Aging Clinical and Experimental Research
https://doi.org/10.1007/s40520-022-02329-z

ORIGINAL ARTICLE

Online physical exercise intervention in older adults during lockdown: Can we improve the recipe?

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Received: 22 September 2022 / Accepted: 16 December 2022

Abstract

Background Recorded and live online physical exercise (PE) interventions are known to provide health benefits. However, the effects of prioritizing the number of live or recorded sessions remain unclear.

Aims To explore which recorded-live sessions ratio leads to the best implementation and benefits in older adults.

Methods Forty-six community-dwelling adults (> 60y.o.) were randomized into two groups completing a 12-week online PE intervention. Each group had a different ratio of live-recorded online sessions as follows: Live-Recorded-Live sessions (LRL; $n = 22$) *vs.* Recorded-Live-Recorded sessions (RLR; $n = 24$).

Results Drop-out rates did not reach significance (LRL:14% *vs.* RLR: 29%, $p = 0.20$), and adherence was similar (> 85%) between groups. Both groups reported similar levels of satisfaction (> 70%), enjoyment (> 75%), and perceived exertion (> 60%). Both groups increased physical health and functional capacities, with greater improvements in muscle power (LRL: LRL: + 35 ± 16.1% *vs.* RLR: + 7 ± 13.9%; $p = 0.010$) and endurance (LRL: + 34.7 ± 15.4 *vs.* RLR: + 27.0 ± 26.5, $p < 0.001$) in the LRL group.

Discussion Both online PE intervention modalities were adapted to the participants' capacities and led to a high level of enjoyment and retention. The greater physical improvements observed in the LRL group are likely due to the higher presence of the instructor compared to the RLR group. Indeed, participants received likely more feedback to appropriately adjust postures and movements, increasing the quality of the exercises.

Conclusion When creating online PE interventions containing both recorded and live sessions, priority should be given to maximizing the number of live sessions and not the number of recorded sessions.

Keywords Exercise · Gerontechnology · Muscle function · Aging

Introduction

A physically active lifestyle is essential for healthy aging. However, several external factors, such as lack of transportation, weather (i.e., heat waves), or pandemic restrictions, represent key barriers to physical exercise (PE) in older adults, which may lead to sedentary behavior (> 50%). However, online PE interventions, also referred to as web-based PE interventions or programs [1–3], have been used by health professionals to deliver PE programs, which may help older adults overcome these barriers. We recently observed that during the COVID-19 pandemic, a live, online, fully remote

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12-week intervention (3x/week on Zoom© with a certified exercise instructor (kinesiologist)) led to lower participant drop-out rates and greater health improvements in physical performance, functional capacities, quality of life, perceived health and level, compared to a pre-recorded, online, self-guided, fully remote 12-week intervention in older adults [3]. These results were in line with previous studies [4–6].

However, the use of a live, online, fully remote intervention presents some limitations, which could affect its scalability. In a real-life setting, the live intervention requires the presence of a kinesiologist at each session and is therefore more expensive and logistically complex than a fully recorded intervention. Thus, to improve public health recommendations (and balance benefits and limitations), we investigated the use of a combined remote exercise modality that includes both live and recorded sessions to determine the ratio of each modality that would be most effective to improve health in older adults. Importantly, to the best of our knowledge, no previous study has investigated the feasibility, acceptability, and health benefits of implementing these combined modalities in older adults, especially during a COVID-19 lockdown where the population was confined to their homes.

The main objective of this study was to investigate the feasibility and acceptability of two web-based PE interventions combining live and pre-recorded online sessions and their efficacy on health parameters in inactive but non-frail community-dwelling older adults. The secondary objective was to compare the efficacy of these two interventions on physical health. Based on our previous study [3], we hypothesized that both combined modalities would be feasible, acceptable, and effective to improve physical health. Furthermore, we also hypothesized that the modality with the higher ratio of live training sessions would lead to a lower drop-out rate and greater improvements in physical functioning than the intervention with the higher ratio of recorded training sessions, which is in line with previous studies [3–6].

Methods

Design

This 12-week community-based feasibility randomized interventional trial was approved by the Centre de Recherche de *l'Institut Universitaire de Gériatrie de Montréal* (CRIUGM) ethics committee (CERVN 20–21-05), and all participants signed a consent form. Participants were screened remotely through a Zoom meeting and were included in the study if they: (a) were aged 60 years and over, (b) had an internet connection, a home digital device with a webcam and an e-mail address, (c) lived independently in the community, (d) were inactive (less than 7 500 steps per day and less than 150 min of exercise per week) based on the Rapid Assessment of Physical Activity questionnaire [7], (e) did not have a contraindication to practice PE, (f) did not use walking aids or were non-frail (based on the Study of Osteoporotic Fractures questionnaire)[8], and (g) were not diagnosed with neurological, cardiovascular, lung, or cognitive diseases/disorders (according to the Telephonic-Mini Mental State Examination)[9]. Participants were recruited through CRIUGM's volunteer database between September and December 2020 (during the second COVID-19 lockdown).

Intervention and randomization

Face-to-face interventions were not possible in fall 2020 due to the second COVID-19 mandatory lockdown. To refine the exercise recommendation from our previous study performed during the first COVID-19 lockdown (for more detail see [3]), we implemented a 12-week intervention using online remote exercise sessions with a different combination of live and pre-recorded sessions. Given the uncertainty of the second lockdown duration in Quebec, participants were randomized using cluster method into: 1) a Live-Recorded-Live (LRL) group, in which participants had live exercise sessions with a kinesiologist on Mondays and Fridays on Zoom© and had a recorded session on Wednesdays on a dedicated website with an access code (www.trainingrecommend.com); or 2) a Recorded-Live-Recorded (RLR) group, where participants followed the same exercise sessions but with an inverse modality of delivery (recorded sessions on Mondays and Fridays and a Live session on Wednesdays) as presented in Fig. 1.

Briefly (for additional details see [3]), in order to ensure the safety of the online interventions, we created three difficulty levels (L1 = non-fit to L3 = fit) and stratified the randomization using a mobility decisional tree during the baseline assessment. Following randomization, participants followed three sessions per week (1 h/session) for 12 consecutive weeks. All training sessions were structured in three blocks of exercises designed to improve muscle function, cardiovascular capacity as well as flexibility. One session per week was predominantly focused on one of the three blocks of exercises. The intervention was identical to the intervention published in Granet et al. 2022 [3]. Full details of the intervention are available as a freely accessible supplementary material of the previously cited publication (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9384240/bin/glac127_suppl_supplementary_material.pdf). Briefly, each session was divided into 3 phases: 1) low-intensity global warm-up using 8 different exercises for a 10-min duration; 2) core of the session for a duration of 45 min and dispatched in circuits of 3 to 5 min of exercise, followed by 30 to 60 s of rest. The core of the session changed every session of the week. The first session of the week focused on balance and

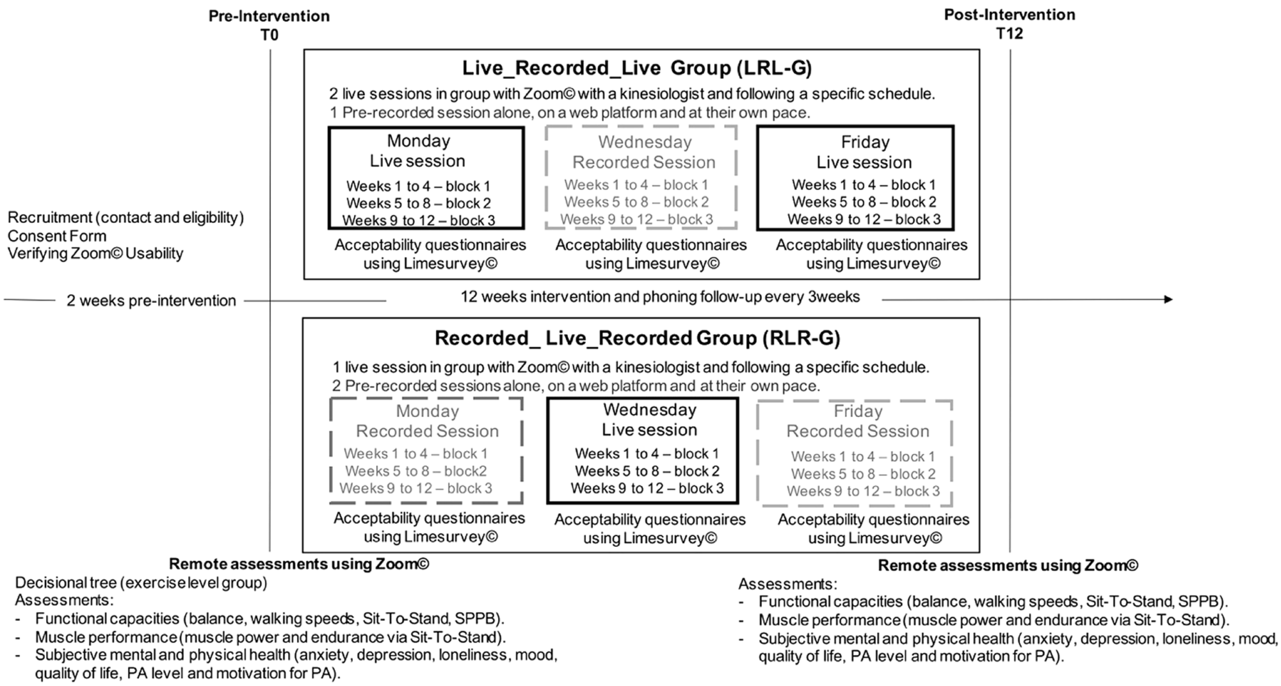

Fig. 1 Overview of the study

coordination. The second session focused on muscle function and cardiovascular capacity and the third session on flexibility (full details of each session are provided in [3]); 3) cool down and stretching period using 5 exercises focusing on the whole body for a duration of 5 min.

Additionally, all participants completed the same exercises and sessions, but the amplitude, position (sitting or standing), intensity, and number of repetitions were adapted during the live sessions according to their level and to allow an adequate progression. The intensity and difficulty of the sessions were adjusted every four weeks. Finally, all the training sessions were supervised by the same certified exercise instructor (certified kinesiologist).

Thus, among the participants recruited and randomized, two LRL groups (Group1 (L3): $n=14$ [W: $n=10$/ M: $n=4$); Group 2 (L2): $n=8$; (W: $n=7$/ M: $n=1$) and two RLR groups (Group1 (L3): $n=14$ [W: $n=13$/ M: $n=1$); Group 2 (L2): $n=10$; (W: $n=8$/ M: $n=2$) were trained.

Measures

Pre- and post-evaluations were conducted by the same assessor (certified kinesiologist), who was not involved in the intervention to limit bias.

Intervention feasibility and acceptability

We assessed feasibility using adherence to the intervention via the proportion of the 36 sessions attended. During the live sessions, adherence was noted by the kinesiologist, whereas for the recorded sessions, adherence was measured using the completion of an online questionnaire at the end of each session. As commonly recommended, participants were expected to complete 80% of the exercise sessions (29/36 sessions) for the study to be considered feasible [10]. Acceptability was also assessed throughout the intervention using five variables rated after each exercise training session via Limesurvey©. Participants rated the difficulty level of the proposed exercises, their overall satisfaction with the training session, perceived exertion, and enjoyment during the training session (for more detail see [3]). We also assessed the participants' technological ability using three questions assessing: (1) whether they considered themselves technology savvy or not; 2) the number of years that they have used technological tools; and 3) the type of technology they have used (tablet, desktop computer/laptop, or smartphone).

Objective and subjective physical health measures

We briefly describe the tests and questionnaires used to assess functional capacities, physical performance, and physical health below (for more details see [3]).

A) Functional capacities

Short Physical Performance Battery (SPPB)

Based on the results of three tests, the SPPB score (x/12) is calculated using bipodal balance, 4-m walking speed [11], and the 5-repetition sit-to-stand test ranked from 0 to 4. This scale is recognized to assess lower extremity function and mobility in older adults [12].

Unipodal balance

With their arms by their sides, participants were asked to stand on one leg for a maximum of 60 s. Unipodal balance capacity is a predictor of fall risk [13].

Timed-up and go [14]

This test consisted in standing from a sitting position on a chair, walking a 3-m distance, turning around, and then sitting down again. The TUG was performed at normal and fast speeds. This measure is related to the risk of falls [15].

B) Physical performance

- Muscle power

Based on the time needed for the participant to perform 10 sit-to-stand repetitions, a power index was calculated using the validated Takaï equation: $P = \frac{(L-A) \times BM \times g \times 10}{T}$ [16], where P = power (watts); $L \equiv$ leg length (the distance from the greater trochanter of the femur to the lateral malleolus) (m); A = height of the chair (m); BM = body mass; g = acceleration due to gravity (9.8 m•s^{-2}); 10 = number of repetitions; T = time to perform the test, respectively.

Muscle endurance

Participants performed as many sit-to-stand repetitions as they could in 30 s. This test is recognized as a valid indicator of lower body muscular endurance in community-dwelling older adults [17].

C) Anthropometrics

Body mass index (BMI)

Using self-reported body mass (kg) and height (m), BMI was calculated using the following equation: body mass (kg)/height (m^2)].

D) Physical health questionnaires

Quality of life

Measured using the EQ-5D questionnaire [18].

Mental health

Psychological distress (anxiety and depression) was evaluated using the Kessler Psychological Distress Scale (K10) [19], while loneliness was evaluated with the UCLA-Loneliness Scale-3 (UCLA-3) questionnaires [20].

Motivation toward PE

The "Échelle de motivation envers l'activité physique en contexte de santé" questionnaire was used to assess motivation toward PE [EMAPS; [21]].

Statistical analyses

Data distributions were tested using the Shapiro–Wilk test. Baseline characteristics were summarized using descriptive statistics. Continuous variables were expressed by means ± standard deviation. Categorical variables were expressed in percentages. A Chi-squared test or Fisher test was used to compare the frequency of observations between groups.

Independent parametric t-tests were used to identify potential between-group differences at baseline (before the start of the intervention). Two-way repeated-measures ANOVA [factors time (pre, post) and group (LRL *vs.* RLR)] was used to test the effects of each intervention on physical health variables. When a main effect or interaction reached significance, Bonferroni post hoc tests were performed to adjust for multiple comparisons. Partial eta squared (ηp^2) were used to report effect sizes, where an ηp^2 between 0.06 and 0.01 was considered to be a low effect, between 0.1 and 0.06 was considered a medium, and an ηp^2 larger than 0.1 was considered a large effect size [22]. The percentage change from baseline ((pre-post/pre) × 100) was estimated to evaluate and compare the clinical significance of our interventions. All statistical analyses were performed using SPSS 27.0 (Chicago, IL, USA). The significance was set at $p \leq 0.05$ (two-tailed) for all analyses.

Results

A total of 46 participants were eligible and randomized into two groups: 1) LRL group: Pre: $n = 22$ (women: 18/men: 4) and Post: $n = 19$ (women: 15/men: 4). Three participants dropped out due to lack of interest ($n = 2$) or a medical issue that was unrelated to the intervention ($n=1$; unrelated to the program). 2) RLR group: Pre: $n=24$ (women: 20/men: 4) and Post: $n=17$ (women: 13/men: 4). Seven participants dropped out due to lack of interest ($n=3$), a medical issue that was unrelated to the program ($n=3$; unrelated to the program) or a move ($n=1$).

Baseline participant characteristics were similar between groups (all $p \geq 0.05$): Participants were highly educated (% university level: LRL = 81% *vs*. RLR = 67%, $p=0.56$), cognitively intact (T-MMSE (x/30): LRL = 25.2 ± 1.0 *vs*. RLR = 25.4 ± 1.1, $p=0.90$), and functionally (walking speed (m/s): LRL = 0.93 ± 0.20 *vs*. RLR = 0.91 ± 0.20, $p=0.85$; SPPB (x/12): LRL = 10.9 ± 1.1 *vs*. RLR = 10.7 ± 1.5, $p=0.72$) and physically healthy (BMI (kg/m^2): LRL = 28.4 ± 3.9 *vs*. RLR = 27.5 ± 5.5, $p=0.82$). The number of prescribed drugs (> 5; %): LRL = 0% *vs*. RLR = 9.5%, $p=0.15$), percentage of women (% women: LRL = 81% *vs*. RLR = 81%, $p=1.00$), and mean age (age (y): LRL = 71.0 ± 7.7 *vs*. RLR = 69.3 ± 3.5, $p=0.58$) were also similar.

Intervention feasibility and acceptability

Among the 46 participants who took part in the intervention, 36 participants completed the study. Group difference in the dropout rate did not reach significance [14% LRL group [Pre: $n=22$ (17 women/5 men) to Post: $n=19$ (14 women/5 men)] *vs*. 29% RLR group [Pre: $n=24$ (17 women/7 men) to Post: $n=17$ (14 women/3 men); $p=0.20$]. The reasons for dropping out were similar between groups and occurred throughout the intervention.

Adherence to the intervention was similar between groups [LRL 92% (min–max: 33–36) *vs*. RLR 85% (min–max:24–36); $p=0.32$] among participants who completed the intervention. Moreover, the modality of the session did not influence adherence, which was similar between groups (Monday: LRL = 86% *vs*. RLR = 74%, $p=0.29$; Wednesday: LRL = 73% *vs*. RLR = 77%, $p=0.66$; Friday: LRL = 81% *vs*. RLR = 77%, $p=0.41$).

Acceptability, satisfaction (satisfied or very satisfied (%): LRL = 71% *vs*. RLR = 74%, $p=0.52$), enjoyment (enjoy or enjoy a lot (%): LRL = 89% *vs*. RLR = 79%, $p=0.38$), perceived difficulty (easy or quite easy (%): LRL = 76% *vs*. RLR = 65%, $p=0.47$), and perceived exertion (a little easy /a little difficult (%): LRL = 58/32% *vs*. RLR = 60/30%, $p=0.32$/$p=0.37$, respectively) were similar in both groups.

Additionally, satisfaction regarding the modality of the session (live *vs*. recorded) was slightly but not statistically different between groups (satisfied or very satisfied (%): Monday: LRL = 61% *vs*. RLR = 52%, $p=0.36$; Wednesday LRL = 67% *vs*. RLR = 68%, $p=0.47$; Friday: LRL = 75% *vs*. RLR = 50%, $p=0.26$). Enjoyment was also slightly but not statistically different (enjoy or enjoy a lot (%): Monday: LRL = 93% *vs*. RLR = 77%, $p=0.45$; Wednesday: LRL = 83% *vs*. RLR = 78%, $p=0.52$; Friday: LRL = 95% *vs*. RLR = 84%, $p=0.40$). The perceived difficulty was similar in both groups (easy or quite easy (%): Monday: LRL = 67% *vs*. RLR = 58%, $p=0.41$; Wednesday: LRL = 60% *vs*. RLR = 50%, $p=0.35$; Friday: LRL = 72% *vs*. RLR = 56%, $p=0.67$).

Objective physical health effects of the intervention

The participants' pre- and post-intervention physical performance is presented in Table 1. A time effect was observed for normal walking speed ($p=0.005$, $\eta p^2=0.12$), normal ($p=0.003$, $\eta p^2=0.25$), and fast Timed-Up and Go ($p=0.007$, $\eta p^2=0.21$), 5-repetition Sit-to-Stand test ($p=0.011$, $\eta p^2=0.19$), muscle power ($p=0.02$, $\eta p^2=0.27$), muscle endurance ($p<0.001$, $\eta p^2=0.37$), and SPPB score ($p=0.012$, $\eta p^2=0.18$). A time × group effect was found for the 5-repetition Sit-to-Stand test ($p=0.013$, $\eta p^2=0.18$), muscle power ($p=0.006$, $\eta p^2=0.27$), and muscle endurance ($p<0.001$, $\eta p^2=0.34$), with the LRL group showing greater improvement than the RLR group.

In addition to greater statistical improvement, the LRL group also had a more clinically significant improvement for muscle power (minimal change expected > 10%: LRL: + 35 ± 16.1 *vs*. RLR: + 7 ± 13.9, $p=0.010$, $d=0.852$), muscle endurance (minimal change expected > 7%: 30-s Sit-to-Stand (%): LRL: + 34.7 ± 15.4 *vs*. RLR: + 27.0 ± 26.5, $p<0.001$, $d=1.232$), and 5-repetition Sit-to-Stand time (minimal change expected:– 2.3 s; 5-STS (sec): LRL:– 2.38 ± 1.1 s; RLR:– 0.1 ± 1.8 s; $p=0.007$, $d=-1.003$).

Subjective physical health effects of the intervention

Pre- and post-intervention subjective health parameters are presented in Table 1. No significant change was observed.

Discussion

The purpose of this study was to evaluate and compare the feasibility, acceptability, and health effects of two online exercise interventions, which included a different proportion of live and recorded sessions, in community-dwelling older adults. First, participants from both groups reported that it was "easy" to perform the sessions (LRL:76% *vs*. RLR: 65%). These results suggest that even if the intensity and the level of difficulty increased every three weeks during the 12-week intervention period, both combined remote exercise interventions were adapted to the participants' capacities.

Table 1 Effect of the intervention on physical characteristics, body composition, and subjective measures

Variables	Pre	Post	2×2 repeated-measures ANOVA		
			Time *p*-value (ηp^2)	Group *p*-value (ηp^2)	Time×Group *p*-value (ηp^2)
Anthropometric variables					
BMI (kg/m2)			0.115 (0.066)	0.875 (0.001)	0.323 (0.033)
Live-recorded-live group	28.4±3.9	28.3±4.0			
Recorded-live-recorded group	27.5±5.5	27.3±3.3			
Functional capacities					
Unipodal balance (X/60 s)			0.162 (0.078)	>0.001 (0.229)	0.744 (0.03)
Live-recorded-live group	24.7±22.4	28.2±23.6			
Recorded-live-recorded group	23.9±16.4	29.2±20.5			
Normal walking speed (m/s)			0.050 (0.118)	0.467 (0.017)	0.447 (0.019)
Live-recorded-live group	0.93±0.20	1.05±0.23			
Recorded-live-recorded group	0.91±0.20	0.95±0.22			
Fast walking speed (m/s)			0.260 (0.0041)	0.347 (0.029)	0.079 (0.096)
Live-recorded-live group	1.38±0.25	1.52±0.26			
Recorded-live-recorded group	1.35±0.27	1.38±0.38			
Normal timed-up and go (s)	9.72±2.00	8.95±1.60	0.003 (0.250)	0.506 (0.014)	0.818 (0.002)
Live-recorded-live group	10.19±2.00	9.31±1.90			
Recorded-live-recorded group					
Fast timed-up and go (s)	7.13±1.40	6.78±1.10	0.007 (0.172)	0.453 (0.018)	0.255 (0.042)
Live-recorded-live group	7.73±1.90	6.90±1.30			
Recorded-live-recorded group					
5 -repetition sit-to-stand (s)			0.011 (0.193)	0.213 (0.005)	0.013 (0.183)
Live-recorded-live group	11.6±3.10	9.2±2.0*			
Recorded-live-recorded group	11.6±2.1	11.5±3.9			
SPPB SCORE (x/12)	10.9±1.1	11.7±0.6	0.012 (0.186)	0.238 (0.045)	0.152 (0.065)
Live-recorded-live group	10.7±1.5	10.9±1.4			
Recorded-live-recorded group					
Physical performance					
Muscle power (W)			0.002 (0.273)	0.591 (0.01)	0.006 (0.222)
Live-recorded-live group	35.4±14.8	48.0±18.9*			
Recorded-live-recorded group	37.1±13.8	39.7±14.0			
Muscle endurance (30 s chair test; *n*)			<0.001 (0.331)	0.042 (0.127)	0.020 (0.269)
Live-recorded-live group	14.8±4.2	19.41±1.3*			
Recorded-live-recorded group	14.4±3.0	18.8±5.6			
Subjective health					
Motivation PE (x/100)			0.371 (0.031)	0.096 (0.103)	0.498 (0.018)
Live-recorded-live group	67.7±10.2	66.7±9.7			
Recorded-live-recorded group	62.2±14.7	55.6±25.6			
Psychological distress (x/50)	15.6±5.3	17.9±3.3	0.150 (0.070)	0.284 (0.046)	0.353 (0.035)
Live-recorded-live group	12.9±5.5	17.7±4.9			
Recorded-live-recorded group					
Loneliness (x/9)	6.4±2.3	5.9±2.1	0.110 (0.099)	0.268 (0.049)	0.362 (0.033)
Live-recorded-live group	7.6±2.5	6.0±2.1			
Recorded-live-recorded group					
Quality of life (x/25)			0.155 (0.073)	0.700 (0.006)	0.317 (0.037)
Live-recorded-live group	7.2±1.3	7.4±3.0			
Recorded-live-recorded group	6.5±1.2	7.6±2.7			

Data are presented as means, Mean±SD. *Significant differences within the group using paired *t*-test. × = Significant differences between groups at baseline using independent *t*-test. Time and time x group effects = 2×2 repeated-measures ANOVA. *BW* body weight. *BMI* body mass index. Partial eta square (ηp^2; small effect: $\eta p^2 = 0.01$; medium effect: $\eta p^2 = 0.06$; large effect: $\eta p^2 = 0.14$); SPPB = Short Physical Performance Battery; motivation was assessed via the EMAPS questionnaire; psychological distress was assessed via the Kessler Psychological Distress Scale (K10); loneliness was assessed via the UCLA-Loneliness Scale-3 questionnaire (UCLA-3); quality of life was assessed via the EQ-5D questionnaire

Furthermore, both groups reported that they were equally "satisfied" with the training program followed during the intervention (LRL:71% *vs*. RLR:74%). These results are relevant because the level of satisfaction is one of the main factors that enable older adults to participate and stay motivated in their practice of PE [23].

We also observed a high and similar level of enjoyment across modalities (LRL:89% *vs*. RLR:79%). This aspect is also important as enjoyment is another main reason for older adults to participate in PE and integrate it into their lifestyle habits [24]. Overall, participant perception is very important, especially in older adults, as exercise adherence is related to concordance with their needs and the level of enjoyment during practice [25]. Indeed, we showed a high adherence and acceptability, independent of the modality performed (LRL:92% *vs*. RLR:85%). Additionally, we observed that the live sessions had slightly higher adherence than the recorded sessions. However, the day of the week when the live or recorded sessions were performed did not seem to impact adherence. Nevertheless, it is important to note that the drop-out rate in the RLR group was higher than in the LRL group (RLR:29% *vs*.LRL:14%). On average, a drop-out rate around 20% is expected during a 12-week intervention in older adults [14]. One reason that could explain the difference in the dropout rate between both combined remote exercise interventions is the increased interaction due to session settings (group & live *vs*. alone & recorded). Indeed, it has been shown that PE interventions with group-based activities may reduce loneliness and social isolation by enhancing the feeling of connectedness [26, 27]. Also, group settings allow participants to interact more and more easily with other participants, which is a known factor for decreasing the feeling of loneliness and social isolation [28].

Moreover, we observed that both remote combined exercise interventions improved physical health significantly. However, regarding normal walking speed, only the LRL group showed clinical improvement (minimal change expected > 0.1 $m.s^{-1}$; delta change (m/sec) = LRL: + 0.13 *vs*. RLR: + 0.04). More specifically, the LRL group went from normal walking speed to good walking speed (LRL: pre:0.92 m/sec to post: 1.05 m/sec), which is associated with lower health risks and mortality in older adults [29]. In addition, the significant effects observed on muscle power and muscular endurance in both groups are important as these parameters are recognized to be the main predictors of fall risk in older adults [30]. In addition, it has been suggested that a substantial and meaningful clinical change on SPPB (range from 0.4 to 1.5 points; [12]) reduces the risk of adverse health outcomes [31]. Based on our findings on SPPB, our interventions should also be considered effective for improving functional capacities [12, 32]. However, only LRL was associated with a clinically significant change that can reduce the risk of adverse health outcomes (LRL: + 0.8 *vs*. RLR: + 0.2 point; [31]). Overall, our results are in line with other studies reporting that participation in exercise programs improves health-related fitness, reduces risky behaviors, and helps reduce the use of various health services [33]. However, the differences between the two groups are likely because, during live supervised sessions, the instructor provides instructions to correct participants' movements, thus improving the quality of the exercise performed. Furthermore, the participants' motivation, adherence, and engagement are potentiated by the presence of an instructor during in-person training sessions [34] which could have impacted the effectiveness of the intervention on health parameters. Consequently, as the LRL group has a higher ratio of live session with a kinesiologist than the RLR group, the previous arguments could justify the greater observed improvements in the LRL group.

Our subjective health results show that depression, loneliness, and quality of life remained stable in both groups in both interventions, even if the study was conducted during the second COVID-19 lockdown. This point is important as the COVID-19 pandemic has been shown to increase feelings of loneliness in older adults, which impacts physical and mental health [35]. As mentioned previously, these results could be explained by the modalities of our remote interventions (live, interactive, and group) but also by their design. We used follow-up phone calls every three weeks for each participant to ensure their safety and confirm their adherence, which could have positively impacted their feelings of depression or loneliness. Indeed, studies have shown that regular follow-up phone calls, provided by layperson callers, could impact feelings of loneliness and depression over a four-week period, but this has not been confirmed in the longer term in older adults [36]. A social desirability bias may have occurred as participants knew they were being assessed throughout the study.

Nonetheless, our study presents some limitations. First, due to our per-protocol analysis, we only reported results from participants who completed the pre- and post-intervention assessments. Moreover, individuals who participated in our study were fairly educated, healthy, and were already using some technological tools daily. Thus, our findings cannot be generalized to the population since 40% of older adults did not have access to these technologies before the COVID-19 pandemic and did not have the skills to use them. However, a recent study has shown that remote exercise programs are also feasible and acceptable to prevent loss of mobility in pre-disabled older adults during the COVID-19 pandemic [37]. In addition, kinesiologists who performed the assessments were not blinded to the intervention. However, they were not involved in the delivery or creation of the exercise intervention to limit this potential bias. Exercise kinesiologists were blinded to the objectives of the study.

Moreover, due to the novelty of the question addressed and the circumstances (study conducted during the second COVID-19 lockdown), we did not perform a power calculation. Thus, our sample size may not have allowed us to observe superiority or inferiority between groups. Finally, the lack of follow-up data to assess whether both groups will maintain their PE levels after the end of the intervention is an additional limitation.

Nevertheless, this study also has some strengths, such as the same number and type of exercises in both interventions, the use of validated measures allowing us to adequately compare one intervention against the other, and the use of a reproducible tool to ensure the safety as well as the tailoring of the intervention to the participants. Additionally, this study suggests great opportunities for promoting healthy aging while providing and specifying the role of remote modalities. Indeed, these remote modalities could be used to fight against sedentary behaviors in multiple structures for the elderly such as geriatric centers and home care where movement is a vital issue and requires continuous encouragement [38]. Finally, future studies should explore the physiological mechanisms responsible for the improved physical performance and functional capacities, such as mitochondrial activity, neuromuscular junction, or metabolic inflammation which are known factors impacting the aging process [39, 40].

Conclusion

This study shows that online exercise interventions combining different types of session modalities are safe and can promote a physically active lifestyle in older adults. Both of these remote combined modalities could help fight against a sedentary/inactive lifestyle caused by lockdowns, extreme weather, or transportation difficulties, providing viable alternatives to full face-to-face training. These results offer insights regarding the different impacts of remote training as well as the optimal ratio for live or recorded training sessions**.** Indeed, our results show that the modality with the higher ratio of live training leads to greater improvements in muscle function as well as a lower drop-out rate. Overall, our findings are important to help health professionals offer the best modality for their patients according to their motivation but also their financial situation, schedule, or travel (lack of transportation; weather limitations, etc.) constraints.

Acknowledgements The authors would like to thank all the trainees and research assistants who took part in the study. Finally, we would like to thank all the older adults who participated in this study.

Author contributions MAL designed and led the project and supervised all the steps of this article. JG recruited, performed some assessments, analyzed the data, and wrote the manuscript. EP, FR, FB, and LBA performed some assessments and revised the manuscript. BP, TTDV, JPG, and MJS contributed to the design or methods of the research and revised the manuscript.

Funding This work was supported by operational funds from MAL (UQAM-FRQS). The study's website (www.trainingrecommend.com) was partly supported by a grant from the Centre de recherche de l'Institut Universitaire de Gériatrie de Montréal (CRIUGM COVID-19 grant support). MAL (senior salary award), TDV (senior salary award), BP (junior 1 salary award), and FB (post-doctoral fellowship) were supported by the Fonds de recherche du Québec en santé (FRQS). JPG was supported by a Canada Research Chair grant. FB received also a post-doctoral fellowship from the Canadian Institutes of Health Research (CIHR). JG, EP, and FR received a scholarship from Centre de recherche de l'Institut Universitaire de Gériatrie de Montréal (CRIUGM or CRIUGM-AGEWELL scholarship).

Data availability The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval This study was performed according to the principles of the Declaration of Helsinki. 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).

Informed consent All participants signed a consent form.

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