compared to the control arm.

Results: The analysis included 376 participants: 254 (26 clusters) in the intervention arm and 122 (12 clusters) in the control arm. At baseline, the ORCHID score and LLMS did not differ significantly between the two arms. The ORCHID score improved significantly with time in both arms (intervention: +10% and +16% increase at T1 and T2 respectively, control: +4% and +11%) with no significant difference between the arms. LLMS improved between T0 and T2 in both arms (intervention: +15%; control: +5%), with a statistically significantly greater increase of 1.3 chair stands over 30 seconds in the intervention vs the control arm (P=0.005).

Conclusion: While dietary diversity improved similarly in both arms, the intervention-specific improvement in LLMS - a parameter associated with functional capacity - suggests the ALAPAGE program has potential as a preventive public health approach for contributing to healthy aging in community-dwelling older adults..

Trial registration: ClinicalTrials.gov Identifier: NCT05140330, November 4, 2021

Keywords: Healthy aging; Elderly; Nutrition; Physical function; Health education; Cluster randomized controlled trial.

Background and objectives

The United Nations projects that between 2020 and 2050 the proportion of people aged 65 and over will rise from 9% to 23% worldwide and from 21% to 28% in France (1). The prevalence of chronic illnesses, frailty and dependency, and their associated costs all increase sharply with population aging (2,3). Both the World Health Organization and French health authorities have identified diet and physical activity as key behaviors that can favor healthy aging by reducing the risk of noncommunicable diseases and maintaining functional independence (4–8).

Many diet and/or physical activity prevention programs exist for community-dwelling older adults, but few have been evaluated, and even fewer evaluated by high-quality research able to demonstrate their effectiveness (9). Some interventions focusing solely on diet, including dietary diversity, have nevertheless shown positive results for nutritional status, dietary diversity, eating habits, and food intake (10). Recent reviews and meta-analyses focusing on intervention studies solely on physical activity have shown positive effects whatever the types of exercise, particularly in improving functional capacity (increasing muscle strength) (11) and in preventing falls (12). Multiple types of exercise can help improving functional capacity. Among them, the Lifestyle Integrated Functional Exercise (LIFE) study reported positive results in terms of reducing falls, improving balance, ankle strength, ability in activities of daily living, and overall level of physical activity in adults aged at least 70 years who had experienced one or more falls (13).

Prevention interventions are generally based, totally or partly, on group workshops (i.e., an intervention including a group of people and conducted at a local organization) led by trained professionals. The number and duration of sessions vary. Some multicomponent programs based on both physical activity and nutrition interventions have proven their effectiveness in older people (14, 15). To our knowledge, only two programs for older adults combining physical activity and dietary diversity specifically have been developed to prevent the need for long-term nursing care. These two randomized controlled trials (RCT) both yielded encouraging results (16,17). As they took place in Japan, it is difficult to extrapolate their findings to other cultural contexts, particularly to a European setting.

We therefore decided to develop and evaluate the ALAPAGE program (18), a combined diet and physical-activity intervention targeted at older adults living at home in France. A pragmatic cluster RCT (named the ALAPAGE study) conducted in 2022-2024 in southeastern France assessed its effectiveness. Our aim here is report its results for its two primary outcome measures: dietary diversity (a proxy for the nutritional quality of older people's diets) and lower-limb muscle strength (LLMS, a predictor of the ability to perform activities of daily living). We hypothesized that a short, pragmatic, group-based intervention would (1) improve dietary diversity and (2) produce a clinically meaningful improvement in lower-limb muscle strength compared with a control group.

Methods

Trial design

The ALAPAGE study is a pragmatic cluster RCT with two parallel arms and a 2:1 ratio (2 intervention clusters for 1 control cluster). Its protocol was pre-registered at ClinicalTrials.gov (NCT05140330) and has been described elsewhere (18). The study was performed among community-dwelling older people (aged 60 or over) in southeastern France (intervention period: January 2022–February 2024). This study is reported according to the Consort Checklist for randomized trials (19) and its extension for cluster designs (20), which are set forth as Supplementary material A.

Clusters

A cluster is composed of a group of approximately 10 older adults recruited by geographically distant local organizations (i.e., social and community centers, run by voluntary associations or municipalities) to participate in either arm of the ALAPAGE study. The ALAPAGE study group (research team, funders and sponsors of previous and current prevention programs in the region) conducted a call for applications and selected local organizations according to operational and feasibility criteria (e.g., availability, materials, and staff resources) (See Supplementary material B for more details).

Participants

The study protocol fully describes the recruitment of older adults and the inclusion criteria (18). Briefly, we included community-dwelling adults aged ≥ 60 years, who had health insurance coverage, and could read and write in French. In addition, not more than three participants per cluster could have attended a workshop on diet or physical activity in the previous two years: this number of 3 results from discussions between the local organisations responsible for organising the ALAPAGE workshops and the members of the research team. A consensus was reached to retain this number in order to facilitate the recruitment of participants and to maintain a balance between those who had already participated in prevention workshops focused on diet and/or physical activity during the previous two years and those who had not participated, i.e. so as not to over-represent the former. Older adults receiving a dependency allowance were excluded. All participants were informed of the study objectives and their rights related to it; all provided written informed consent. The Tours Ouest 1 human ethics committee approved the study protocol (approval number 20.11.18.72507).

Participants were mostly recruited according to the usual practices of local organizations with announcements and advertisements within the organization, local newspapers, public posters, and leaflets. In addition, an active recruitment strategy, the INVITE procedure, was used to increase the number of socioeconomically disadvantaged older adults in the clusters (21): this procedure included 1) the identification of socially deprived/isolated older people in retirement fund databases; 2) a postal invitation letter; 3) a phone call and 4) an home visit by a social worker. All participants received a 15€ gift voucher at the end of the study to compensate them for the related constraints

Intervention arm

The intervention arm included supervised and unsupervised activities. The supervised activities took place during weekly group sessions over a 7-week intervention period: one introductory session, 4 sessions covering diet and 2 physical activity, each 2.5 hours in duration (4 of these sessions included the assessments described below). A dietician and/or a qualified professional in adapted physical activity (APA) conducted these workshops. Unsupervised activities were encouraged between all sessions and during a 12-week post-session period.

The dietary component of the ALAPAGE diet program primarily focused on dietary diversity, complemented by activities about nutritional profiles, budget-friendly healthy eating, and sustainable diets to increase food diversity. Moreover, participants were encouraged to set personalized objectives based on the dietician's advice and their first diet self-assessment (two 24-hour dietary recalls –24hDR - and a simplified food frequency questionnaire). As Table 1 shows, this assessment was repeated at the end of the supervised intervention (T1, at 7 weeks) and then 12 weeks later (T2).

The physical activity component of the ALAPAGE program combines a modified version of the LIFE intervention (13) extended by adding flexibility and endurance exercises with a standardized 10-minute exercise routine; each participants in the intervention also received a pedometer to encourage walking . The program was supervised by APA professionals during 2 group sessions with the idea of performing ALAPAGE activities in dual tasks (simultaneous exercise and cognitive tasks). Senior Fitness Tests including LLMS --the primary outcome according to the protocol (18)-- were performed at the beginning (T0) and the end of the study (T2). It was not assessed at T1 as 7-weeks would not be long enough to observe an effect on LLMS (22,23) (Table 1). According to these tests' results, participants received at the second session (S2) one of three practice manuals that illustrated functional exercises to improve either balance, flexibility - strength, and endurance. The 2 other practice manuals were offered at S6. Exercises were presented with different levels of difficulty, adapted to each participant according to the test results (low, below average, to be maintained, and good). During this session, the qualified professional in adapted physical activity explained the different exercises and difficulty levels on the basis of the practice manuals, and helped the participants to perform some functional exercises. More specifically, the strategies to improve LLMS included the following types of exercises: sit-to-stand, stair climbing, knee extension repetitions, and semi-squats. These were to be integrated into daily tasks and 3 one-minute exercises into the standardized 10-minute exercise routine (knee raises, heel-to-butt exercise, sit-to-stand). Participants were encouraged to set personalized objectives based on their results on the first senior fitness test and/or on their number of weekly steps. Between sessions, participants were encouraged to perform unsupervised functional exercises as often as possible throughout the day and to gradually progress when they felt secure enough to increase the level of difficulty. They were also encouraged to do the 10-minute exercise routine, and/or to walk more.

During these periods, in order to motivate participants in their daily exercises, they were required to record their daily exercise and number of steps in a weekly calendar, which they were to bring to each session. At the beginning of each session, participants shared tips and tricks to increase physical activity, with comments and advice from the nutritionist or APA professional. Self-reporting their exercises on a weekly calendar was thus a motivating monitoring tool to become independent, by enabling a feedback on their activity. Adverse events during the exercises, if any, were reported to the research team by the professional.

As part of this pragmatic trial, professionals (e.g., dieticians, APA professionals, and staff from local organizations) had some flexibility in the implementation of the ALAPAGE program to take real-life constraints into account (e.g., opting for a two-week rather than one-week interval between sessions when necessary).

Control arm

Participants in the control arm received no interventions during the study, including no advice from professionals related to their results on the different tests and questionnaires (Table 1), which they completed at the same time as the intervention participants. At inclusion, they were informed that they were offered the possibility of participating in the ALAPAGE workshop, only at the end of the ALAPAGE study. Nonetheless, to minimize dropouts from the control arm, the first visit (V0) included light refreshments and the intermediate visit (V2 for evaluation) also included a one-hour activity on waste recycling, and they had to come at V3 to receive the gift voucher.

Table 1: Study calendar including time of assessments for the intervention and control arms for 24hDR, FFQ, and LLMS

	W1	W2	W3	W4	W5	W6	W7	W8-17	W18	W19
INTERVENTION	T0			T1					T2	
	S0	S1	S2	S3	S4	S5	S6	Home	Home	S7
ORCHID score (self-administered-questionnaires)	24hDR +FFQ	24hDR				24hDR	24hDR +FFQ		24hDR	24hDR +FFQ
Lower-limb muscle strength test			30s Chair Stand Test							30s Chair Stand Test
CONTROL	T0					T1			T2	
	V0	V1	Home	Home	Home	Home	V2	Home	Home	V3
ORCHID score (self-administered questionnaires)	24hDR +FFQ	24hDR				24hDR	24hDR +FFQ		24hDR	24hDR +FFQ
Lower-limb muscle strength test		30s Chair Stand Test								30s Chair Stand Test

W: Week; 24hDR: 24-hour diet recalls; FFQ: Food frequency questionnaire; T0 (at baseline), T1 (at 7 weeks) and T2 (3 months later); S group sessions; V visit

Data collection and outcomes

Dietary primary outcome: Dietary diversity

Dietary diversity was measured with the ORCHID score (24), in a version adapted to the needs of the study (24). The score is based exclusively on the occurrence of consumption of food categories and does not take quantities into account. In the original version, consumption occurrences are derived from three 24hDR covering 12 food categories (Supplementary material C) and from one simplified Food Frequency Questionnaire (FFQ) covering 8 less frequently consumed categories (Supplementary D). Each reported consumption contributes positive or negative points according to the nutritional quality of its food category, and the total sum yields the individual's score, with higher values reflecting greater dietary diversity (24).

In the present study, for feasibility reasons, participants completed two 24hDR at each assessment time instead of three. The ORCHID score was calculated at baseline ("T0"), at 7 weeks ("T1" at the end of the ALAPAGE program) and then 3 months later ("T2", Table 1). Participants missing a session received the questionnaires by e-mail or through another participant. The adapted scoring algorithm used when only one 24hDR was available is provided in Supplementary material E.

Physical activity primary outcome: Lower-limb muscle strength (LLMS)

LLMS was assessed using the 30-s Chair Stand Test from the Senior Fitness Test battery (SFT, adapted into French) (25). Briefly, within 30 seconds the participants had to complete as many repetitions as possible of switching from a sitting to a full standing position with arms crossed over their chest. The APA professional supervised each evaluation (Table 1). Make-up tests were not possible for participants absent at a test session. LLMS was measured at T0 and T2 (Table 1).

Other characteristics

During the first sessions (questionnaires S0 and S1 for intervention arm; questionnaire V0 for control arm), participants' demographic (sex, age, household situation) and socioeconomic (educational level, perceived financial situation) characteristics were also collected, as well as their perceived global health, fall history, professional home assistance, and participation in social activities.

Sample size

We calculated the sample size with simulations that assumed $\alpha = 0.05$, similar participant characteristics in both arms, a 30% dropout rate between T0 and T2, and an intracluster correlation of 0.03, as described in the study protocol (18). We found that 300 participants in the intervention arm (i.e., 30 groups of 10 people) and 150 participants in the control arm (15 groups of 10 people) were required to obtain 95% power for both primary outcomes.

Randomization

Block randomization of the clusters was performed with 2 intervention clusters for 1 control (see full details in (18)). We created four time-based blocks (clusters starting at different dates across time according to their block). Selection of local organizations and allocation of clusters within local organizations have previously been described (18) (See Supplementary material F for more details).

Statistical methods

Participants were included in the analyses if they had participated in at least one session that included an evaluation (T0, T1, or T2). Participants who did not complete any 24hDR questionnaire were excluded from the ORCHID score analysis.

We used chi-square tests (categorical variables) and Wilcoxon rank-sum tests (continuous scores) for baseline comparisons of participants' characteristics. To compare the difference over time between the two groups — that is, the impact of the intervention — on the ORCHID score and LLMS, we computed hierarchical linear mixed models with random intercepts, including an interaction between arm and time, to create difference-in-difference (D-I-D) models. These allow changes over time (T0, T1, T2) of an outcome to be compared between arms while taking into account both the clustered and repeated nature of the data (26,27). The D-I-D models were adjusted for sex, age, educational level, perceived health, and number of sessions/visits attended. The model was also adjusted for the number of 24hDR completed for the dietary diversity outcome (as the score calculation depended directly on it). Analyses were performed by intention-to-treat (ITT). Missing data were handled by the mixed model without imputation (28). We also conducted sensitivity analyses by ITT with no adjustment for covariables, and with adjustment but by per protocol (PP), including only participants with data at each evaluation time (See Supplementary material G). Finally, for the LLMS model, we conducted a sensitivity analysis to examine the plausibility of non-random missing data at T2, which might be related to a lack of motivation toward the end of the study. We used a tipping point method for participants with low attendance (<5 sessions attended in the intervention group out of the 7 expected). We first ran a mixed-effects model, without adjusting for covariates, with multiple imputation of missing values in the control and intervention groups at T0 or T2. We then shifted the LLMS T2 imputed values of the participants with low participation from the intervention group towards the control group until the D-I-D effect became non-significantly different from zero, and examined whether that tipping point seemed plausible. Analyses used SAS 9.4 (SAS Institute Inc.), with statistical significance set at 0.05.

Results

Flow of clusters

In all, 26 local organizations hosted 38 clusters (Figure 1). In order to facilitate the recruitment, 5 local organizations hosted clusters both arms which were organized several months apart.

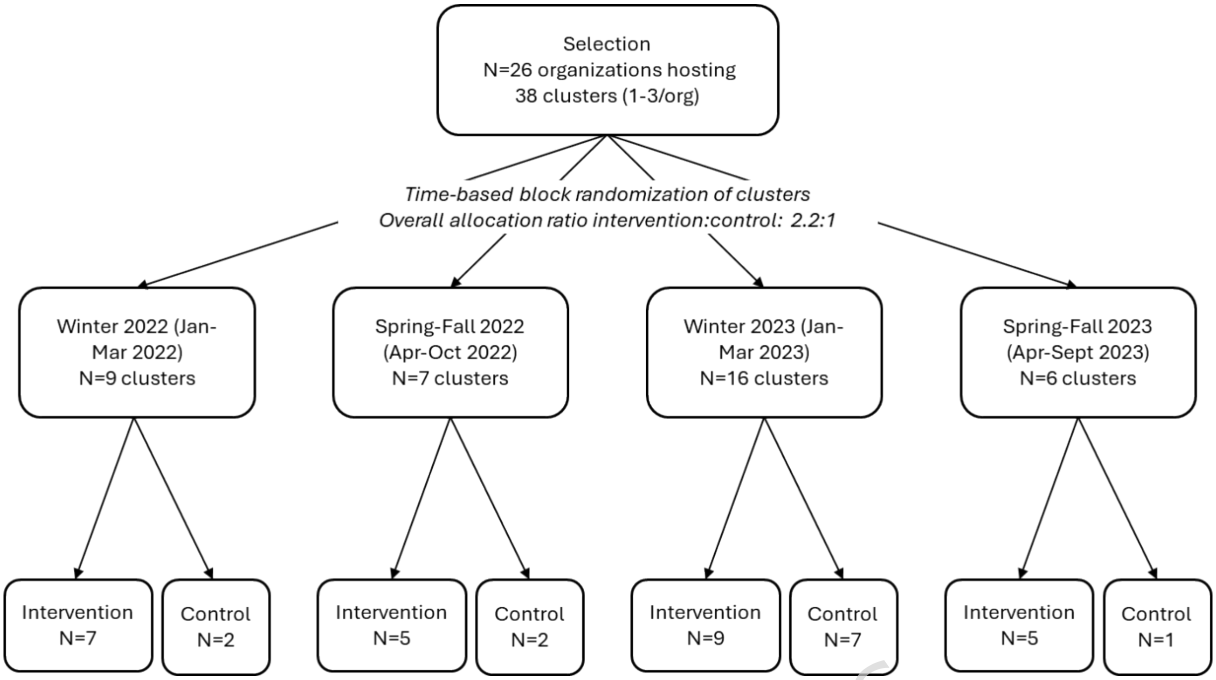

Figure 1. Flowchart of cluster randomization of the local organizations responsible for hosting clusters and inviting participants.

Participant flow

Between December 2021 and September 2023, the organizations recruited 379 older adults who met the inclusion criteria and volunteered to participate (Figure 2). Eventually, 257 older adults were included in the intervention arm and 122 in the control arm. The participation rate at S1 or V1 (i.e., just after presenting the study to the participants) did not differ between the two arms: 211/257 (82.1%) in the intervention arm and 105/122 (86.1%) in the control arm (*P*=0.33).

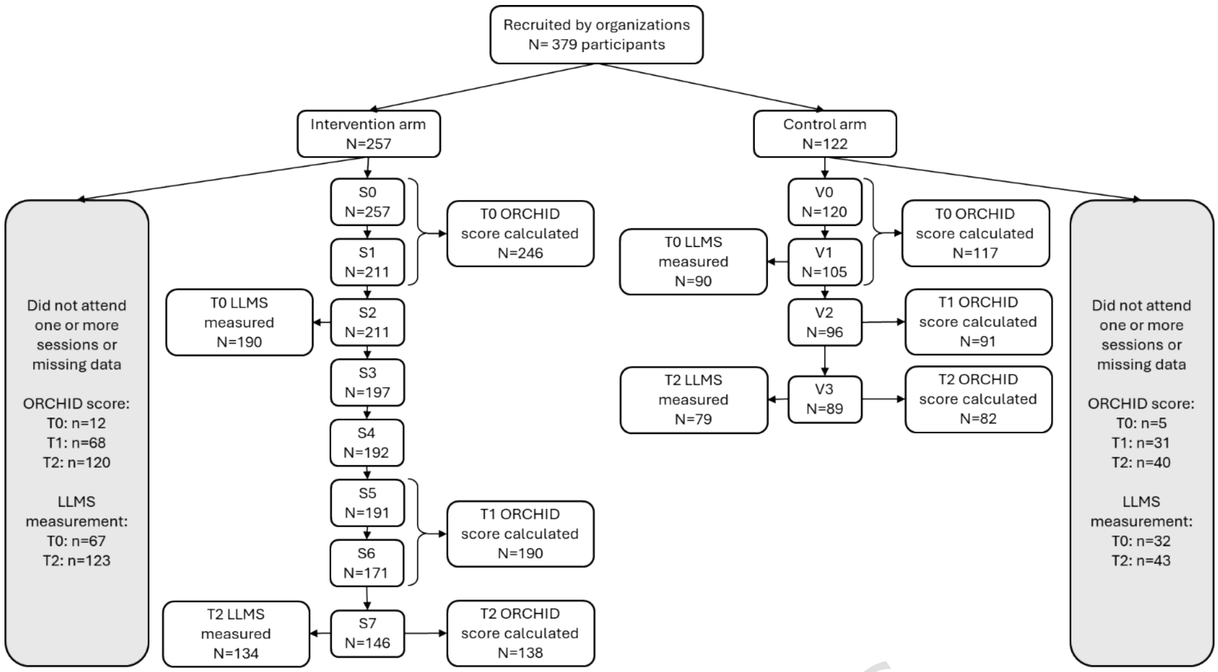

Figure 2. Flowchart of participants' attendance

S: session; V: visit; T: evaluation time; ORCHID score: dietary diversity score; LLMS: lower-limb muscle strength

Baseline data

Among the 379 participants, 3 participants had no available data for either primary outcomes or any assessment time. Accordingly the analysis included only 376 individuals (73.4±7 years old): 85% were women, and 63% reported living alone; about one-third were aged 60-70 years and 21% 80 years or older (Table 2). Overall, 58% had not completed high school, and 29% reported feeling financially insecure; 18% perceived their global health negatively, and 34% reported falling in the previous 12 months. The INVITE procedure accounted for the recruitment of 6% of the participants. Seventeen percent were receiving professional home assistance, and one quarter had never participated in organized social activities. At T0, the mean ORCHID score of participants who completed only one 24hDR was 19.7±7.7, and 42.2±12.6 for those who completed two (Table 2). On average, at T0, LLMS was 14.1±3.3, that is, they performed 14 stands of their chair in 30 seconds. Participants' characteristics did not differ between the intervention and control arms, nor did their mean ORCHID score or LLMS at T0.

Table 2. Characteristics of study participants and of primary outcome values at baseline in intervention and control arms

	Intervention (n=254)		Control (n=122)		All (n=376)		*P*-value[a]
	n	%	n	%	n	%	
Sex[b]							0.61
Men	35	14.3	19	16.4	54	15.0	
Women	209	85.7	97	83.6	306	85.0	
Age (years)[c]							0.27
60-64	34	14.0	10	8.7	44	12.3	
65-69	48	19.8	23	20.0	71	19.8	
70-74	63	25.9	33	28.7	96	26.8	
75-79	43	17.7	30	26.1	73	20.4	
80-84	37	15.2	14	12.2	51	14.3	
>=85	18	7.4	5	4.4	23	6.4	
Household situation[d]							0.17
Lives alone	153	60.5	82	67.8	235	62.8	
Lives with 1 person or more	100	39.5	39	32.2	139	37.2	
Educational level[e]							0.52
Did not complete high school (or lower)	106	56.1	70	62.0	176	58.3	
Completed high school	40	21.2	23	20.4	63	20.9	
At least some postsecondary education	43	22.8	20	17.7	63	20.9	
Perceived financial situation[f]							0.70
Not insecure	177	70.8	88	72.7	265	71.4	
Insecure	73	29.2	33	27.3	106	28.6	
Recruited through the INVITE procedure[d]							0.17
No	235	93.3	118	96.7	353	94.4	
Yes	17	6.8	4	3.3	21	5.6	
Perceived global health[g]							0.07
Good to excellent	174	78.7	105	86.8	279	81.6	
Poor or bad	47	21.3	16	13.2	63	18.4	
Fall in the 12 last months[h]							0.17
Yes	63	31.3	40	39.2	103	34.0	
No	138	68.7	62	60.8	200	66.0	
Professional home assistance[d]							0.13
Yes	47	18.6	15	12.4	62	16.6	
No	206	81.4	106	87.6	312	83.4	
Participation in social activities[i]							0.21
At least once a week	154	69.7	73	60.8	227	66.6	
Less often	19	8.6	11	9.2	30	8.8	
Never	48	21.7	36	30.0	84	24.6	
T0 ORCHID score[j] – *mean (SD)*							
With 1 24hDR completed	57	20.1 (7.4)	29	18.8 (8.3)	86	19.7 (7.7)	0.26
With 2 24hDR completed	189	41.9 (13.0)	88	42.8 (11.8)	277	42.2 (12.6)	0.39
T0 LLMS[k] – *mean (SD)*	190	14.1 (3.4)	90	14.1 (3.1)	280	14.1 (3.3)	0.64

[a] Chi² tests for categorical variables, Wilcoxon rank-sum test for continuous variables; [b] 16 missing values; [c] 18 missing values; [d] 2 missing values; [e] 74 missing values; [f] 5 missing values; [g] 34 missing values; [h] 73 missing values; [i] 35 missing values; [j] 13 missing values (no 24hDR completed); [k] 96 missing values
LLMS: lower-limb muscle strength, measured by number of complete stands from a chair in 30 seconds

Participants analyzed

Available data enabled the calculation of the ORCHID score in the intervention arm for 246 participants (96%) at T0, 190 (74%) at T1, and 138 (53%) at T2, and in the control arm, 117 (96%) at T0, 91 (75%) at T1, and 82 (67%) at T2. LLMS in the intervention arm was measured in 190 participants at T0 (74%) and 134 at T2 (52%), and in the control arm in 90 (74%) and 79 (65%), respectively.

Overall, 376 participants were included in the analyses: 374 in the ITT analyses for the ORCHID score and 296 for LLMS; in the PP analyses, these figures were respectively 196 and 197. Estimations of unconditional mixed models (with no explanatory variable included) allowed to calculate intraclass correlation coefficients (ICC): the variations between clusters accounted for 11% of the total variance of the ORCHID score and 12% of that of LLMS.

Impact of the intervention on the ORCHID score and LLMS

Table 3 presents the course over time of the ORCHID score and of LLMS in the intervention and control arms, after adjustments. The ORCHID score increased in both arms, with a progression from 32.9 to 38.1 (+16%) in the intervention arm ($P \leq 0.001$) and from 35.5 to 39.3 (+11%) in the control arm ($P=0.003$) between T0 and T2. However, the net adjusted D-I-D effect (+1.7 point at T1, $P=0.26$ and +1.4 point at T2, $P=0.40$) was not statistically significant, indicating no evidence of a differentiated evolution between the intervention and control arms. Without adjustment for covariables, the results were similar (increase from T0 to T2: +11%, $P<.0001$ in the intervention arm; +9%, $P=0.001$ in the control arm; net D-I-D effect: +1.5 point, $P=0.28$), as were those from the PP analyses (increase from T0 to T2: +13%, $P<.0001$ in the intervention arm; +12%, *P*=0.001 in the control arm; net adjusted D-I-D effect: +0.4 point, *P*=0.81) (Supplemental material F, Tables S1 and S2).

The LLMS improved significantly in both arms between T0 and T2 with an increase from 12.7 to 14.7 (+15%) chair stands in the intervention arm (*P*≤0.001) and from 13.6 to 14.3 (+5%) in the control arm (*P*=0.04). The net adjusted D-I-D effect (+1.3 chair stands) was statistically significant (*P*=0.005), indicating that at T2, the intervention group could perform 1.3 more chair stands than the control group. When no adjustment was performed for covariables, the results were similar (increase from T0 to T2: +13%, *P*<0.0001 in the intervention arm; +5%, *P*=0.05 in the control arm; net D-I-D effect: +1.1 chair stand, *P*=0.01), as were those from the PP analyses (increase from T0 to T2: +19%, *P*<.0001 in the intervention arm, +5%, *P*=0.052 in the control arm; net adjusted D-I-D effect: +1.4 chair stand, *P*=0.003) (Supplemental material F, Tables S1 and S2). The tipping point analysis showed that if the true LLMS T2 values of the missing data of participants with lower attendance were 2.8 units lower than those imputed in the intervention group, statistically significant differences between evolutions in the intervention and control groups would no longer be observed. That tipping point means that LLMS would have regressed between T0 and T2 among participants with low attendance. No adverse event was reported during the exercises.

Table 3. Course of ORCHID score and LLMS in intervention and control arms:

	ORCHID score1 (n=292)					LLMS2 (n=245)		
Estimate [95% CI]	T0	T1	T2	From T0 to T1 (% change)	From T0 to T2 (% change)	T0	T2	From T0 to T2 (% change)
Intervention	32.9 [24.2 ;41.5]	36.1 [27.2 ;45.1]	38.1 [29.0 ;47.3]	+3.3 [1.4 ;5.1]*** (+10%)	+5.3 [2.9 ;7.6]*** (+16%)	12.7 [9.6 ;15.9]	14.7 [11.5 ;17.9]	+2.0 [1.4 ;2.5]* (+15%)
Control	35.5 [29.0 ;41.9]	37.0 [30.2 ;43.8]	39.3 [32.5 ;46.1]	+1.5 [-1.0 ;4.0] (+4%)	+3.8 [1.3 ;6.4]** (+11%)	13.6 [11.2 ;16.1]	14.3 [11.9 ;16.8]	+0.7 [0.02 ;1.4 (+5%)
D-I-D effect[3]				+1.7 [-1.3 ;4.7]	+1.4 [-1.9 ;4.7]			+1.3 [0.4 ;2.1]*

† Results from D-I-D hierarchical linear mixed models adjusted for sex, age, educational level, perceived health, attendance at sessions/visits and, for the dietary diversity model, the number of 24hDR completed. The % change between T0 and T1 and between T0 and T2 were calculated *a posteriori*, based on the model estimates, as follows: (T1 - T0)/T0 and (T2 - T0)/T0).
[1] In all, 82 participants were excluded due to missing values for adjustment variables (sex: 14 missing values: age: 16 missing values, educational level: 73 missing values; perceived health: 33 missing values). Excluded participants were not significantly different from those retained regarding their ORCHID score at each measurement time (results not shown).
[2] LLMS: Lower-limb muscle strength, i.e., number of complete stands from a chair in 30 seconds. A total of 51 participants were excluded due to missing values for adjustment variables (sex: 16 missing values; age: 17 missing values, educational level: 42 missing values; perceived health: 7 missing values). Excluded participants were not significantly different from those retained regarding their LLMS at each measurement time (results not shown).
[3] Net difference from T0 to T1 or from T0-T2: difference between intervention and control arms
* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

Discussion

The results show that, compared to the control arm, participation in the ALAPAGE intervention resulted in significantly better lower-limb muscle strength in community-dwelling older adults in southeastern France, but did not lead to any additional improvement regarding dietary diversity, as shown by the similarity of the improvement of the ORCHID score over time in both arms.

Other public health prevention programs for older people have shown beneficial impacts on dietary diversity. The Japanese program "TAKE10!® For Older Adults" (sessions once every 2 weeks for 3 months) is relatively similar to the ALAPAGE program in its combination of dietary education and physical activity (instruction and practice), aimed at encouraging older people to eat a diversity of foods and to introduce physical activity at home (17). In the "TAKE10!®" program, the dietary diversity score, based on the daily consumption of 10 food groups measured over 10 days, improved by 29% in the intervention arm and not at all in the control arm (17). Another Japanese program (a weekly 90-minute active learning program for 24 weeks) on exercise, diet and nutrition, and cognitive activity for health promotion in older age showed a 16% increase in the dietary diversity score in the intervention arm, significantly higher than in the control arm (16). The ALAPAGE study should have shown a difference in the effect of dietary diversity between the intervention and control arms. One notable difference between the "TAKE10!® For Older Adults" program and the ALAPAGE program is that in the former, participants in intervention had to enter their diet every day for 10 consecutive days into a table for a simple and quick assessment of the variety of their food intake. The dietary questionnaires in ALAPAGE were not as frequent (6 days over the study's 5-month duration), which may explain at least in part the differences between our results for dietary diversity and those of the TAKE10 study. Compared with ALAPAGE, the second Japanese study, which focused on an active learning program, was much more intensive, with a 1.5-hour session each week for 24 weeks and homework (searching for information by themselves outside the sessions) and feedback during the sessions. In the ALAPAGE program, since the ORCHID score also improved in the control group, the improvement in the diversity score may be due to participation in the study and completion of the questionnaires (24hDR and FFQ). This may be related to the Hawthorn effect, i.e., individuals' alteration of behavior (self-reported or not) simply because of their awareness they are being observed (29). Moreover, self-monitoring is recognized as an effective behavior change technique (30).

The physical activity component of the ALAPAGE program effectively increased LLMS more in the intervention than the control group. The two Japanese programs mentioned above did not show any significant effect on muscle strength function. The Japanese active learning program did not report more improvement in grip strength in the intervention than the control group (16). This program was substantially longer (session once a week for 24 weeks) than ALAPAGE. Another notable difference, however, is that the Japanese active learning program (16) focused only on courses on methods of lower-limb and upper-limb muscle resistance training with no prescription for exercises at home and no practice exercises during the course, unlike ALAPAGE. The physical activity component of the "TAKE10!® For Older Adults" program involved 10 min at least 2–3 times per day of walking at a self-determined pace, stretching daily, and muscle strength training. Specifically, for resistance training, they recommended 8 strength training exercises to be performed at home once every two days. Nonetheless, they did not find any increase in the frequency of strength training exercises in the intervention group, as assessed by questionnaires (15). The ALAPAGE program embeds, as recommended (31), LIFE exercises focused on strength and balance as well as its own exercises targeting flexibility and endurance into activities of daily living; it also adds a 10-minute daily exercise routine and provides a pedometer to encourage participants to walk more. The ALAPAGE program is effective in improving LLMS, which is deemed to be very important for daily life and has been shown to protect older adults against falls (31).

This study has some limitations. First sets of limitations concerned inclusion and attrition. Compared to the target of 450 participants with a 2:1 ratio (300 intervention, 150 control), only 379 participants were recruited (257 intervention, 122 control). However, this 16% shortfall did not affect the statistical power of our analyses, because the target numbers had been deliberately increased to ensure the best statistical power: in fact, our simulations indicated that to achieve 95% statistical power, exactly 254 participants in the intervention group and 127 in the control group were required. These figures were very close to those ultimately recruited. The percentage of participants who were lost to follow-up and/or skipped an evaluation session was elevated and, at T2, significantly higher in the intervention group (48%) than in the control group (35%), which could be partly related to the greater number of sessions in the intervention group than in the control group; data were also missing during the tests. The mixed models implemented for the D-I-D analyses allowed us to handle missing data, and more particularly to take unequal dropout into account for the ITT analyses (32), contrary to other methods such as covariance or change score analyses. Although sessions may be missed at random due to events unrelated to the study (health issues, medical appointments, family events, etc.) as suggested by the implementation fidelity study (results not shown), we cannot rule out a possible bias due to nonrandom attrition, where only the most motivated participants would have attended the last sessions (32). The tipping-point analysis suggested that participants to the intervention group with low attendance woul have regressed in T2 compared to T0, which does not seem plausible. This, combined with results similar in ITTT analyses with and without adjustment for covariates and in the per-protocol (PP) analysis, suggests that the results on the LLMS are robust. Second sets of limitations concerned general characteristics of the participants. We did not have information about previous functionality, cognitive profile, and comorbidities. Our sample was not representative of the general population of older adults; despite adjustments of our analyses for confounding covariables, our results might not be generalisable to all of them. Third, the ALAPAGE program was relatively shorter than the two similar studies in Japan (16,17), but in the range of duration shown to increase the chance of observing an effect (31,33). Four, the home-based exercises were self-reported in a weekly calendar and not directly measured. Five, the assessment process has certain limitations : a) the LLMS test was administered by the same APA professionals who had conducted the intervention, which may have led to some performance bias; b) the imprecision and reporting bias of dietary assessment methods (34). The recognized gold standard for dietary assessment relies on three quantitative 24hDRs spaced over time (35). We considered however that this would have been difficult to implement into a public health intervention because it demands too much of participants. We therefore simplified the data collection as much as possible (2 nonquantitative 24hDR, and one simplified nonquantitative FFQ) and adapted the ORCHID score calculation to take this adaptation into account (see supplementary material E). The real-life implementation of the ALAPAGE program in this population necessarily means that the protocol was not always well followed. Notably, participants often forgot the second 24hDR, to be done at home — an oversight that affected the variability of their ORCHID scores. Even though the statistical analysis took the number of 24hDR into account and even though the adapted version of the ORCHID score – with two 24hDR- remained valid compared with three 24hDR (personal data), adapted version's sensitivity might have reduced and this might have masked the differences between the two arms, especially if these differences were not marked.

This study has several strengths. It is a pragmatic cluster RCT with two parallel arms. Muscle strength was assessed with an objective test, unlike in other studies (17); moreover, the LLMS is predictive of the ability to perform activities of daily living (36) and to prevent falls (12). The ALAPAGE program was co-

constructed with older adults, the ALAPAGE coalition, community and municipal centers, dieticians, and APA professionals. It thus took the needs and constraints of all of these stakeholders into account, which may facilitate its scaling up. Implementation fidelity was assessed using the Carroll framework (37), as modified by Hasson (38) (data not shown), through a mixed methods approach combining quantitative and qualitative data. Overall, this demonstrated excellent quality of delivery: session content was delivered as intended, and participants were actively engaged in the activities during the sessions and reported high satisfaction levels. The local organizations responsible for organizing the workshops reported certain difficulties related to research constraints and to participant real life constraints (e.g. babysitting grandchildren, medical appointments…). Among participants, reduced attendance frequency and missing data were largely attributable to external factors independent of the ALAPAGE intervention. Efforts were made to recruit socioeconomically disadvantaged older adults, in part through the INVITE procedure (21), as this type of population is underrepresented in health promotion activities for older people.

Conclusion

The ALAPAGE program, designed for autonomous older adults, proved effective in improving LLMS. Nonetheless, it had no specific impact on dietary diversity, which increased in both arms. Improving LLMS is important for daily life, as it is one of the parameters associated with functional capacity. This program thus has the potential to be a preventive public health approach for contributing to healthy aging among community-dwelling older people.

List of abbreviations

24hDR: 24-hour diet recall

APA: Adapted physical activity

RCT: randomized controlled trials

FFQ: Food Frequency Questionnaire

LLMS: Lower-limb muscle strength

Declarations

Ethics approval and consent to participate

The French ethics committee “Comité de Protection des Personnes TOURS - Région Centre - Ouest 1” (FDA IRB n°IORG0008143) on March 30, 2021 (n° 2021 T2–06) approved this study. Written, informed consent was obtained from all participants prior to entering the study. The study protocol was conducted in accordance with the declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

Data is available upon reasonable request at the corresponding author after signing an appropriate data transfer agreement.

Competing interests

The authors declare that they have no competing interests.

Funding

The ALAPAGE study was funded by the French Institute for Public Health Research (IReSP) as part of the general call for proposals 2018 (project LIDARMONAAP18- PREV-004), the Regional Health Agency Provence-Alpes-Côte d’Azur (ARS PACA), the southeastern France retirement fund (Carsat Sud-Est), the

Région Sud – Provence-Alpes-Côte d'Azur, La Fondation d'Entreprise Mutuelle Générale and the University of Bordeaux. The IReSP, the ARS PACA, the Région Sud - Provence-Alpes-Côte d'Azur, the University of Bordeaux and La Fondation d'Entreprise Mutuelle Générale had no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript. The Carsat Sud-Est was part of the steering committee for the study and took part in the design of the study.

Authors' contributions

AB, HT, ND, SD, AV, CC, AFJ, PV, and CB designed the study, CC, AFJ, CR and GM conducted the study, VH and LF analyzed the data. AFJ and CC were responsible for writing the first draft, which was then collaboratively reviewed and refined by all authors.

Acknowledgments

The authors want to thank all the dietitians, APA professionals, coordinators of local organizations and older adults who participated in the ALAPAGE study, as well as Jo Ann Cahn who revised the English version of the manuscript.

†The ALAPAGE Study Group includes the authors of this manuscript and: Valérie Arquier (Caisse d'assurance retraite et de la santé au travail Sud-Est (Carsat Sud-Est), Marseille, France), Guillaume Briclot (Caisse d'assurance retraite et de la santé au travail Sud-Est (Carsat Sud-Est), Marseille, France), Rachel Chamla (Association Géront'ONord Pôle Infos Séniors Marseille Nord, Marseille, France), Florence Cousson-Gélie (Université Paul-Valéry Montpellier 3, Univ. Montpellier, EPSYLON, Montpellier, EA, France), Karin Delrieu (Mutualité Française Sud Provence-Alpes-Côte d'Azur, Marseille, France), Julie Dessirier(Mutualité Française Sud Provence-Alpes-Côte d'Azur, Marseille, France), Catherine Féart (Université de Bordeaux - Campus Carreire, Bordeaux, France), Christine Fusinati (Association Géront'ONord Pôle Infos Séniors Marseille Nord, Marseille, France), Rozenn Gazan(MS-Nutrition, Marseille, France), Mélissa Gibert (SudEval Provence-Alpes-Côte d'Azur Corse, Marseille, France), Valérie

Lamiraud, Matthieu Maillot (MS-Nutrition, Marseille, France), Dolorès Nadal (SudEval Provence-Alpes-Côte d'Azur Corse, Marseille, France), Christelle Trotta (Caisse d'assurance retraite et de la santé au travail Sud-Est (Carsat Sud-Est), Marseille, France), Eric O. Verger (Moisa, Univ montpellier, Cirad, Ciheam-Iamm, Inrae, Institut agro, Ird, Inrae - Centre Occitanie-Montpellier, Montpellier, France), Valérie Viriot (Association de Santé, d'Éducation et de Prévention sur les Territoires Provence-Alpes-Côte d'Azur (ASEPT PACA, Marseille, France).

References

1. United Nations. Department of Economic and Social Affairs. World Population Prospects 2019. Volume II: Demographic Profiles. New-York; 2019.

2. Chang AY, Skirbekk VF, Tyrovolas S, Kassebaum NJ, Dieleman JL. Measuring population ageing: an analysis of the Global Burden of Disease Study 2017. Lancet Public Health. 2019 Mar 1;4(3):e159–67.

3. Roussel R. Personnes âgées dépendantes : les dépenses de prise en charge pourraient doubler en part de PIB d'ici à 2060. Etudes Résultats [Internet]. 2017;1032. Available from: https://drees.solidarites-sante.gouv.fr/sites/default/files/er1032.pdf

4. Ministère des Solidarités et de la Santé. Stratégie Nationale de Santé 2018-2022 [Internet]. Paris; 2017. Available from: https://sante.gouv.fr/IMG/pdf/dossier_sns_2017_vdefpost-consult.pdf

5. World Health Organization. Global strategy and action plan on ageing and health. Geneva; 2017.

6. Rudnicka E, Napierała P, Podfigurna A, Męczekalski B, Smolarczyk R, Grymowicz M. The World Health Organization (WHO) approach to healthy ageing. Maturitas. 2020 Sep;139:6–11.

7. World Health Organization. UN Decade of Healthy Ageing: Plan of Action 2021–2030 [Internet]. Geneva; 2020. Available from: https://cdn.who.int/media/docs/default-source/decade-of-healthy-ageing/decade-proposal-final-apr2020-en.pdf?sfvrsn=b4b75ebc_28

8. World Health Organization. World report on Ageing And Health. Geneva; 2015.

9. Teggart K, Ganann R, Sihota D, Moore C, Keller H, Senson C, et al. Group-based nutrition interventions to promote healthy eating and mobility in community-dwelling older adults: a systematic review. Public Health Nutr. 2022 May 16;25(10):1–32.

10. Zhou X, Perez-Cueto FJA, Santos QD, Monteleone E, Giboreau A, Appleton KM, et al. A Systematic Review of Behavioural Interventions Promoting Healthy Eating among Older People. Nutrients [Internet]. 2018 Jan 26 [cited 2020 May 11];10(2). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5852704/

11. Labata-Lezaun N, González-Rueda V, Llurda-Almuzara L, López-de-Celis C, Rodríguez-Sanz J, Bosch J, et al. Effectiveness of multicomponent training on physical performance in older adults: A systematic review and meta-analysis. Arch Gerontol Geriatr. 2023 Jan 1;104:104838.

12. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, et al. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. Br J Sports Med. 2017 Dec;51(24):1750–8.

13. Clemson L, Singh MAF, Bundy A, Cumming RG, Manollaras K, O'Loughlin P, et al. Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): randomised parallel trial. BMJ. 2012 Aug 7;345:e4547.

14. Teh R, Barnett D, Edlin R, Kerse N, Waters DL, Hale L, et al. Effectiveness of a complex intervention of group-based nutrition and physical activity to prevent frailty in pre-frail older adults (super): a randomised controlled trial. Lancet Healthy Longev. 2022 Aug;3(8):e519–30.

15. Bernabei R, Landi F, Calvani R, Cesari M, Del Signore S, Anker SD, et al. Multicomponent intervention to prevent mobility disability in frail older adults: randomised controlled trial (SPRINTT project). BMJ. 2022 May 11;377:e068788.

16. Uemura K, Yamada M, Okamoto H. Effects of Active Learning on Health Literacy and Behavior in Older Adults: A Randomized Controlled Trial. J Am Geriatr Soc. 2018 Sep;66(9):1721–9.

17. Kimura M, Moriyasu A, Kumagai S, Furuna T, Akita S, Kimura S, et al. Community-based intervention to improve dietary habits and promote physical activity among older adults: a cluster randomized trial. BMC Geriatr. 2013 Jan 23;13:8.

18. Bocquier A, Jacquemot AF, Dubois C, Tréhard H, Cogordan C, Maradan G, et al. Study protocol for a pragmatic cluster randomized controlled trial to improve dietary diversity and physical fitness among older people who live at home (the 'ALAPAGE study'). BMC Geriatr. 2022 Aug 4;22(1):643.

19. Schulz KF, Altman DG, Moher D, the CONSORT Group. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMC Med. 2010 Mar 24;8(1):18.

20. Campbell MK, Piaggio G, Elbourne DR, Altman DG. Consort 2010 statement: extension to cluster randomised trials. BMJ. 2012 Sep 4;345:e5661.

21. Bianchi CM, Bocquier A, Cogordan C, Tréhard H, Badiou M, Nadal D, et al. Recrutement actif de seniors socio-économiquement défavorisés pour des ateliers de prévention : la procédure INVITE. Santé Publique. 2025 Mar 11;37(1):89–99.

22. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, et al. Resistance Training for Older Adults: Position Statement From the National Strength and Conditioning Association. J Strength Cond Res. 2019 Aug;33(8):2019–52.

23. Sherrington C, Fairhall N, Kwok W, Wallbank G, Tiedemann A, Michaleff ZA, et al. Evidence on physical activity and falls prevention for people aged 65+ years: systematic review to inform the WHO guidelines on physical activity and sedentary behaviour. Int J Behav Nutr Phys Act. 2020 Nov 26;17(1):144.

24. Jacquemot AF, Prat R, Gazan R, Dubois C, Darmon N, Feart C, et al. Development and validation of an occurrence-based healthy dietary diversity (ORCHID) score easy to operationalise in dietary prevention interventions in older adults: a French study. Br J Nutr. 2024 Mar;131(6):1053–63.

25. Fournier JF, Vuillemin A, Cren FL. Mesure de la condition physique chez les personnes âgées. Évaluation de la condition physique des seniors : adaptation française de la batterie américaine « Senior Fitness Test ». Sci Sports. 2012;27(4):254.

26. Gertler PJ, Martinez S, Premand P, Rawlings LB, Vermeersch CMJ. Impact Evaluation in Practice, second edition [Internet]. Inter-American Development Bank and World Bank. Washington, DC; 2016. 336 p. Available from: 10.1596/978-1-4648-0779-4

27. Warton E, Parker M, Karter A. How D-I-D you do that? Basic Difference-in-Differences Models in SAS®. 2016.

28. Twisk JWR, Rijnhart JJM, Hoekstra T, Schuster NA, Wee M ter, Heymans MW, et al. Intention-to-treat analysis when only a baseline value is available. Contemp Clin Trials Commun. 2020 Dec;20:1–7.

29. McCarney R, Warner J, Iliffe S, van Haselen R, Griffin M, Fisher P. The Hawthorne Effect: a randomised, controlled trial. BMC Med Res Methodol. 2007 Jul 3;7:30.

30. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med Publ Soc Behav Med. 2013 Aug;46(1):81–95.

31. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International Exercise Recommendations in Older Adults (ICFSR): Expert Consensus Guidelines. J Nutr Health Aging. 2021 Jul 1;25(7):824–53.

32. Bell ML, Kenward MG, Fairclough DL, Horton NJ. Differential dropout and bias in randomised controlled trials: when it matters and when it may not. BMJ. 2013 Jan 21;346(jan21 1):e8668–e8668.

33. Murimi MW, Kanyi M, Mupfudze T, Amin MR, Mbogori T, Aldubayan K. Factors Influencing Efficacy of Nutrition Education Interventions: A Systematic Review. J Nutr Educ Behav. 2017 Feb;49(2):142-165.e1.

34. Willett W. Nutritional Epidemiology - - [Internet]. Oxford University Press. Oxford; 2012 [cited 2025 Apr 29]. Available from: https://global.oup.com/academic/product/nutritional-epidemiology-9780199754038?cc=fr&lang=en&

35. Ma Y, Olendzki BC, Pagoto SL, Hurley TG, Magner RP, Ockene IS, et al. Number of 24-Hour Diet Recalls Needed to Estimate Energy Intake. Ann Epidemiol. 2009 Aug 1;19(8):553–9.

36. Brahms CM, Hortobágyi T, Kressig RW, Granacher U. The Interaction between Mobility Status and Exercise Specificity in Older Adults. Exerc Sport Sci Rev. 2021 Jan;49(1):15–22.

37. Carroll C,Patterson M, Wood S et al. A conceptual framework for implementation fidelity. Implementation Sci 2, 40 (2007).

38. Hasson H, Blomberg S and Duner A. Fidelity and moderating factors in complex interventions: a case study of a continuum of care program for frail elderly people in health and social care. Implementation Sci 7, 23 (2012).