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'Prime Time of Life', A 12-Week Home-Based Online Multimodal Exercise Training and Health Education Programme for Middle-Aged and Older Adults in Laois

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Introduction: Multimodal exercise training can ameliorate the physiological decline associated with ageing. This study aimed to investigate whether 12 weeks of a home-based online multimodal training and health education intervention could improve functional ability and perceptions of physical and mental health in middle-aged and older adults.

Methods: Sixty-one male (N = 18, 59.1 ± 7.0 years) and female (N = 43, 60.9 ± 6.8 years) participants with various clinical conditions completed two 60-minute training sessions per week for 12 weeks delivered online via Zoom. All sessions included aerobic, resistance, balance, and flexibility exercises. One weekly session incorporated 15 minutes of health and fitness education. The pre/post testing sessions were conducted in a local community centre in line with COVID-19 public health guidelines. Paired samples t-tests and the Wilcoxon signed rank tests were utilised to compare scores pre and post intervention.

Results: There were significant improvements in participants 6-minute walk ($p < 0.0001$), sit-to-stand ($p < 0.0001$), timed-up-and-go ($p < 0.0001$), sit-and-reach ($p < 0.0001$), squat jump ($p < 0.0001$), core endurance ($p < 0.0001$), grip strength (right hand $p = 0.03$, left hand $p = 0.04$) and balance (right leg $p < 0.0001$, left leg $p = 0.004$) tests post intervention. Perceptions of physical ($p < 0.0001$) and mental ($p < 0.0001$) health also improved significantly.

Discussion: Twelve weeks of online multimodal training and health education can significantly improve cardiovascular fitness, strength, power, balance, flexibility, and perceptions of physical health, mental health, and quality of life in middle-aged and older adults. While there are some limitations to online interventions, the benefits are numerous and equal to those reported for onsite interventions and should be considered for wider rollout in this population.

Keywords: multimodal activity; online; middle-aged; older adult

Introduction

Ageing results in numerous negative physiological adaptations including reductions in cardiovascular fitness (Stratton et al., 1994), muscle mass, strength, power and function (Larsson et al., 2019), bone mass (Layne and Nelson, 1999), flexibility and range of motion (Singh, 2004), balance (Sturnieks et al., 2008), and cardiovascular and metabolic health (Harber et al., 2017). These adaptations can increase the risk of developing clinical conditions including type 2 diabetes, hypertension, cardiovascular disease, arthritis and osteoporosis (Singh, 2004). Additionally, sarcopenia associated with ageing can increase the risk of frailty and falls, poor physical and mental health, loss of independence and poor quality of life (Larsson et al., 2019). These negative physiological adaptations are exacerbated when ageing is combined with physical inactivity (Strasser and Burtscher, 2018).

Conversely, physical activity (PA), specifically multimodal PA incorporating aerobic, strength, balance and flexibility training can ameliorate the physiological decline associated with ageing (Chodzko-Zajko et al., 2009, Tiedemann et al., 2011). Aerobic training improves aerobic fitness, the functioning of the cardiovascular system (Huang et al., 2005), body composition, lipid profile and insulin sensitivity (Chodzko-Zajko et al., 2009) and is a strong independent predictor of health (Strasser and Burtscher, 2018). Aerobic training also plays an important role in the prevention, treatment and management of cardiovascular and metabolic conditions that are prevalent in the ageing population (Strasser and Burtscher, 2018). Resistance training increases muscle mass, function, strength, power and endurance (Hughes et al., 2018), bone density (Layne and Nelson, 1999), balance (Orr et al., 2006), ability to perform activities of daily living (ADL) independently (Muehlbauer et al., 2012) and reduces frailty (Larsson et al., 2019). Muscle strength and power are independent predictors of health and are among the strongest predictors of mortality in older adults (OA) (Metter et al., 2004). Total muscle mass declines by approximately 20–30% from young adult to 80 years of age (Carmeli et al., 2002). This is particularly evident in untrained individuals and contributes significantly to frailty (Larsson et al., 2019). With ageing, there is a reduction in the size and amount of type II muscle fibers (Larsson, 1983). This reduces the ability to perform activities that require powerful movements (Reid et al., 2008) such as postural corrections when balance is challenged (Henwood and Taaffe, 2005).

Balance, particularly one-legged balance, is a crucial component of most ADL e.g. walking and getting dressed (Sturnieks et al., 2008). Balance declines with age and is associated with poor gait speed, frailty, falls, fractures, hospitalisation and premature mortality (Lord et al., 1994). Balance training improves balance and reduces the risk of falls and the morbidity and mortality associated with same (Tiedemann et al., 2011). Due to the debilitating and detrimental consequences of poor balance in OA, balance training is recommended as an important and effective intervention for adults aged 65 years and older (Tiedemann et al., 2011). However, from a fall prevention perspective, the assessment and training of balance and muscle strength should also be incorporated into interventions for middle-aged adults (MAA).

Flexibility and range of motion deteriorate with age, which can limit the ability to perform specific movements in ADL and is associated with reduced mobility and independent living (Singh, 2004). Flexibility training improves mobility, range of motion, the performance of ADL, functional independent living, and reduces pain and stiffness (Singh, 2004), a commonly cited barrier to PA participation in this age group (Spiteri et al., 2019). Despite these benefits, very few studies focus on documenting the effect of specific range of motion exercises on flexibility outcomes (Chodzko-Zajko et al., 2009).

The physiological adaptations to aerobic, resistance, balance and flexibility training are specific to the mode of training undertaken as are the benefits they each elicit for healthy ageing (Chodzko-Zajko et al., 2009). Regular participation in all four modes of training result in increased functional ability, increased physical and mental health, a longer life span and health span, functional independent living and good quality of life (Chodzko-Zajko et al., 2009). These benefits are particularly evident when comparing the functional ability and health status of trained MAA and OA to their age matched untrained counterparts (McKendry et al., 2020).

Unfortunately, globally one in four adults are currently not meeting the minimum weekly PA recommendations for health (WHO, 2018). The majority of the PA participation data that exists to date pertains to aerobic exercise. While limited research has examined participation in resistance, balance and flexibility training, what is available (CDC, 2021, Cooper et al., 2020) suggests that adults are likely not meeting the weekly guidelines for multimodal training, which has serious implications for health and quality of life in later years (Chodzko-Zajko et al., 2009).

There is a need to design and implement effective multimodal PA interventions for OA (>65 years) that assess and develop aerobic fitness, muscle strength, power and endurance, flexibility and balance. From a pre prevention perspective it is equally important to do this for MAA (aged 50–64 years) since baseline levels of strength (Rantanen et al., 1999) and fitness (Blair et al., 1996) in this population predict frailty, independent living and quality of life in older age. This is particularly true for MAA who have clinically significant chronic conditions or functional limitations, and who are consequently included in the definition of "older adult" (Nelson et al., 2007). Since this group have these issues at a much younger age, they are likely to be at high risk of early frailty, early deterioration in physical and mental health and quality of life, prolonged morbidity and early mortality. Also, multimodal training sessions for this population should be designed so that they can cater for a variety of clinical conditions and musculoskeletal injuries that are prevalent in this population in the same session. Many PA interventions reported in the literature focus on the management of a specific clinical condition e.g. hypertension (Noone et al., 2018), but it is often the case that OA are living with a number of conditions simultaneously, so it may be more important to adapt PA interventions to be

inclusive of individuals with multiple conditions. Particularly since a lack of classes and programmes that cater for same is cited as a barrier to PA participation in this population (Spiteri et al., 2019).

Additionally, multimodal PA interventions for this population should incorporate simple and practical evidence-based health and fitness education workshops on topics relevant to them. These workshops can increase self-efficacy, which in turn can promote participation in PA and the long-term maintenance of this health behaviour (McAuley et al., 2007). Education workshops can be designed to address and help overcome known barriers to PA participation in MAA and OA (Spiteri et al., 2019), including being unaware of the benefits of PA for healthy ageing, not having the knowledge or skills to be physically active (Gray et al., 2016, Das et al., 2016), and not understanding the crucial role of multimodal PA in the treatment and management of injuries and clinical conditions that are prevalent in this population (Miller and Brown, 2017).

Traditionally PA interventions for OA take place on site in community or clinical settings. However, it can be necessary to provide safe and effective home-based online interventions. Online interventions offer many benefits for overcoming commonly cited barriers to PA participation including lack of time (Rodrigues et al., 2017), lack of accessibility due to distance (Paluck et al., 2006), lack of transport (Rodrigues et al., 2017) and weather (Eronen et al., 2014). The convenience of home-based online training may make it easier for individuals to be physically active.

This study aimed to investigate whether a 12-week home-based online multimodal PA and health education intervention could improve fitness, strength, balance, flexibility, and perceptions of physical and mental health in MAA and OA in Ireland with and without injuries and clinical conditions.

Methods

Study Design

This was a pre-test-post-test intervention study using quantitative data from a 12-week online multimodal training and health education intervention. Pre and post testing occurred in a community multipurpose hall over a two-day period three-four days before and after the 12-week intervention. Participants were required to attend one two-hour testing session before and after the intervention. Testing was completed in small groups of ten participants in line with COVID-19 restrictions in place at the time in the Republic of Ireland. An overview of the study is displayed in **Figure 1**.

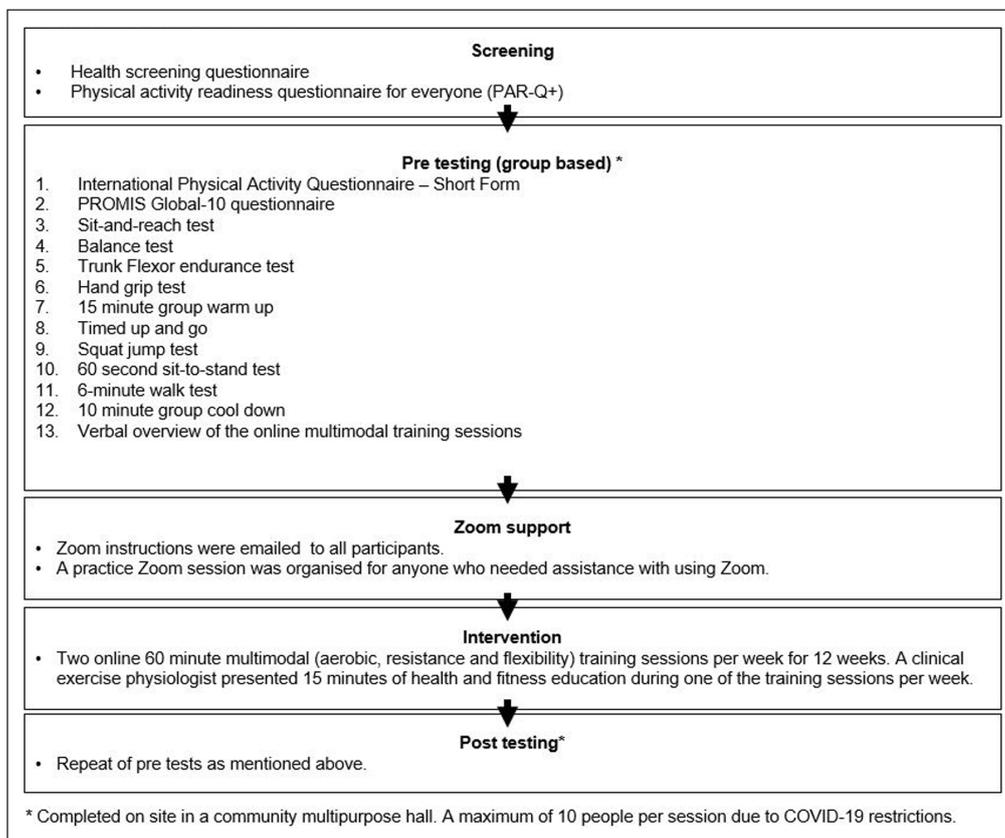


Figure 1: Overview of the study.

Participants

Male and female adults aged between 50–80 years living in County Laois, Ireland were recruited via social media, advertisements in local newspapers and from clubs and societies in the geographical location. Ethical approval was granted by Dublin City University's research ethics committee (reference number DCUREC/2020/008).

Participants read a plain language statement and provided written informed consent prior to testing. A 24-question health screening questionnaire was used enquiring about their contact details, age, sex, participation in PA and if they had any medical conditions or musculoskeletal injuries. Participants with clinical conditions and/or musculoskeletal conditions were eligible to take part in the study. Participants completed the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Warburton et al., 2011). Those who answered 'yes' to any of the questions were required to gain written medical clearance from their general practitioner.

Questionnaires

The International Physical Activity Questionnaire - Short Form (IPAQ-SF) was self-administered and completed to assess the number of participants classified as inactive, minimally active and health enhancing physically active in the past seven days (Craig et al., 2003). The IPAQ-SF is a reliable and reasonably valid instrument to assess habitual PA for OA (Craig et al., 2003). The PROMIS Global-10 v.1.2 questionnaire is a valid questionnaire for assessing general health related quality of life (Hays et al., 2009). The questionnaire was scored according to manufacturer's guidelines (HealthMeasures, 2017). A higher physical health t-score and mental health t-score indicates greater perceived physical and mental health.

Physical tests

Sit-and-Reach: This is a valid test to estimate hamstring flexibility (Lemmink et al., 2003). Participants completed three trials and the highest score was recorded (Whaley et al., 2006).

Balance: One-legged balance performance was assessed using the 30 second balance test (Blodgett et al., 2020) with eyes open. This is considered a valid and reliable test of static balance (Springer et al., 2007).

Trunk Flexor Endurance: Trunk flexor and core strength endurance was assessed using the validated Trunk Flexor Endurance Test (McGill et al., 1999). Total time spent in the correct position was recorded.

Hand grip strength: Maximum isometric strength of the hand and forearm muscles were assessed using the reliable and valid hand grip strength test (Schaubert and Bohannon, 2005) performed on the Harpenden Dynamometer. Participants completed three trials on each hand, alternating between hands with a rest period of 20 seconds between trials. The highest score for each hand was noted.

Timed Up and Go (TUG): Balance and basic mobility skills were assessed by the TUG (Kear et al., 2017) which is a valid prognostic assessment to predict fall risk in older adults (Nightingale et al., 2019).

Squat Jump (SJ): The SJ test was performed using the Jump Mat Pro. This is considered a valid and reliable test to assess lower body explosive muscle strength and power (Markovic et al., 2004). Participants completed three trials and the best SJ height and flight time was recorded.

60 second sit-to-stand test (STS): The STS test is recognised as a reliable field-based test used to assess lower body strength and endurance (Bohannon and Crouch, 2019). Participants were asked to stand up from a chair to a fully upright position with their arms folded across their chest (harder version), or hands placed on thighs (easier version) and return to a seated position as many times as possible in 60 seconds.

6-minute walk test (6-MWT): The 6-MWT, a modification of the 12-minute walk/run test (Cooper, 1968), is a field-based test used to obtain reasonably reliable and valid measures of cardiovascular fitness in older adults (Enright, 2003). Participants were asked to walk, jog or run from cone A (0m) to cone B (20m) and back as many times as possible in 6 minutes.

12-week intervention

The 'Prime Time of Life' intervention was designed and delivered by a clinical exercise physiologist and four qualified fitness instructors. Prior to the intervention, the fitness instructors underwent a 6-week Clinical Exercise Physiology 'Train the Trainer' course to upskill them in multimodal session design, exercise prescription, exercise selection, exercise modifications, and special exercise considerations for MAA and OA with a range of clinical conditions. Participants took part in two 60-minute multimodal (strength, flexibility, balance and fitness) training sessions per week for 12 weeks. The training sessions consisted of a 15-minute warm up, a 35-minute main phase and a 10-minute cool down. The warm up incorporated mobility exercises for all joints, low-to-moderate intensity aerobic exercises and concluded with dynamic stretching. The main

phase alternated aerobic and resistance exercises. For the first two weeks of the intervention, participants completed a total of 10 exercises in the main phase. This increased by two exercises every two weeks building up to a total of 20 exercises in the main phase in weeks 11 and 12 of the intervention. The instructors demonstrated three versions of each exercise (1 = beginner, 2 = intermediate, 3 = advanced). Chair based versions of the exercises were also given when necessary. Participants were continuously instructed to choose the level that was most appropriate for their current ability and level of fitness. Each main phase exercise was performed for 45 seconds, followed by a 15 second rest. Balance exercises were undertaken as the final part of the main phase. The cool down incorporated low intensity aerobic exercises and flexibility exercises. Supplementary file 1 outlines a sample 'Prime Time of Life' session.

The sessions were delivered online via Zoom (Zoom Video Communications, California, USA) by a trained exercise instructor. All sessions were additionally monitored by a member of the research team. Participants were given a pre training check list which instructed them to bring their phone to every session so that the research team could call them privately if necessary. Participants were also instructed to bring their colour coded intensity cards with them to class, which were given to them in the pre-testing session. The green, orange and red intensity cards reflected rate of perceived exertion's of 9–12, 13–17 and 18–20 respectively (Borg., 1982). At various points in the training session participants were asked to hold up the card that reflected their perceived intensity at that time.

Health education

Participants underwent a 15-minute health education workshop once per week for 12 weeks, delivered by a clinical exercise physiologist as part of one of the training sessions (**Table 1**). This element of the intervention was designed to enhance the knowledge, attitudes and self-efficacy of the participants.

Participants questions were answered at the end of each workshop and take-home resources in the form of workshop notes, a video voiceover of the workshop, sample aerobic, resistance, balance and flexibility exercise videos, circuit cards and training diaries were emailed to the participants each week.

Table 1: Overview of the health education workshop content.

Week	Health education workshop content
1	Understanding the exercise intensity that is appropriate for you.
2	The role of aerobic exercise training in healthy ageing (including the F.I.T.T. principles).
3	The role of resistance training in healthy ageing (including the F.I.T.T. principles).
4	The role of balance training in healthy ageing (including the F.I.T.T. principles).
5	The role of flexibility training in healthy ageing (including the F.I.T.T. principles).
6	How to structure your multimodal training week.
7	How to progress your training over time safely and effectively using the principles of overload and recovery.
8	The role of multimodal training in cardiovascular health and the prevention, treatment, and management of cardiovascular disease.
9	The role of multimodal training in metabolic health and the prevention, treatment and management of insulin resistance and type 2 diabetes.
10	Exercise prescription for osteoporosis.
11	Exercise prescription for arthritis.
12	Self-monitoring and goal setting.

F.I.T.T; Frequency, Intensity, Time, Type.

Data analysis

Data were analysed on SPSS version 26 (IBM Corp. Released 2019. IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp). Normality was examined. Squat jump height, flight time, sit-and-reach, mental health t-score, physical health t-score were normal. Balance, grip strength, TUG, trunk flexor endurance, STS, 6-MWT, MET-min/week were non-normal. For the variables that were normal, a mixed between-within ANOVA was calculated to examine if any differences exist between time (pre and post intervention) and sex (male and female). Partial eta squared (η_p^2) were used to examine effect sizes and were classified as small (0.01),

medium (0.06), and large (0.14) (Cohen, 1988). For non-normal variables, the Wilcoxon signed rank test was utilised to identify the differences between time (pre and post intervention) and the Mann Whitney U test examined differences between sex (male and female) pre and post intervention. Effect sizes were calculated and classified as small ($r = 0.1$), medium ($r = 0.3$), and large ($r = 0.5$) (Cohen, 1988). Descriptive statistics (mean, standard deviation, range) or proportions were calculated for demographic characteristics.

Results

Seventy-six participants were recruited for this study. One participant withdrew from the study for non-related medical reasons. Fourteen participants could not complete post testing. Therefore, 61 participants completed post testing to give an adherence rate of 80.3%. Participants were primarily female (70.5%) with an average age of 60.3 ± 6.8 years. **Table 2** displays the participants' characteristics. Participants frequently reported clinical conditions which can be seen in **Table 3**.

PA participation categorised as inactive, minimally active and health enhancing physically active pre and post intervention as determined by the IPAQ-SF is presented in **Table 4**. An increase in the proportion of participants engaging in health enhancing PA was observed.

There were significant improvements in participants perception of their own physical and mental health post intervention. Significant improvements were also found post intervention in lower back and hamstring flexibility and lower body explosive strength and power as measured by the sit-and-reach and squat jump tests respectively. Males displayed greater scores than females in the squat jump test (**Table 5**).

Functional skills as assessed by the TUG test improved significantly post intervention. Cardiovascular fitness measured by the 6-MWT also improved significantly post intervention. Lower body strength endurance, core strength, and grip strength improved significantly post intervention as assessed by the sit-to-stand test, trunk flexor endurance test and hand grip test respectively. Greater hand grip strength scores were observed in males. Balance improved significantly in the right and left leg post intervention. Participation in PA improved significantly post intervention, which was reflected by an increase in MET-min/week (**Table 6**).

Grip strength scores were greater in male participants than in female participants, but no other sex differences were observed (**Table 7**).

Table 2: Demographics of participants.

	Total	Male	Female
Participants (n)	61	18	43
Age M \pm SD (range)	60.3 \pm 6.8 (50–77)	59.1 \pm 7.0 (50–74)	60.9 \pm 6.8 (50–77)
Height (m) M \pm SD	1.7 \pm 0.1	1.7 \pm 0.1	1.6 \pm 0.1
Weight (kg) M \pm SD	82 \pm 15.2	91.5 \pm 10.2	78.1 \pm 15.3
BMI (kg/m²) M \pm SD	29.86 \pm 6.7	31.1 \pm 4.8	29.3 \pm 7.4
Participation in PA % (n)	Yes % (n)	88.5% (54)	88.9% (16)
	No % (n)	11.5% (7)	11.1% (2)
		11.6% (5)	

M; Mean. SD; Standard deviation. M; metres. Kg; kilograms. BMI; body mass index. %; Percentage. n; Number.

Discussion

The key findings of this study were that 12 weeks of home-based online multimodal training with health education significantly improved cardiovascular fitness, muscle strength, power, endurance, balance, flexibility, participation in health enhancing PA, and perceptions of physical health, mental health and quality of life in MAA and OA. This indicates that home-based online interventions for this population are equally effective to onsite programmes in improving components of fitness and perceptions of health that are crucial for healthy ageing.

Health Related Components of Fitness

There was a significant increase in distance walked in the 6-MWT post intervention which translates to increased aerobic exercise capacity and cardiovascular fitness. Increased cardiovascular fitness is an important outcome since it is identified as an independent predictor of health (Strasser and Burtscher., 2018). It is also

Table 3: Clinical conditions among participants.

Clinical condition	N (%)
High cholesterol	28 (45.9)
Family history of heart disease	26 (42.6)
Obesity	25 (41)
Back pain	19 (31.1)
High blood pressure	17 (27.9)
Joint pain	7 (11.1)
Heart condition	6 (9.8)
Type 2 diabetes	6 (9.8)
Muscle injuries	6 (9.8)
Asthma	6 (9.8)
Osteoporosis	5 (8.2)
Rheumatoid arthritis	5 (8.2)
Osteopenia	4 (6.6)
Osteoarthritis	4 (6.6)
Low blood pressure	3 (4.9)
Sarcoidosis	2 (3.3)
Kidney disease	1 (1.6)
Congenital glaucoma	1 (1.6)
Hip replacement	1 (1.6)
Tendonitis	1 (1.6)
Chronic obstructive pulmonary disease	1 (1.6)
Dystonia	1 (1.6)
Dropped foot	1 (1.6)

Obesity is classified as BMI ≥ 30 kg/m² (WHO, no date).

Table 4: IPAQ-SF classification pre and post intervention.

	Pre intervention % (n)	Post intervention % (n)
Inactive – Category 1	23.0% (14)	1.7% (1)
Minimally Active – Category 2	45.9% (28)	41.4% (24)
Health Enhancing PA – Category 3	31.1% (19)	56.9% (33)

associated with improvements in physical function and walking, which is an important component in ADL and improved capacity in this regard is crucial for quality of life in this population (Enright, 2003). Twelve weeks of telehealth (Hwang et al., 2017) and onsite training incorporating different combinations of aerobic and resistance exercises twice per week have also reported an increase in distance walked in the 6-MWT post intervention in OA (Agner et al., 2018, Zamboni-Ferraresi et al., 2015).

The maintenance and development of muscle strength in MAA and OA is very important because strength is a strong predictor of frailty, morbidity, mortality and functional independent living in these individuals (Metter et al., 2004). There was a significant increase in STS performance post intervention, which reflects increased strength endurance in the muscles of the lower limbs, increased ability to perform this ADL (Fiatarone et al., 1990) and is associated with increased gait speed (Fiatarone et al., 1990). Our findings are in line with the results of other 12-week onsite concurrent (strength and aerobic exercise) and multimodal (similar training mode and load to current study) interventions for OA (Oreská et al., 2020). Grip strength

Table 5: Pre and post total, male and female mean values, and main effects for time, sex and interaction effects for normal variables.

	Total		Male		Female		Interaction effect		Sex		Time	
	Pre	Post	Pre	Post	Pre	Post	P	η_p^2	P	η_p^2	P	η_p^2
	Mean \pm SD											
Mental health t-score	46.2 \pm 7.0	49.9 \pm 5.9	47.0 \pm 6.6	48.8 \pm 6.6	45.8 \pm 7.2	50.3 \pm 5.6	0.15	0.04	0.94	0.00	0.001	0.21
Physical health t-score	44.6 \pm 7.4	49.0 \pm 6.1	43.8 \pm 8.0	47.6 \pm 6.3	45.0 \pm 7.3	49.6 \pm 6.1	0.62	0.01	0.43	0.01	<0.0001	0.35
Sit-and-reach test (cm)	16.2 \pm 8.4	20.9 \pm 7.4	15.9 \pm 7.3	20.3 \pm 5.8	16.3 \pm 8.9	21.1 \pm 8.0	0.79	0.00	0.79	0.00	<0.0001	0.46
Squat Jump Height (mm)	147.9 \pm 55.7	161.6 \pm 54.3	195.7 \pm 42.0	204.9 \pm 48.3	127.0 \pm 47.7	142.6 \pm 45.5	0.41	0.01	<0.0001	0.33	0.002	0.16
Flight time (ms)	340.2 \pm 46.0	357.9 \pm 62.6	395.6 \pm 46.0	405.6 \pm 48.0	315.9 \pm 62.2	336.9 \pm 56.8	0.21	0.03	<0.0001	0.29	0.001	0.19

mm; millimetres, ms; milliseconds.

Table 6: Differences pre and post intervention for non-normal variables.

	Total			Time		
	Pre		Median	Post		P
	Mean \pm SD	Median		Mean \pm SD	Median	
Timed Up and Go (sec)	5.2 \pm 1.2	4.9	4.8 \pm 1.0	4.6	<0.0001	0.48
Sit To Stand (reps)	26.6 \pm 7.2	25.5	35.4 \pm 9.2	33.0	<0.0001	0.82
6-minute walk test (m)	624.8 \pm 121.8	630.0	736.7 \pm 197.3	720.0	<0.0001	0.83
MET-min/week	2364.5 \pm 2230.6	715.5	5468.0 \pm 4441.6	4413.0	<0.0001	0.59
Trunk flexor endurance test (sec)	42.9 \pm 20.3	52.7	57.2 \pm 9.1	60.0	<0.0001	0.62
Hand grip strength test (kg)	28.0 \pm 9.9	25.0	29.5 \pm 11.2	26.0	0.03	0.39
30 Sec Balance test (sec)	27.5 \pm 10.4	24.5	28.4 \pm 10.9	25.0	0.04	0.26
Right	21.4 \pm 10.5	27.3	25.4 \pm 8.2	30.0	<0.0001	0.45
Left	22.0 \pm 10.8	30.0	25.3 \pm 8.2	30.0	0.004	0.36

Sec; Seconds, Reps; Repetitions, M; Metres, MET; Metabolic Equivalent, Min; minutes, Kg; Kilograms.

Table 7: Differences pre and post intervention in male and females for non-normal variables.

	Male			Female			Sex – Pre			Sex – Post		
	Pre		Post	Pre		Post	P		r	P		r
	Mean ± SD	Median	Mean ± SD	Mean ± SD	Median	Mean ± SD	Mean ± SD	Median		Mean ± SD	Median	
Timed up and go test (sec)	5.1 ± 1.5	4.6	4.3 ± 0.8	4.2	5.3 ± 1.1	4.9	5.0 ± 0.9	4.7	0.26	0.14	0.01	0.36
Sit-to-stand test (reps)	26.5 ± 8.9	25.5	36.3 ± 10.0	33.0	26.7 ± 6.5	25.5	35.1 ± 9.0	33.0	0.52	0.08	0.75	0.04
6-minute walk test (m)	670.0 ± 141.5	650.0	811.7 ± 280.5	770.0	605.5 ± 108.5	600.0	705.4 ± 142.7	720.0	0.05	0.25	0.19	0.17
MET-min/week	3163.2 ± 2354.4	2686.0	6000.3 ± 5136.1	3885.0	2030.2 ± 2115.8	1386.0	5247.2 ± 4170.2	4506.0	0.05	0.25	0.77	0.04
Trunk flexor endurance test (sec)	39.2 ± 22.2	46.6	59.7 ± 1.5	60.0	44.5 ± 19.6	60.0	56.2 ± 10.7	60.0	0.24	0.15	0.19	0.17
Hand Grip strength test (kg)	40.4 ± 7.4	42.0	44.4 ± 8.8	46.0	22.7 ± 4.5	22.0	23.4 ± 4.3	24.0	<0.0001	0.78	<0.0001	0.74
Left	41.2 ± 6.6	42.0	43.1 ± 8.3	45.0	21.6 ± 4.4	22.3	22.5 ± 4.1	22.0	<0.0001	0.71	<0.0001	0.72
Right	23.7 ± 9.5	30.0	25.6 ± 8.9	30.0	20.4 ± 10.9	24.0	25.3 ± 8.0	30.0	0.27	0.14	0.87	0.02
Left	22.5 ± 8.8	27.2	25.9 ± 8.4	30.0	21.8 ± 11.6	30.0	25.1 ± 8.2	30.0	0.48	0.09	0.70	0.05

Sec; Seconds, Reps; Repetitions, M; Metres, MET; Metabolic Equivalent, Min; minutes, Kg; Kilograms

improved significantly in the right and left hands post intervention. Greater strength scores were observed in male participants as expected due to their increased muscle mass and ability to generate strength when compared to females (Skelton et al., 1994). These improvements are associated with a number of health variables including improved physical functioning, walking performance, cardiovascular health, and depression (Rantanen et al., 1999). Other onsite and telehealth interventions of similar duration and training volume reported no improvement in grip strength post intervention (Hwang et al., 2017). Core strength endurance improved significantly post intervention. This is important because good core strength may allow OA to use their upper and lower limbs more effectively in ADL and increase the effectiveness of corrective movements at times when balance is challenged e.g. trips, thus preventing falls (Granacher et al., 2013a). A systematic review of core strength training interventions for OA delivered onsite consistently report significant increases in maximal isometric strength of the trunk extensor, trunk flexor and trunk rotator muscles (Granacher et al., 2013b). These interventions predominantly focus on developing core strength and consist of 2–3 sessions per week, with 20–60 minutes of core exercises per session, for four to twelve weeks (Granacher et al., 2013a). The volume of core exercises incorporated in the current intervention was 5–7 minutes per session, twice per week for 12 weeks, which is a lower training load than many of the studies contained in the systematic review, but importantly was still significantly effective. Ultimately, the gains in strength observed in this study reduce the risk of frailty and falls, disability, morbidity, mortality and promote functional independent living and good quality of life in later years (Taaffe and Marcus, 2000).

Squat jump height and flight time, which are indicators of lower limb explosive strength and power, improved significantly post intervention. Male participants displayed greater scores than female participants, due to the higher muscle mass present in males and thus greater ability to generate explosive strength and power compared to females (Skelton et al., 1994). This increase in explosive strength and power suggests improved recruitment and performance of the type II muscle fibers and thus reversal of the age-related decline in same. Improved lower limb explosive capacity is highly correlated with improved performance of ADL including walking speed, stair climbing and sit-to-stand ability (Bassey et al., 1992). It is also associated with quicker postural reaction and correction in response to a challenge to balance (Henwood and Taaffe, 2005), which is crucial for falls prevention. A systematic review of resistance training interventions in MAA and OA reports improved lower limb power in response to intervention (Straight et al., 2016). Many of these studies involved traditional resistance training using equipment or high velocity/high power training, 2–3 days per week, with low to high training volume. Home-based multimodal interventions have also been shown to improve strength and functional ability in this population (Thiebaud et al., 2014).

Balance improved significantly in the right and left leg post intervention. This is associated with falls prevention, functional independent living and enhanced quality of life in later years (Tiedemann et al., 2011). The training sessions in the current study incorporated 5–10 minutes of balance exercises twice per week. Our findings of improved balance post intervention are supported by a systematic review of other onsite interventions for OA incorporating balance training (Cadore et al., 2013). In contrast, another 12-week online (telehealth) intervention for OA incorporating a similar total weekly volume of training, reported no change in balance post intervention (Hwang et al., 2017). While balance was measured as a secondary outcome in the afore mentioned study, only strength and aerobic exercises were listed as components of the intervention. Also, 12 weeks of participating in Tai Chi training, which requires balance to execute the movements, twice per week, had no effect on balance in OA (Takeshima et al., 2017). If improved balance is an intended outcome of interventions for OA, it is important to include specific balance exercises to improve this component of fitness.

Flexibility, measured by sit-and-reach performance increased significantly post intervention which reflects improved flexibility and ROM in the lower back and hamstrings (Lemmink et al., 2003). Participants in the current study reported pain, joint issues, bone issues and muscle injuries at baseline screening. The gains in flexibility observed post intervention are associated with greater mobility and functional independent living (Chodzko-Zajko et al., 2009). Our findings are supported by other 12 week onsite interventions involving two training sessions per week (Wallace et al., 2014), but are in contrast to another 12 week onsite multimodal training intervention (Grant et al., 2004). Similar to our study, the participants in the latter study also engaged in two 60-minute multimodal sessions per week, but the authors reported no change in sit-and-reach performance post intervention.

Time taken to complete the TUG test decreased significantly post intervention, with females taking longer to complete the test. This particular test incorporates a number of functional movements including sit-to-stand and stand-to-sit transitions, straight gait, turning, balance and the ability to sequence tasks, which is

similar to many tasks of daily living (Ibrahim et al., 2017). Thus, improved performance in this test indicates improved mobility and functional skills for daily life (Ibrahim et al., 2017). TUG performance has been shown to increase in OA in response to 12 weeks of onsite multimodal training twice per week (Grant et al., 2004), 12 weeks of onsite strength and balance training twice per week (Lacroix et al., 2016), and 12 weeks of onsite strength, balance and aerobic training three times per week (Shahtahmassebi et al., 2019). Other 12-week telehealth or onsite interventions have reported no change in TUG post intervention (Hwang et al., 2017).

Behaviour Change and Perceptions of Health

The literature consistently reports that participation in PA is associated with improved physical health, mental health and quality of life (Chodzko-Zajko et al., 2009, Harber et al., 2017). Independent associations are also reported between individual components of fitness (strength, balance, flexibility and cardiovascular fitness) and physical health, mental health and quality of life (Chodzko-Zajko et al., 2009). There was a significant increase in physical health t-scores and mental health t-scores derived from the PROMIS-10 questionnaire post intervention. This indicates improved perception of fatigue, pain, emotional distress, overall physical function, social health and overall quality of life (Hays et al., 2009), which supports the findings of the existing literature.

Analysis of the IPAQ-SF revealed a significant increase in total PA participation per week post intervention, expressed as MET-min/week. A shift in PA behaviour was also observed. The number of participants classified as inactive (category 1) and minimally active (category 2) decreased, while the number of participants classified as taking part in health enhancing PA (category 3) increased from 31.1% pre intervention to 56.9% post intervention. This outcome is important because the physiological adaptations that occur in response to greater participation in PA have significant implications for healthy ageing and quality of life (Chodzko-Zajko et al., 2009, Harber et al., 2017). The increase in PA participation per week and the change in PA behaviour observed post intervention may be due to increased self-efficacy. While the current study did not directly assess self-efficacy, it is possible that the increased fitness, strength, balance and flexibility gained by the participants throughout the intervention, combined with increased knowledge and skills in relation to engaging in PA and understanding the role of PA in healthy ageing and the treatment and management of their injuries and clinical conditions, may have augmented self-efficacy. Other home-based, group based and educational PA interventions have reported positive results in terms of participants increasing PA behaviour (van der Bij et al., 2002). Research shows that a positive attitude towards a health behaviour, PA in this case, and a greater perceived control over that behaviour (i.e. self-efficacy) leads to behavioural intention and behaviour change in adults (Duncan and McAuley, 1993) and OA (Litt et al., 2002, McAuley et al., 2007). Other web-based interventions based on this theory have been shown to produce large effects on health behaviour (Webb et al., 2010, Irvine et al., 2013).

Limitations and Future Recommendations

While our online home-based 'Prime Time of Life' programme reports numerous positive outcomes post intervention, there were some limitations. The education workshops encouraged participants to meet the recommended weekly guidelines for aerobic, resistance, balance and flexibility training for healthy ageing, and take-home resources in the form of videos and circuit cards were provided to assist with same. Participant engagement in PA outside of the supervised training sessions was not tracked or monitored but should be in future studies. The aim of the weekly education sessions was to increase the participants knowledge and skills regarding multimodal PA and the role it plays in healthy ageing and the treatment and management of clinical conditions. This in turn facilitates an increase in self-efficacy to adopt and maintain this health behaviour. However, self-efficacy was not measured directly as part of this study and should be measured in future interventions. Social interaction is a crucial component of community based interventions, particularly for those designed for OA (Roberts et al., 2017). While the authors facilitated social interaction between the participants and the research team (e.g. checking intensity during class, question and answer sessions during and after health workshops, phone calls during the week), it was difficult to replicate the social interaction that would occur between participants themselves in onsite programme.

The current intervention was delivered during the peak of the COVID-19 restrictions in Ireland and actively sought to recruit vulnerable individuals who were cocooning with clinical conditions. Thus, it provided them with an opportunity which ultimately improved their functional ability and perceptions of physical and mental health. These positive outcomes lie in stark contrast to the extreme sedentary behaviour, weight gain and muscle atrophy that has been reported in similar populations during the same time period

(Kirwan et al., 2020). The results of our intervention add support to the literature regarding the effectiveness of online PA interventions for improving functional capacity, physical health, mental health and quality of life in MAA and OA. Online interventions are as good as onsite interventions (Hwang et al., 2017) and should be considered for wider rollout. Upskilling existing qualified community-based fitness instructors in clinical exercise physiology, as occurred in the current study, may be a cost-effective way of rolling out safe and effective multimodal PA programmes for this population moving forward.

Conclusion

Twelve weeks of home-based online multimodal training and health education can significantly improve cardiovascular fitness, strength, power, balance, flexibility, participation in physical activity and perceptions of physical health, mental health, and quality of life in MAA and OA. Online interventions can overcome many of the barriers to PA participation that are frequently reported in the literature by this population. They may also improve accessibility to programmes and require less professional and financial resources to deliver when compared to onsite interventions. While there are some limitations to online interventions, the benefits are numerous and equal to those reported for onsite interventions and should be considered for wider rollout in this population.

Additional File

The additional file for this article can be found as follows:

- **Supplementary File 1:** Sample 'Prime Time of Life' session. DOI: <https://doi.org/10.5334/paah.122.s1>

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

DC, RK and JB were contracted by Laois Sports Partnership to design, deliver and evaluate the intervention. CM is the coordinator of Laois Sports Partnership, a not-for-profit organisation.

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