Web-based physical activity interventions are feasible and beneficial solutions to prevent physical and mental health declines in community-dwelling older adults during isolation periods.

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ABSTRACT:

Background: Periods of prolonged lockdown increase the risk of physical inactivity, which can contribute to physical decline among older adults. Online technology could be an innovative solution to promote physical activity habits in this context. The goal of this study was to examine and compare the acceptability, feasibility and potential benefits of two modalities of web-based PA interventions in older adults during the COVID-19 lockdown. **Methods:** Eighty-three non-physically active community-dwelling older adults (age 60 and over) were randomized to a 12-week web-based PA intervention delivered either in a Live Group (LG; n=38) or a Recorded Group (RG; n=45). Acceptability, feasibility as well as functional capacities, physical performance, quality of life and PA level were assessed pre- and post-intervention. **Results:** There were fewer dropouts in the LG than RG (LG:16% *vs*. RG:46%). However, adherence rate (LG:89%; RG:81%), level of satisfaction (LG:77% *vs*. RG:64%) and enjoyment (LG:68% *vs*. RG:62%) were similar across groups, even if the participants found the intervention slightly difficult (LG:58% *vs*. RG:63%). Both groups significantly improved on functional capacities, physical performance and quality of life. Only the LG showed significant improvements in perceived health and PA level. The LG showed greater improvements in physical performance and quality of life than the RG. **Conclusion:** Web-based PA interventions are feasible, acceptable and beneficial for improving functional capacities and physical performance during periods of lockdown. However, the interactive web and live modalities appear to be more effective for promoting some of these outcomes than recorded and individual modalities.

Keywords: exercise; web-based intervention; muscle function; aging; COVID-19 lockdown.

INTRODUCTION:

Physical inactivity, defined as a lack or absence of regular physical activity (PA) [1] affects more than 50% of older adults and is recognized as the fourth most important risk factor for early mortality [2]. The lockdowns or social isolation that occurred during the COVID-19 pandemic limited opportunities to practice PA [3]. Indeed, during the first wave of the COVID-19 pandemic, sedentary time, defined as time spent doing activities that do not increase energy expenditure at rest (i.e., sitting, lying down), increased from five to eight hours per day [4]. In addition, it has been observed that 40% of previously inactive people became even more inactive during the COVID-19 pandemic. These individuals reported poorer mental health than individuals who engaged in more PA [5, 6]. In addition to negative effects on mental health and quality of life, lack of PA and sedentary behaviours are also known to be detrimental to older adults' physical health and functional independence [7], especially during the COVID-19 pandemic [8]. In this context, online technologies represent an approach to deliver PA services while respecting social distancing guidelines. In addition, more than 60% of community-dwelling older adults in Canada have digital devices (i.e., tablet, computer or smartphone) and 70% connect to the internet daily [9].

It has been shown that a 10-week web-based recorded PA intervention leads to high adherence in obese older women, and could be used as an alternative to supervised exercise for weight loss [10]. In addition, another study reported that a nine-month web-based recorded PA intervention had a high and similar acceptance rate in older adults compared to an in-person PA intervention [11]. It has been observed that a web-based recorded PA intervention (3x/week from 12-16 weeks) improved metabolic health (i.e., weight, fat mass, waist circumference, insulin and glycated hemoglobin) in obese older adults [12] and the levels of mobility, functional balance and muscle strength [13] in inactive older adults. However, a systematic review shows that web-based PA interventions providing live feedback, such as live webconferences (Zoom©; Skype©; etc.), are an interesting alternative that lead to the same adherence than supervised in-person PA interventions in older adults [14]. Studies using web-based live PA interventions (i.e. Zoom© live group training; duration of 8- 10 weeks) have shown that this type of intervention could be feasible in older adults living with cognitive decline or chronic pain [15]. Studies also demonstrated that the intervention was safe (no adverse events) and led to low drop-out rates and high adherence and satisfaction in older adults [16]. In addition, it has been shown that the presence of an instructor, who provides live feedback during in-person group PA, potentiates the effectiveness of the intervention on health parameters by increasing participants' motivation, adherence and engagement [17]. Indeed, a study investigating the effect of an eight-week web-based live PA intervention (live web real-time communication) demonstrated positive effects on fall-related risk factors [18] in older adults. In addition, another study conducted in older adults observed that a 12-week live PA intervention (Skype©) led to positive effects on sarcopenia-related factors (i.e., total-body skeletal mass, appendicular lean soft tissue, lower limb muscle mass and chair sit-and-reach score; [19]). Finally, another study observed that implementing an 8-weeks web-based live PA intervention (Facebook© live group exercise) improved functional fitness compared to a control group in older adults [20].

While these recent studies showed the interesting potential of the implementation of web-based PA interventions (recorded or live) in older adults, it is important to note their limitations, especially in relation to the COVID-19 pandemic. First, despite the likely difference in motivation induced by the presence of an instructor during live (interactive web-based intervention) compared to recorded online training sessions (non-interactive web-based intervention), none of the aforementioned studies compared the effects of these two modalities (recorded *vs.* live training) nor their feasibility and acceptability in older adults in the same study. Second, none of these studies performed objective fully remote evaluations of physical function before and after the intervention. Finally, and more importantly, none of the studies reported a clear and replicable methodology for tailoring the content of the training sessions to a remote setting (i.e., personalization within the live session based on the instructor's guidance), thus compromising the validity, replicability and transferability of the previous results. This aspect is of high importance since it has been shown that a personalized and tailored approach, based of the participant's needs and individual characteristics, is necessary to implement remote interventions in older adults [21].

In this context, the primary objective of this study was to confirm the feasibility and acceptability of two web-based PA interventions (i.e., recorded video training on website platform or live-interactive training on Zoom© platform) during the first COVID-19 lockdown. The secondary objective was to assess and compare the effects of two fully remote and tailored web-based PA interventions on physical and mental health in inactive community-dwelling older adults. We hypothesized that both interventions would be feasible and acceptable but that the live interactive modality would lead to a greater adherence than the recorded. Finally, we hypothesized that both interventions would lead to health improvements, which would be higher in the live interactive modality.

METHODS:

Intervention overview

The study design, procedures used to assess participants and the measures are presented in Figure 1.

INSERT FIG 1 HERE

Design & randomization:

This study was a 12-week community-based feasibility randomized interventional trial conducted during the first wave of the COVID-19 pandemic in Montreal, from April to August 2020 (lockdown/homebound period). This study has been approved by the ethics committee of the Centre de recherche de l'Institut universitaire de gériatrie de Montréal (CRIUGM; CERVN 20-21-05) and participants signed a consent form.

Participants were randomized to either a live and interactive exercise training group [22] or a recorded exercise training group (RG). Randomization was performed using a cluster method given the uncertainty of the lockdown duration at the beginning of the COVID-19 pandemic.

Participants:

Participants were recruited, between March and April 2020, from the CRIUGM's volunteer database, which contains a large number of community-dwelling older adults, who voluntarily registered to be invited to participate in research projects related to aging. To be included in the study, participants needed to: (a) have an email address, an internet connection, and a digital device with a webcam at home, (b) be aged 60 and over, (c) live independently in the community, (d) be inactive (less than 7.500 steps per day and less than 150 minutes of exercise per week) based on the Rapid Assessment of Physical Activity questionnaire (RAPA, [23]), (e) have no counter-indication to practice PA, (f) not be frail (based on the Study of Osteoporotic Fractures (SOF) questionnaire [24]) or use walking aids, and (g) not be diagnosed with neurological, cardiovascular, lung (auto-reported) or have cognitive diseases/disorders (based on the Telephonic-Mini Mental State Examination (T-MMSE); [25]).

Procedures:

To recruit participants, an email was sent to potentially eligible older adults from the CRIUGM database. For those who replied and expressed interest in the study, a phone screening was performed in order to: 1) confirm their eligibility, 2) obtain their verbal consent, and 3) verify their ability to use Zoom©. After the screening phone call, the consent form and security training procedures were sent by email. Participants were asked to either return the consent form with their signature, or send a pre-formatted email confirming their consent to volunteer in the study. Thereafter, participants received the email including the Zoom© schedule for the training sessions and the link to perform the assessment. Participants who had never used Zoom© were sent a link by email and taught how to use

Zoom© by phone. This step was needed by 20% of our sample. Both groups (LG & RG) underwent Zoom© evaluations conducted by an assessor and including physical tests as well as questionnaires before and after the intervention. In addition, at the end of each training session, participants completed Limesurvey© questionnaires on various outcomes.

A total of 83 older adults were randomized to the LG (LG; n=38) or RG (RG; n=45), as shown in Figure 2. This sample size was determined based on the resources available to conduct the project between April and August 2020. As no other comparable study in older adults was available at the time, we were not able to perform an a priori power calculation.

INSERT FIG 2 HERE

Intervention:

During the COVID-19 lockdown, face-to-face interventions could not be performed. Thus, to ensure the safety of our web-based PA interventions (live *vs.* recorded), we created four levels (L1 = non-fit to L3 = fit) of difficulty to tailor the exercise intervention for each participant. Allocation to exercise group levels was performed using a mobility decisional tree as done previously [26]. Briefly, the mobility decisional tree included six tests (30-second sit-to-stand, bipodal balance, semi-tandem balance, tandem-balance, unipodal balance and level of PA) to obtain a score from 0 to 14 (Level 1: score < 6; Level 2: $6 \leq$ score ≥ 10; Level 3: score > 11. This mobility decisional tree was performed during the evaluation session at baseline. Participants of the same level were grouped together and allocated to the appropriate exercise intervention. The 12-week exercise intervention included three 55-minute sessions per week. All sessions were structured into three blocks of exercises that aimed to improve muscle function, flexibility and cardiovascular capacity, respectively. During each week of the intervention, one session per week was predominantly focused on one of the three blocks of exercises previously mentioned. Full details of the weekly structure can be found in Supplemental Material 1. In addition, every four weeks, the difficulty and intensity of the sessions were adjusted to maximize the health effects, adherence and enjoyment. Moreover, the position (sitting or standing), amplitude, number of repetitions and intensity of the exercises were modified and adapted to the level of the participants, which allowed a safe and appropriate progression. Finally, both groups followed the same training program, but the LG sessions included a certified exercise instructor (kinesiologist; using Zoom©) following a specific schedule (Monday, Wednesday and Friday mornings) whereas the RG attended individual video sessions, which were pre-recorded by a certified exercise instructor (kinesiologist). To ensure safety in the LG, the number of participants in each level was limited to 10 (L1) to 14 (L3) individuals.

During our study, three specific LGs (Group 1 (L3): n=12 [W: n =10/ M: n= 2); Group 2 (L3): n=14; L3 (W: n =12/ M: n= 2); Group 3 (L2) n=12 [W: n= 8; M: n= 4]) were trained. Moreover, all the training sessions were supervised by the same two certified exercise instructors (kinesiologists) during the 12-week intervention. The first certified kinesiologist was in charge of training the LG participants each Monday, while the second trained them each Wednesday and Friday throughout the intervention.

In contrast, the RG followed the training program individually using a secured website (www.trainingrecommend.com; access code required). Participants in the RG were free to complete the recorded sessions at any time, but they did not receive supervision or feedback while completing the exercises. To ensure safety in the RG, participants (L1 to L3; n= 45; L3: n=34 / L2: n=11) had access to nine specific and adapted videos according to their exercise group level (similar exercise sessions to the LG). During the first four weeks of the program (weeks 1 to 4), participants had access to the first three videos. Thereafter, they followed a second block of three videos for four weeks (weeks 5 to 8) and a third block of three videos for the four subsequent weeks (weeks 9 to 12) in order to increase the difficulty/intensity level (similarly to LG participants). Regarding safety, before each training video or PA session, a short video was presented to remind participants of the safety protocol to follow before their training (i.e., phone close by, remove objects or carpets from path, etc.). Like LG participants, they were required to fill out a Limesurvey© questionnaire at the end of each session on various outcomes and report any adverse events. A phone number was provided in the same questionnaire to contact the team if needed.

Measures:

- **Intervention feasibility and acceptability:**

Feasibility and acceptability were assessed throughout the intervention.

In this study, feasibility was assessed using adherence to the intervention, i.e., the proportion of sessions completed out of the 36 prescribed among the participants who did not drop-out. In the LG, adherence (proportion of completed weekly sessions out of the total sessions prescribed among the participants who did not drop-out, i.e., completed pre- and post- assessments) was measured by the certified exercise instructor (kinesiologist) according to the presence or absence of the participants during the live training. In the RG, adherence was measured using the number of questionnaires completed by the participants at the end of their training sessions. For the intervention to be considered feasible, participants were expected to complete 80% of the web-based exercise sessions (29/36 sessions) as commonly recommended [27].

Acceptability was assessed using five variables rated after each exercise training session using Limesurvey©: 1) perceived exertion, 2) difficulty level of the exercises, 3) enjoyment during the training session, 4) pride related to performing the training sessions, and 5) overall satisfaction with the training session. More specifically, perceived exertion was estimated using the OMNI perceived exertion scale [28]. The difficulty of the exercises was assessed using a 4-Likert scale from "low", "rather low" to "high" or "very high". Enjoyment during the training session was rated using a 5-Likert scale from "not at all", "a little", "neutral" to "well" or "a lot". Pride was assessed using a 4-

Likert scale from “no pride at all”, “a little pride”, to “some pride” or “a lot of pride”. Finally, overall satisfaction level with the training session was assessed using a 4-Likert scale: “very unsatisfied”, “not very satisfied”, “satisfied” or “very satisfied”. Finally, follow-up phone calls were done every three weeks to ask the participants to confirm the adherence and safety of the intervention.

Objective physical health measures:

We briefly describe the tests assessing functional capacities and physical performance. Full descriptions can be found in Supplementary Materials 2 and 3.

A) Functional capacities:

- *Short Physical Performance Battery (SPPB):* The SPPB score (x/12) was based on three tests (bipodal balance, 4-m walking speed (sec) and the five-repetition sit-to-stand test [26]) ranked from 0 to 4. This scale is recognized to assess lower extremity function and mobility in older adults [29].

- *Unipodal Balance*: Participants were asked to stand on one leg for 60 seconds (maximum) with their arms along the sides of their body. Unipodal balance capacity is a predictor of fall risk [30].

B) Physical performance:

- ***Body mass index (BMI)***: BMI was evaluated using self-reported body mass (kg) and height (m) following this equation: [body mass (kg)/height (m^2)].

- *Muscle power*: First, we evaluated the time requested by participants to perform 10 sit-to-stand repetitions. Based on this time, a power index was also calculated using the Takaï equation [31]*:* $P = \frac{(L-A) \times BM \times g \times 10}{T}$.

- ***Muscle endurance***: We performed the validated 30-second sit-to-stand test. This test is recognized as a valid indicator of lower body muscular endurance in community-dwelling older adults [32]. It consisted in measuring the maximum number sit-to-stand repetitions in 30 seconds.

Subjective mental and physical health measures:

During the Zoom© sessions dedicated to evaluation (pre- and post-intervention), the assessor helped the participants complete the physical and mental health questionnaires as well as lifestyle habits questionnaire (potential covariates). To limit bias, the assessors asked the same questions in the same order for the pre- and post-evaluations. Full descriptions can be found in Supplemental Material 4.

- ***Mental health***. Anxiety and depressive symptoms were evaluated with the Kessler Psychological Distress Scale (K10; [33]) and loneliness using the UCLA-Loneliness Scale-3 (UCLA-3; [34]), respectively. ***Mood*** was evaluated as follows: "How strongly have you felt the following emotions during the past two weeks?" Participants were asked to rank the following key mood states: "joy", "calm", "enthusiasm", "boredom", "fear and anxiety", "frustration and anger" and "guilt" [35]. The participants ranked each mood state by choosing either: "not at all", "a little", "moderately", to "a lot" and "extremely". Answers were scored from 1 to 5 for positive mood items and from 5 to 1 for negative mood items. Responses for all items were added to yield a global score ranging from 1 to 30, with a higher score indicating a better mood [35].

- ***Quality of life*** was measured using the EQ-5D questionnaire [36].

-***Lifestyle habits: PA level*** was estimated using the validated Rapid Assessment of Physical Activity (RAPA) questionnaire [23]. ***Motivation toward PA*** was also estimated using the validated motivation scale towards health-oriented physical activity [EMAPS; [37]]. ***Emotional eating habits*** were assessed using the validated Emotional Eating Scale [EES; [38]]. ***Insomnia symptoms*** were evaluated using the validated Insomnia Severity Index [ISI; [39]].

Ability to use technology:

Participants' ability to use technology was measured using three questions regarding: 1) the number of years they have been using technological tools, 2) whether they considered themselves "tech savvy", and 3) the types of technology they were currently using (tablet, desktop computer/laptop or smart phone).

Reproducibility and safety of measures:

To limit measurement errors, the same trained assessor conducted the pre- and post-evaluations and used specific technical webcam instructions. During the 4-m walking test, the webcam captured the starting and finishing point, which foot was used, and whether the webcam was placed in front or behind the participant. Regarding participant safety during the 4-m walking test, the kinesiologist ensured to ask the participant to remove any objects that could obstruct the exercises and also verified that participants could correctly and safely stop after the stop line. To perform the balance test, a webcam was placed in front of or beside the participant, which allowed the assessor to observe the participant's foot and hand during the test. Regarding safety, participants were asked to be close to a wall or chair for them to hold in the event of loss of balance. Finally, for the sit-to-stand tests, a webcam was placed beside the participant to fully capture them in the sitting and standing position. For safety, a chair was placed against a wall to ensure that it could not move backward during the test.

In addition, for each test, the assessor assisted the participants in measuring the distance (4 meters) or safely positioning the chair during the balance or stair tests. No help from any family member was provided for the webcam set-up. None of our participants had to reposition their webcam during the assessments.

Finally, a recent study from our laboratory comparing remote assessment sessions with in-person assessments (performed on participants from our study) showed that the 4-m walking test, 5-rep sit-to-stand test, 30-second chair test and 10-rep of sit-to-stand test have high relative reliability, acceptable absolute reliability and low variability. These results suggest that online and remote assessments are valid methods of performing these tests, which can be compared to other tests done in person and laboratory settings [40].

Statistical analyses:

Data distributions were tested using the Shapiro-Wilk test. Baseline characteristics were summarized using descriptive statistics. Continuous variables were expressed by mean ± standard deviation. Categorical variables were expressed in percentages. The Chi-squared test or Fisher test were used to compare frequency of observations between groups. Due to our design (aims and sample size), we used a per protocol analysis instead of an intent-to-treat analysis. Thus, only participants who completed the 12-week intervention and the pre- and post-evaluations were included in the analysis (drop-out participants non included).

An independent parametric t-test was used to identify between-group baseline differences. A 2×2 repeated measures ANOVA was used to estimate the time and time × group effects. A paired t-test was used to assess the effect of the intervention within each group. The effect size partial eta squared (ηp^2) was used to estimate the clinical relevance of the effects. Partial eta squared between $0.06< \eta p^2 >0.01$, $0.1< \eta p^2 >0.06$ or $\eta p^2 >0.1$ were considered as low, medium or large effects, respectively [41]. The percentage change from baseline ((pre-post/pre)×100) was estimated to evaluate and compare the clinical effect of our interventions. All statistical analyses were performed using SPSS 27.0 (Chicago, IL, USA). The significance was set at p≤0.05 (two tailed) for all analyses.

RESULTS:

Baseline characteristics:

Baseline physical characteristics, sociodemographic characteristics and technological ability of the participants were similar for both groups (p≥ 0.05) as shown in Table 1, except for fast walking speed (LG:1.21±0.30 *vs.* RG:1.47±0.40 m/sec, p=0.029), the SPPB total score (LG:11.0±1.4 *vs.* RG:10.1±1.6 /12, p=0.030), quality of life (LG:5.3±1.9 *vs.* RG:6.2±1.7/25 p=0.017) and motivation to practice PA (LG:68.1±10.0 *vs.* RG:60.6±9.3 /100; p=0.008).

INSERT TABLE 1 HERE

Intervention feasibility & acceptability:

Among the 83 randomized participants, the dropout rate was 16% in the LG [Pre: n=38 (30women/8men); Post: n=32 (26women/6men)] and 46% in the RG [Pre: n=45 (38women/7men); Post: n=24 (20 women/4 men)]. The reasons for dropping out were similar between groups (see Table 2) and were mainly related to a lack of interest (LG:11% *vs.* RG:33%) or health problems (LG:5% *vs.* RG:13%).

Among participants who completed the study, the average of training sessions attended over 12 weeks was 30/36 sessions (average adherence: 85%). The adherence rate was slightly better in the LG than RG (LG:89% (min-max:17-36) *vs.* RG:81% (min-max:16-36)). Participants' satisfaction, enjoyment, perceived exercise difficulty and perceived exertion in each session were similar for both groups (p≥ 0.05; Table 2). Finally, no falls were observed nor reported during evaluations or training sessions.

INSERT TABLE 2 HERE

Effects of the intervention on objective physical health

Table 3 presents pre- and post-intervention functional capacities and physical performance in the participants.

First, a time effect was observed for muscle power ($p=0.01$, $\eta p^2=0.12$), normal ($p<0.001$, $\eta p^2=0.34$) and fast ($p=0.012$, $\eta p^2=0.12$) walking speed and sit-to-stand tests [5 repetitions ($p<0.001$, $\eta p^2=0.59$), 10 repetitions ($p<0.001$, $\eta p^2=0.57$) and 30-seconds ($p<0.001$, $\eta p^2=0.53$)]. More specifically, both groups significantly improved their normal walking speed (change: LG: +0.15m/s^{-1}, p=0.049; RG:+0.18m/s^{-1}, p<0.001) and time to perform the 5-repetition (change: LG: -3,6s, p<0.001; RG: -2,2s, p<0.001) and 10-repetition (change: LG: -7,6s, p<0.001; RG: -4,6s, p<0.001) sit-to-stand tests, as well as, the number of sit-to-stand repetitions performed in 30 seconds (change: LG: +5-repetitions, p<0.001; RG: +3.3-repetitions, p<0.001).

Finally, only the LG significantly improved their fast walking speed (p=0.022) and total SPPB score (p=0.010) after the intervention.

Second, the time × group interaction reached significance for the 5-repetition ($p=0.047$, $\eta p^2=0.07$) and 10-repetition ($p=0.02$, $\eta p^2=0.10$) sit-to-stand tests.

Finally, based on percentage change from baseline following the 12-week intervention, we observed a greater improvement on muscle endurance (minimal change expected:>7%; 30s Sit-to-Stand: LG: +37.6±34.1% *vs.* RG: +8.6±60.0%, p<0.001, d=0.925) and time to complete the 5-repetition sit-to-stand (minimal change expected: -20%; LG: -45.0±39.8% *vs.* RG: -28.0±18.7%, p=0.023, d=0.552) in the LG than the RG. Both groups significantly improved their normal walking speed (minimal change expected:>0.1 m.s^{-}1) following the intervention (LG: +9.8±50.9%, p=0.012, d=-0.701; RG: +18.9±38.8%, p<0.001, d=-0.711). Finally, only the LG improved their fast-walking speed (LG: +17.9±36.8%, p=0.042, d=-0.405) and total SPPB score (minimal change expected: +0.5point; LG: pre: 11.0±1.4 *vs.* post: 11.6±0.6, p=0.001, d=0.514).

INSERT TABLE 3 HERE

Effect of the intervention on subjective mental and physical health

Table 4 presents participant pre- and post-intervention subjective mental and physical health

A time effect was observed for motivation to practice PA (p=0.014, ηp^2=0.11), mood (p=0.002, ηp^2=0.15) and perceived health (p=0.008, ηp^2=0.13). A significant time × group effect was found for the PA level (p=0.033, ηp^2=0.06).

Finally, based on the percentage change from baseline following the 12-week intervention, we observed improvements in the RG only for the motivation to practice PA (RG= +16%, p=0.001, d=0.552) and in the LG only for perceived health (LG= +1.4%, p=0.016, d=0.512).

INSERT TABLE 4 HERE

DISCUSSION:

The purpose of this study was to: 1) confirm the feasibility and acceptability of two modalities of remote PA interventions (video website: recorded or Zoom© platform: live and interactive) during the first wave of the COVID-19 pandemic, and 2) evaluate and compare their effects on health parameters using fully remote assessments.

First, our results show a high level of acceptability and adherence for older adults who completed the intervention, independently of the remote PA modality (interactive or recorded). More than half of the participants from both groups reported that the PA sessions were “easy” to perform (LG:69%; RG:82%). These results suggest that the PA program was adapted to the participants' capacities even if the intensity and level of difficulty were increased every three weeks during the 12-week program. Furthermore, both groups reported a similar level of satisfaction (LG:77%; RG:64%) throughout the remote PA intervention. These results are promising because the level of satisfaction is one of the main factors that enables older adults to participate and stay motivated in the practice of PA [42]. These results are in line with other studies using web-technologies in older adults ([20]; [15]; [16]). We also observed the same level of enjoyment in both groups (LG: 68%; RG: 62%). This result is important since this aspect is considered as one of the key reasons for older adults to regularly practice PA [43].

Overall, among the participants who completed the exercise intervention (sessions >80%) and pre- and post-assessments, the adherence rate could be considered high in both remote exercise modalities, with a slightly better adherence rate in the LG compared to the RG (LG: 89%; RG: 81%). The minimum and maximum number of attended sessions was similar in both groups (LG [min-max]:16-36 sessions; RG [min-max]: 17-36 sessions). The high adherence rate could be explained by the improvement in quality of life as well as affinity for the technologies themselves [44]. It can also be explained by the customization of the exercises to the participants needs, which is important for older adults and leads to enjoyment during practice [43]. Nevertheless, it is important to note that the dropout rate (participants who did not complete the study) was significantly different between the two remote exercise modalities (LG:16% *vs.* RG: 46%). Some studies have reported that the drop-out rate in remote exercise interventions was related to older peoples' motivation to engage in PA [44].

Among those who remained in the intervention, the motivation to practice PA significantly improved only in the RG (RG [delta change]: +16%; p<0.001). These results can be explained by the fact that these two remote exercise modalities do not involve the same type of motivation. For example, the LG participants received live feedback from a kinesiologist and sessions were completed in groups. Social interactions and personalized feedback on performance are both known to influence PA adherence [45]. In contrast, the RG participants practiced their exercise sessions on their own and increased the training difficulty at their own pace every four weeks. The self-directed and individual nature of this intervention may help strengthen feelings of self-efficacy, a powerful predictor of PA adherence [46]. In addition, giving older adults control over the pace of the intervention may also contribute to motivation [46].

Moreover, our results show that both of the remote exercise interventions significantly and clinically improved walking speed (clinical threshold: +0.10 m/s^{-1}; Delta change: LG: +0.15m/s^{-1}; RG: +0.17m/s^{-1}). More specifically, both groups went from at-risk to safe/good walking speed (LG= pre:0.86 to post:1.01 m/s^{-1}; RG= pre:0.95 to post:1.13 m/s^{-1}), which is associated with reduced health risks and mortality in older adults [47].

In addition, we also observed beneficial effects on muscle endurance in both groups. As muscle endurance is recognized to predict risk of falls in older adults [48], both of our remote interventions could help reduce these falls, which occur in 50% of older adults aged over 80.

Physical health improvements were also observed on functional capacities. More specifically, a meaningful clinical change was observed on the total SPPB score (range: from 0.4 to 1.5 points) in the LG only (SPPB Delta change: LG= +0.6point; RG= -0.1point, [29]). This meaningful clinical change on the SPPB is important as it has been shown to reduce the risk of adverse health outcomes [49]. Other studies also report that older adults taking part in exercise programs improved health-related fitness, which reduced the use of healthcare services [50].

Moreover, quality of life (perceived health) significantly improved in the LG only (EQ-5D [delta change]: LG= +4%; p=0.016). It is well-known that quality of life can predict the risk of all-cause mortality and hospitalization in older adults [51]. In a pandemic period, reducing hospitalizations can be important to reduce pressure on the healthcare system. In addition, mood tended to deteriorate significantly more in the RG than in the LG (mood [delta change]: RG= +33% *vs.* LG= -6%; time×group effect: p=0.06). This result suggests that the live interactive modality may be recommended as a first choice of remote exercise intervention since it could help prevent depression and ultimately the risk of mortality [52]. Furthermore, even if the study was conducted remotely during the first lockdown of the COVID-19 pandemic, the feeling of loneliness remained stable in both groups. This result could be considered a positive impact as it has been argued that social isolation during the COVID-19 lockdown increased loneliness [22], which raises the rate of depression, suicide or mental-health mortality [53]. This result could be explained by the modality of our remote interventions (live, interactive and group) and the follow-up phone calls done every three weeks for each participant [54]. Our results are important as quality of life and depression are known to deteriorate in older adults during social isolation and/or pandemics like COVID-19 [55].

Overall, it appears that during a lockdown period, an interactive and live remote exercise modality leads to greater improvements in physical and mental health than a remote recorded exercise modality and helps increase quality of life. Nevertheless, the remote recorded exercise modality requires fewer human resources and also leads to physical and mental health improvements.

In addition, the improvements following these two remote web-based PA interventions were similar to those obtained in other studies carried out in laboratory settings [14]. This point is very important as these two remote interventions can be performed anywhere (no specific infrastructure needed), anytime (even during extreme hot or cold weather) and involve all older adults (even those living in urban or rural areas or who have limited transportation). In addition, these two remote exercise modalities are less expensive than on-site physical training. Finally, from a public health perspective, the interactive exercise modality may be preferred as the drop-out rate was lower than the recorded modality. This lower dropout rate suggests that this type of intervention (fully interactive and live using Zoom©) could help older adults integrate PA habits into their lifestyle. This aspect is significant as more than 50% of older adults are inactive and sedentary, even though it is recognized that exercise helps preserve health.

Nonetheless, our study presents some limitations. The relatively small sample size (post-intervention: n=56) and the exploratory design may reduce our capacity to detect small differences between groups. Due to our design and per-protocol analysis, the adherence rate reported includes only participants who completed the two assessment sessions (pre- and post-intervention). Thus, the adherence observed in this study limits our public health recommendations, even if the adherence rate was slightly higher in the live interactive modality. Moreover, study participants were fairly educated, healthy and were already using some technologies on a daily basis. Thus, our findings cannot be generalized to the population as 40% of older adults did not have access or the skills to use technology before the COVID-19 pandemic. However, a recent study has shown that remote exercise programs are feasible and acceptable to prevent loss of mobility in pre-disabled older adults during the COVID-19 pandemic, thus supporting the importance of our study [56]. It is important to highlight that the health professionals who performed the assessments (assessors) were not the same as those (certified exercise instructors) who trained the participants during the intervention. It is crucial to note that our experimental design included a follow-up phone call every three weeks, which did not allow us to keep the assessors blind of the group allocation. Nevertheless, even if the assessors and instructors were not blinded, they were unaware of the primary aim of the study. Furthermore, even if there were significant differences in our data for fast walking speed, total SPPB score, quality of life and motivation to practice PA at baseline, these differences were not clinically significant as both groups had the same functional capacity levels (SPPB score >10 and fast-walking speed > 1.2 $m.s^{-1}$), quality of life (Score > 60/100; good quality of life) and motivation to practice PA (Score > 5/7 ; good motivation). Finally, the unexpected absence of between-group differences regarding loneliness and isolation could be due to the follow-up phone call in <u>both</u> groups (every three weeks). Therefore, additional double-blind randomized control trials are needed to generalize our results.

This study also has some strengths, such as the same number and type of exercises in both remote interventions, the use of standardized and implementable exercise interventions and the use of validated measures, which allowed the generalization and adequate comparison of the exercise interventions.

In conclusion, our study provides evidence that recorded or live-interactive web-based PA interventions are innovative, feasible, acceptable, and safe modalities for community-dwelling older adults during isolated periods such as the COVID-19 pandemic lockdown. However, it is important to keep in mind that adherence was slightly higher and the drop-out rate was lower in the live interactive group. These results suggest that remote live interactive group interventions should be favoured over the recorded modality. However, recorded sessions may be appropriate for participants who cannot temporarily follow online and live group sessions (e.g., constrained hours, loss of internet connection or insufficient internet bandwidth). In addition, exercise physiologists (trainers and researchers) using the recorded exercise modality must keep in mind that a closer follow-up should be carried out to reduce, or at least try to attenuate the drop-out rate.

Overall, the use of web technology to deliver PA interventions is not only feasible and acceptable but also seems effective to mitigate the impact of lockdown periods by maintaining mental health, improving physical health (functional capacities and physical performance) and quality of life. Nevertheless, further studies are needed to determine the best dose of interactive/recorded sessions in order to implement the most efficient intervention at a larger scale in at-risk populations.

AUTHORS CONTRIBUTIONS:

MAL designed and directed the project and supervised all the steps of this article. JG recruited, performed the measurements, analysis the data and wrote the first draft of the manuscript. EP, FR, FB and LBA performed the measurements and revised the manuscript. BP, TTDV, JPG and MJS contributed to the design and methods of the research and revised the manuscript. All authors agreed to the final version of the manuscript.

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CONFLICT OF INTEREST: None

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TABLES:

Table 1: *Baseline physical and sociodemographic characteristics of the participants enrolled in the study.*

	LG (n = 38)	RG (n = 45)	p-values
Socio-demographic characteristics			
Age (years)	70.7 ± 5.2	69.6 ± 5.1	0.22
Sex (%; Women)	81%	83%	0.86
BMI (kg/m^2)	26.3 ± 3.9	27.5 ± 5.5	0.85
SPPB score (x/12)	11.0 ± 1.4	10.1 ± 1.6	0.030
Education level (%; university level)	79.3%	78.4%	0.67
Income (%; >55000$)	34.5%	43.2%	0.44
Marital status (%; single)	37.9%	59.5%	0.21
Health characteristics			
Frailty (SOF; x/6)	1.35 ± 0.60	1.25 ± 0.60	0.79
Insomnia (x/28)	4.8 ± 4.7	6.1 ± 4.1	0.14
Eating behaviour (x/44)	6.8 ± 4.3	7.8 ± 3.6	0.12
Quality of life (x/25)	5.3 ± 1.9	6.2 ± 1.7	0.017
PA motivation (x/100)	68.1 ± 10.0	60.6 ± 9.3	0.008
T-MMSE (x/30)	24.7 ± 1.7	24.5 ± 1.4	0.90
Number of medications (%; >5drugs)	6.9%	2.7%	0.41
Chronic diseases	55.2%	54.1%	0.92

(%; presence)			
Ability to use technology			
Using technologies (%; >1year)	79.3%	78.4%	0.82
Perceived feeling(s) of user (%; yes)	82.8%	83.8%	0.84
Type of technology used (%; touch pad)	62.1%	59.5%	0.44

Note. Data are presented as means (Mean ± SD; P ≤ 0.05 = significant differences between groups using chi-squared test or Fisher test). LG= Live Group; RG= Recorded Group; BMI: Body Mass Index. SPPB = Short Physical Performance Battery; SOF: Study of Osteoporotic Fractures; T-MMSE: Telephonic-Mini Mental State Examination; Using technologies = time since the participant used the same technology as the study. Perceived feeling(s) of user: Participant's feeling(s) regarding their ability to use of the technology. Type of technology used: participants were asked which technology they usually used and are comfortable with.

Table 2: *Acceptability of the remote exercise interventions.*

	LG (n=32)	RG (n=28)	p-values
Satisfaction **(%; satisfied or very satisfied)**	77%	64%	0.22
Enjoyment **(%; enjoyed /enjoyed a lot)**	32% /68%	38% /62%	0.31 /0.33
Perceived difficulty **(%; easy or quite easy)**	69%	82%	0.18
Perceived exertion **(%; a little easy /a little difficult)**	42% /42%	48% /37%	0.32 /0.36

Note. Data are presented as Mean ± SD; $P \leq 0.05$ =significant differences between groups using chi-squared test or Fisher test. LG= Live Group; RG= Recorded Group.

Table 3*: Effects of the intervention on objective health (functional capacities and physical performance)*

Variables	Pre	Post	2×2 ANOVA repeated measures		
			Time p-value (ηp²)	**Group p-value (ηp²)**	**Time×Group p-value (ηp²)**
Functional capacities					
Unipodal Balance (x/60s)			0.09 (0.04)	0.41 (0.006)	0.41 (0.01)
Live Group	44.1±19.6	46.3±20.1			
Recorded Group	44.6±20.0	50.9±15.8			
Normal walking speed (m/s)			**<0.001 (0.34)**	**0.024 (0.09)**	0.59 (0.006)
Live Group	0.86±0.20	1.01±0.20			
Recorded Group	0.95±0.20	1.13±0.20			
Fast walking speed (m/s)			**0.012 (0.12)**	**0.003 (0.16)**	0.75 (0.002)
Live Group	1.21±0.3	1.35±0.3			

	0$^{\times}$	0			
Recorded Group	1.47±0.40$^{\times}$	1.58±0.30			
5-repetition sit-to-stand (s)			**<0.001 (0.59)**	0.54 (0.007)	**0.047 (0.07)**
Live Group	11.7±3.8	8.1±2.3			
Recorded Group	10.6±2.4	8.4±2.5			
10-repetition sit-to-stand (s)			**<0.001 (0.59)**	0.54 (0.007)	**0.047 (0.07)**
Live Group	23.9±7.9	16.3±5.0			
Recorded Group	22.5±5.1	18.2±5.6			
SPPB SCORE (x/12)			0.16 (0.03)	**0.001 (0.14)**	0.12 (0.03)
Live Group	11.0±1.4$^{\times}$	11.6±0.6			
Recorded Group	10.1±1.6$^{\times}$	10.0±2.6			
Physical performance					
BMI (kg/m^2)			0.93 (0.17)	0.76 (0.11)	0.93 (0.17)
Live Group	26.3±3.9	26.2±4.0			
Recorded Group	27.5±5.5	27.3±3.3			
Muscle Power (W)			**0.01 (0.12)**	0.25 (0.02)	***0.073 (0.062)***
Live Group	35.9±11.0	57.3±42.8			

Recorded Group	38.1±13.6	42.1±23.9			
Muscle endurance (30 sec chair test, n)			**<0.001 (0.53)**	0.61 (0.005)	0.17 (0.03)
Live Group	15.3±4.5	20.3±4.8			
Recorded Group	15.5±3.3	18.9±5.3			

Note. Data are presented as Mean ± SD; P ≤ 0.05 =significant; $^{\times}$= Significant differences between groups using independent t-test. Time, group and time x group effects = 2×2 ANOVA repeated measures. Clinical significance = Effect size (Small effect: ηp^2=0.01; medium effect: ηp^2=0.06; large effect: ηp^2=0.14)). BW: Body Weight. BMI: Body Mass Index. SPPB: Short Physical Performance Battery. Muscle power was estimated through the Takaï equation using the 10-repetition sit-to-stand test [31]: $P = \frac{(L-A)\times BM\times g\times 10}{T}$.

Table 4: Effect of the intervention on subjective health

Variables	Pre	Post	2×2 ANOVA repeated measures		
			Time p-value (ηp²)	Group p-value (ηp²)	Time×Group p-value (ηp²)
PA motivation (x/100)			**0.014 (0.117)**	**0.044 (0.08)**	0.32 (0.02)
Live Group	68.1±10.0×	71.4±14.2			
Recorded Group	60.6±9.3×	68.1±13.4			
Psychological distress (x/50)			0.20 (0.034)	0.98 (0.001)	0.36 (0.017)
Live Group	16.9±5.8	14.9±5.8			
Recorded Group	16.1±6.3	15.7±5.4			
Loneliness (x/9)			0.89 (0.001)	0.13 **(0.074)**	0.89 (0.001)
Live Group	7.1±1.5	7.1±1.7			
Recorded Group	7.6±1.7	7.7±1.8			
Mood (x/35)			**0.002 (0.151)**	**0.019 (0.094)**	***0.066 (0.059)***
Live Group	17.3±2.5	16.3±2.5			
Recorded Group	16.8±2.3	12.6±7.4			

Quality of life (x/25)			***0.054 (0.064)***	**0.024 (0.086)**	0.66 (0.003)
Live Group	5.3±1.9$^{\times}$	6.1±2.3			
Recorded Group	6.2±1.7$^{\times}$	6.8±1.4			
Perceived health (x/100)			**0.008 (0.138)**	**0.072 (0.066)**	0.91 (0.002)
Live Group	87.2±8.7	91.2±6.1			
Recorded Group	82.8±13.0	87.1±9.5			
PA habits (RAPA: x/10)			0.62 (0.004)	0.75 (0.002)	**0.033 (0.068)**
Live Group	4.5±2.0	5.7±2.6			
Recorded Group	5.6±3.3	4.9±2.5			

Note. Data are presented as Mean±SD; P ≤ 0.05 =significant; $^{\times}$= Significant differences between groups using independent t-test. Time, group and time×group effects = 2×2 ANOVA repeated measures. Clinical significance = Effect size (Small effect: ηp^2=0.01; medium effect: ηp^2=0.06; large effect: ηp^2=0.14); PA = physical activity.

Figure 1

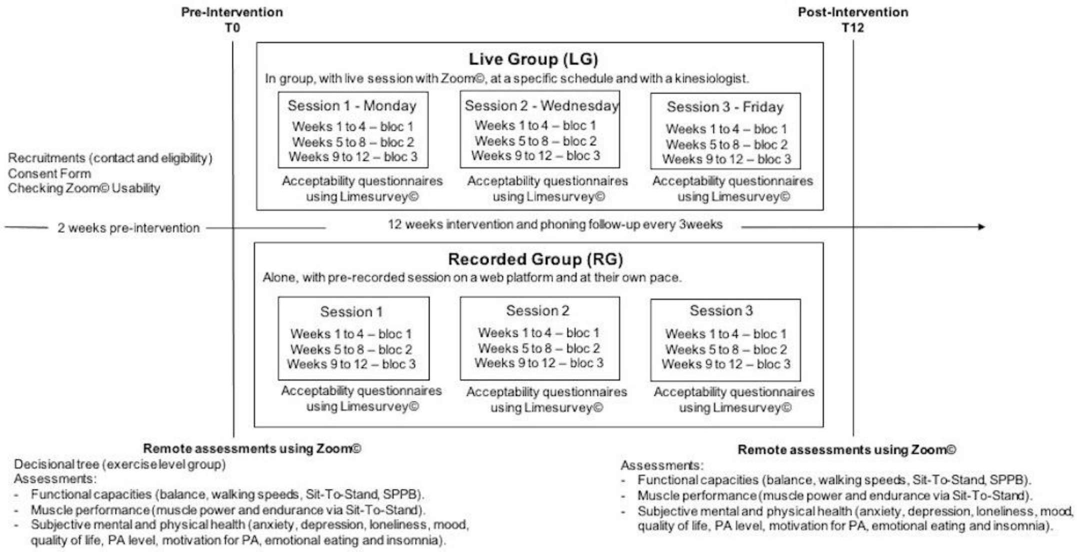
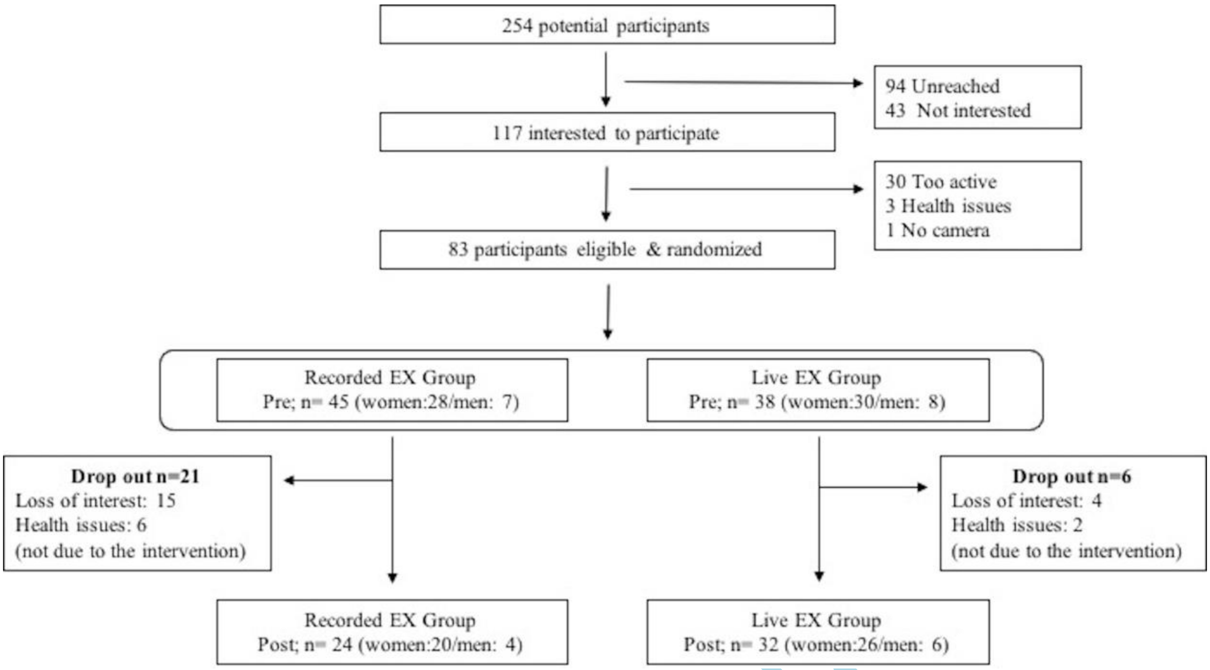

Pre-Intervention
T0
Post-Intervention
T12
Live Group (LG)
In group, with live session with Zoom©, at a specific schedule and with a kinesiologist.
Session 1 - Monday
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Session 2 - Wednesday
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Session 3 - Friday
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Acceptability questionnaires using Limesurvey©
Acceptability questionnaires using Limesurvey©
Acceptability questionnaires using Limesurvey©
Recruitments (contact and eligibility)
Consent Form
Checking Zoom© Usability
2 weeks pre-intervention
12 weeks intervention and phoning follow-up every 3weeks
Recorded Group (RG)
Alone, with pre-recorded session on a web platform and at their own pace.
Session 1
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Session 2
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Session 3
Weeks 1 to 4 – bloc 1
Weeks 5 to 8 – bloc 2
Weeks 9 to 12 – bloc 3
Acceptability questionnaires using Limesurvey©
Acceptability questionnaires using Limesurvey©
Acceptability questionnaires using Limesurvey©
Remote assessments using Zoom©
Decisional tree (exercise level group)
Assessments:
- Functional capacities (balance, walking speeds, Sit-To-Stand, SPPB).
- Muscle performance (muscle power and endurance via Sit-To-Stand).
- Subjective mental and physical health (anxiety, depression, loneliness, mood, quality of life, PA level, motivation for PA, emotional eating and insomnia).
Remote assessments using Zoom©
Assessments:
- Functional capacities (balance, walking speeds, Sit-To-Stand, SPPB).
- Muscle performance (muscle power and endurance via Sit-To-Stand).
- Subjective mental and physical health (anxiety, depression, loneliness, mood, quality of life, PA level, motivation for PA, emotional eating and insomnia).

Figure 2


254 potential participants
94 Unreached
43 Not interested
117 interested to participate
30 Too active
3 Health issues
1 No camera
83 participants eligible & randomized
Recorded EX Group
Pre; n= 45 (women:28/men: 7)
Live EX Group
Pre; n= 38 (women:30/men: 8)
Drop out n=21
Loss of interest: 15
Health issues: 6
(not due to the intervention)
Drop out n=6
Loss of interest: 4
Health issues: 2
(not due to the intervention)
Recorded EX Group
Post; n= 24 (women:20/men: 4)
Live EX Group
Post; n= 32 (women:26/men: 6)