Co-funded by the
Erasmus+ Programme
of the European Union

ERASMUS+ BIG COLLABORATIVE PARTNERSHIP

“FIT-OLD” PROJECT

Journal Paper 3

Technische Universität Berlin

Mine Vaganti NGO

Cracow University of Technology

Spor Elçileri Derneği

Journal Paper 3

Preprint

This is the authors' version before the revision

An SMS-based intervention for promotion of daily mobility in elderly from five countries: results of the Fit-Old project

Marija Rakovac1, Danijel Jurakić1, Davor Šentija1, João Martins2, Adilson Marques2,3, Vânia Loureiro4, Nuno Loureiro4, Houshmand Masoumi5,6, Melika Mehriar5, Andrzej Bahr7, Marta Tomczyk7, Wojciech Dynowski7, Roberto Solinas8,9, Maria Grazia Pirina8,9, Donatella Coradduzza10, Giannangelo Boccuzzi9, Birol Çağan11, Ahmet Dalcı12, Athanasios Papageorgiou13, Soultana Smaga13, Georgios Parisopoulos13, Georgios Patsakas13 and Ioannis Meimaridis13

1 - University of Zagreb Faculty of Kinesiology, Zagreb, Croatia
2 - Faculdade de Motricidade Humana, Universidade de Lisboa, Lisboa, Portugal
3 - ISAMB, Faculdade de Medicina, Universidade de Lisboa, Lisboa, Portugal
4 - Departamento de Artes, Humanidades e Desporto, Instituto Politécnico de Beja, Beja, Portugal
5 - Technische Universität Berlin, Center for Technology and Society, Berlin, Germany
6 - Department of Transport and Supply Chain Management, College of Business and Economics, University of Johannesburg, Johannesburg, South Africa
7 - Cracow University of Technology, Sports and Recreation Centre, Kraków, Poland
8 - National Sport Academy "Vassil Levski" Sofia, Bulgaria
9 - Mine Vaganti NGO, Sassari, Italy
10 - Department of Biomedical Sciences, University of Sassari, Sassari, Italy
11 - Malatya Erman Ilıcak Science High School, Malatya, Turkey
12 - İnönü Univierstiy Hayriye Basdemir Middle school, Malatya, Turkey
13 - Northern Greece Physical Education Teachers' Association Northern Greece Physical Education Teachers' Association (EGVE), Thessaloniki, Greece

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Abstract

This study aimed to determine the effect of a six-month mobile phone-based intervention for promoting physical activity, focused on the daily mobility domain, on objectively-measured physical activity and fitness in community-dwelling elderly persons living in urban areas of five European countries. The participants were 172 community-dwelling elderly persons (68% women, aged 60-92 years), randomly allocated to either the intervention group (N=90) or the control group (N=82). Physical activity of different intensities and sedentary time were measured by accelerometer, while aerobic fitness was assessed by the 2-min step test, initially and at the 6-month post-intervention follow-up testing. A 6-month text message-based intervention for promotion of physical activity was performed, based on the Capability, Opportunity, and Motivation Behavior (COM-B) model. The intervention did not produce significant changes in light, moderate or vigorous physical activity at the 6-month post-intervention assessment. There was an insignificant trend of increase in light activity of the intervention group and both groups performed significantly better in the follow-up fitness test. Also, a significant increase in sedentary behavior was detected for both groups in the follow-up assessment, potentially attributed to the effect of seasonality, with no significant between-group difference in this result when controlling for their sedentary time in the initial measurement, and the group allocation explaining only 0.9% of the variance in the follow-up sedentary time. Future studies should consider interventions of longer duration, combined interventions of higher intensity and accounting for the possible seasonality impact.

Key words: physical activity, daily transport, older age, behavior change, text message

Introduction

Health benefits of physical activity are long-known and well-established, especially its role in preventing and treating chronic non-communicable diseases (Warburton & Bredin, 2017). Regular physical activity has been associated with a reduced risk of premature deaths and there is strong evidence of the effectiveness of physical activity and targeted exercise in prevention and treatment of more than 25 different chronic diseases and conditions (Pedersen & Saltin, 2015; Warburton & Bredin, 2017).

This is of particular importance for the elderly, an ever-growing part of the population due to the demographic ageing, with more than one-fifth (21.1 %) of the population of the European Union being 65 years and older in 2022 and with an expected increase of this share in the coming years (Eurostat, 2023). There is a higher prevalence of chronic diseases in the elderly population globally, with older persons reporting one or more chronic conditions which require long-term treatments, represent a significant economic burden for the individual, but also for the healthcare systems, and can result in significant limitations, dependence in activities of daily living or disability (Maresova, et al., 2019).

Although the benefits of regular physical activity are well-known, there is a high prevalence of insufficient physical activity, with an estimated 27.5 % of adults globally not meeting the minimum level of weekly physical activity recommended by the World Health Organization (Bull, et al., 2020; WHO, 2020). Again, this is of special importance for the elderly, since the epidemiological reports regularly describe a decline in activity in the ageing population (European Commission, 2022).

The mentioned facts call for increased initiatives in active lifestyle promotion. Previous interventions for the promotion of physical activity in community-dwelling elderly included different behavior change techniques and were heterogeneous in their designs, although with often a positive outcome of increased physical activity, usually within a 12-month period (Zubala, et al., 2017). Zubala et al. (2017) identified the recommendation of low- to moderate-intensity physical activity as one of the characteristics of interventions more pronouncedly associated with their positive effects, although a general uncertainty remains around the characteristics and components of interventions that would prove to be most beneficial. Mobile phone-based interventions using mobile applications

FIT-OLD
This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

showed potential for promotion of activity and reduction of sedentary time within shorter periods of 3-6 months, although performed in smaller samples and providing moderate quality evidence (Yerrakalva, Yerrakalva, Hajna, & Griffin, 2019).

Within the Erasmus+ Sport co-funded project "Interventions in the Elderly's Mobility Modes for Promotion of their Physical Activity and Fitness" (Fit-Old), and based on the observed positive results of previous interventions recommending low- to moderate-intensity physical activity, the purpose of this study was to determine the effect of a six-month mobile phone-based intervention for the promotion of physical activity, focused on daily mobility domain, on objectively-measured physical activity and fitness in community-dwelling elderly persons living in urban areas of five European countries.

Methods

Participants and study design

This prospective intervention study was performed as part of the Erasmus+ project "Interventions in the Elderly's Mobility Modes for Promotion of their Physical Activity and Fitness" (Fit-Old), funded by the European Union [Grant Agreement No 622623-EPP-1-2020-1-DESPO- SCP] in the period 2021-2023, with the participation of partner institutions (academic and non-governmental organizations) from seven countries: Germany (coordinator), Portugal, Poland, Croatia, Italy, Greece, and Turkey.

Data collection and intervention for promoting physical activity were undertaken in six of the mentioned countries (coordinating partner from Germany did not collect data). In the present study, due to the validity issues of accelerometry data, cumulative data are presented only from five countries (Portugal, Croatia, Poland, Greece, and Italy).

In each country, persons aged 60 or older were invited to participate in the study through project partners' networks (community services working with older people, fitness and recreation clubs, senior universities, etc.). To be included in the study, participants had to meet the following criteria: a) being healthy or in a controlled heath situation; b) being able to actively engage in conversation; c) being able to walk without an aid. Exclusion criteria comprised: a) unstable health condition; b) physical or mental (dis)abilities limiting the participation; c) visual or auditive limitations; d) history of falls during the previous year; e) living in senior homes or similar institutions; f) refusal to participate. After the approval from ethics committees of respective partner institutions, elderly citizens were approached. The study protocol, involved benefits and risks were explained and a written information was provided to the participants. Written informed consent was attained from participants and a brief exercise pre-participation health risk screening was performed. Participants filled-out a general questionnaire on sociodemographic data, physical activity, perceived characteristics of their respective neighborhoods and preferred mode of daily mobility.

A sub-sample of participants, who reported not being active in their daily mobility, and who owned mobile phones and were able to read text messages, agreed to participate in the intervention study which included initial and post-intervention objective measurement of physical activity (7-day accelerometry), assessment of aerobic fitness (2-min step test) and a 6-month SMS-based intervention for the promotion of physical activity, with emphasis on walking in daily mobility. Initial measurements were performed during spring and follow-up measurements were performed during autumn/winter in 2022.

The final sample of participants in this study consisted of 172 community-dwelling elderly persons (68% women, 60-92 years) from five urban areas in Croatia, Greece, Italy, Portugal, and Poland. The sample characteristics are presented in Table 1. Participants were randomly allocated to the intervention group (N=90, 62 females) or the control group (N=82, 55 females).

Insert Table 1 here

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Assessment of physical activity and sedentary time by accelerometry

Time spent in light-, moderate-, and vigorous physical activity, and sedentary time was estimated by the ActiGraph wGT3X-BT triaxial accelerometer (ActiGraph, GT3X model, Fort Walton Beach, FL). Participants wore the accelerometer on an elastic belt at the waist, at the level of the right iliac crest, and were informed to wear it for seven consecutive days, including weekend. They were given the advice to wear the device under the clothes, during all waking hours, except during bathing and other water activities. The participants were provided with a registration form in which they recorded the time and reason for possible device removal during waking hours. The research group defined a protocol for personal delivery of the accelerometers, which was strictly followed. Before the start of data collection, training and pilot accelerometry measurement was performed under the supervision and support of partners from the University of Lisbon. During the download, the epochs were set to 15 seconds, and the biometric data was filled-out. Both .agd and .gt3x files were stored using the participants' codes as file names.

In data processing, non-wear time was defined as a period of at least 90 consecutive 0 counts. A valid day comprised > 10 hours of wear time (Troiano, et al., 2008). Furthermore, to be included in the final analysis, a participant had to have at least three valid days (at least one of which a weekend day). In the quality control and harmonization process, an initial preliminary data validation analysis, as described above, was performed by each country on their respective data. After that, a centralized reprocessing with the highest data resolution using the *Actilife* software, following standardized procedures was assured from FMH. The cutoff values defining physical activity intensity and enabling quantification of the mean time spent sedentary at light-, moderate- or vigorous intensity were the following: sedentary: < 100 counts·min- 1; light: 100-2019 counts·min-1; moderate: 2020-5998 counts·min-1 (corresponding to 3-5.9 METs); vigorous: ≥ 5999 counts·min-1 (corresponding to ≥ 6 METs) (Troiano et al., 2008).

Aerobic fitness assessment

The participants' aerobic fitness was assessed by the 2-minute step test from the *Senior Fitness Test* battery (Rikli & Jones, 1999). Firstly, a point on the participants' thigh at the midpoint between the patella and iliac crest was marked. Then the distance between this point and the floor was measured with a measuring tape, and a mark with masking tape was made on the wall beside the participant, at the height from the ground to the measured mid-thigh point. The participants were then asked to march in place, lifting the knees to the height of the mark on the wall. The test result was the total number of times the right knee reached the marked level within two minutes. The results were interpreted according to the instructions by Rikli and Jones (1999, 2013).

Intervention for physical activity promotion

The intervention for physical activity promotion was text-message based. It lasted six months (24 weeks). During this period, participants received a total of 42 SMS-messages on their mobile phones. Two messages per week were sent for the duration of the intervention, one message on Monday and the other on Thursday. Messages were delivered around the time of day when participants were most receptive (around 11am or midday).

The employed message strategy comprised the usage of: a positive and encouraging tone, reminders; direct, simples and concise language; one idea per message; emphasizing the benefits of action (positive framing) over the consequences of inaction (negative framing). The messages were designed as clear and direct, offering practical and relevant advice, in simple language for older adults. To avoid participant boredom each message was unique. Messages were first composed in English and then translated and culturally adapted into the languages of partner countries.

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The following message structure was applied: Week 1 – introduction, followed by 11 cycles of two weeks, each cycle composed of: 1 information/motivation message, 1 challenge message, 1 self-monitoring message, 1 - feedback message; Week 24 – conclusion.

The theoretical background for message design was the Capability, Opportunity, and Motivation Behavior (COM-B) model (Michie, van Stralen, & West, 2011). Behavior Change Techniques used to address capability, opportunity and motivation were as follows: verbal persuasion, prompt cues, information about health consequences, instruction on how to perform a behavior, graded tasks (advice about the gradual increase in physical activity), goal setting (behavior and outcome – advice on setting SMART goals), action planning, self-monitoring behavior, problem-solving (identifying motivators and barriers to physical activity, advice on action planning), feedback on behavior, social comparison, demonstration of the behavior, social support (Michie, et al., 2013).

Data analysis

All continuous data are presented as mean ± SD, range. Categorical data are presented as frequencies. The normality of distribution of continuous data was tested by the Kolmogorov-Smirnov test. For the variables that were not normally distributed, pre-post changes within groups were tested by the Wilcoxon Signed-Rank Test. Between-group difference at the initial and the final measurement was tested by Mann-Whitney U Test. The pre-post difference in mean sedentary time per day between the two groups, while controlling for their initial results, were tested by one-way analysis of covariance (ANCOVA). The within-group pre-post change in sedentary time per day was tested by paired samples t-test. All analyses were performed using IBM SPSS Statistics ver. 29.0.1.0(171). Statistical significance was set at $p<0.05$.

Results

The levels of light-, moderate- and vigorous physical activity and sedentary activity, expressed in minutes/day, as well as the results of the two-minute step test, pre- and post-intervention, are presented in Table 2.

Insert Table 2 here

Since solely daily sedentary activity followed a normal distribution in both measurements $p = .200$), non-parametric tests were employed to analyze all the other measured variables. Results of the Wilcoxon Signed-Rank Test to check for pre-post within group differences in the measured variables for the intervention and control group are presented in Table 3.

Insert Table 3 here

A statistically significant pre-post difference was found for the two-minute step test assessing physical fitness, for both groups. Both the intervention group ($z = -7.560$, $p < .001$) and the control group ($z = -6.573$, $p < .001$) performed better in the follow-up measurement.

The between-group differences in the variables of physical activity and fitness at the initial and follow-up measurement are presented in Table 4. The median values differed significantly between the intervention and control group in the follow-up measurement for vigorous activity domain, with the intervention group performing significantly better ($U = 3040$, $z = -2.038$, $p = .042$).

Insert Table 4 here

After preliminary checks were made to ensure there was no violation of necessary assumptions, a one-way between-group analysis of covariance was performed to compare the

FIT-OLD

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

follow-up sedentary time between the intervention and control group (independent variable), while controlling for their sedentary time in the initial measurement (Table 5). The dependent variable was sedentary time measured after the intervention, while the covariate was sedentary time measured in initial assessment. There was no significant difference between the two groups in the follow-up sedentary time ($F(1, 169) = 1.60$, $p = .207$, partial eta squared = .01). Group allocation explained only 0.9% of the variance in the follow-up sedentary time. There was a significant relationship between pre-intervention and post-intervention sedentary time – 24% of the variance in post-intervention time was explained by pre-intervention sedentary time (partial eta squared = .24).

Insert Table 5 here

Within-group differences in pre- and post-intervention sedentary activity are presented in Table 6. In the intervention group there was a statistically significant increase in sitting time between initial (525.5 ± 70.5 min/day) and follow-up measurement (573.8 ± 76.6 min/day). The mean increase was 48.3 min/day with a 95% confidence interval of 32.1-64.5 min/day, with a medium effect size (d= .63).

Insert Table 6 here

In the control group the sitting time increased as well, from 515.3 ± 78.3 min/day to 555.2 ± 81.5 min/day. The mean increase was 39.8 min/day with a 95% confidence interval of 22.6-57.1, with a medium effect size ($d = .51$).

Discussion and conclusions

The study aimed to explore the effect of a six-month SMS-based intervention for physical activity promotion on accelerometry-measured physical activity of different intensities, sedentary time and physical fitness in a convenient sample of community-dwelling people aged 60 years or older from five European countries, randomly allocated to either intervention or control group. The intervention group had a significantly better result than the control group in the post-intervention measurement only for vigorous activity (Table 4). Both groups performed significantly better in the follow-up fitness test. Also, a significant increase in sitting time was detected for both groups in the follow-up measurement, with no significant between-group difference in this result when controlling for their sedentary time in the initial measurement, and the group allocation explaining only 0.9% of the variance in the follow-up sedentary time.

Although there was no significant pre-post intervention difference in physical activity, the inspection of mean and median values of measured variables in the intervention group shows a trend of increase in light-intensity activity in the follow-up measurement (mean ± SD (median), 220.6±56.9 (225.2) *vs* 212.1±54.7 (204.2) min/day), which could be considered as being in line with the promotion of active daily mobility. In the same group moderate and vigorous activity decreased in the follow-up measurement, although not significantly. In the control group there was an insignificant decrease in activities of all intensities. Previous studies using SMS-based interventions yielded different results and the comparison is limited due to their diverse design and methodology (Elavsky, Knapova, Klocek, & Smahel, 2019).

E.g., a short, six-week SMS-based intervention (three motivational messages per day, three days per week) in African Americans aged 60-85 years (N = 36) significantly increased pedometer-measured step count (+679 vs +398 in the control group, receiving only pedometers and walking manuals; $p < .05$) (Kim & Glanz, 2013). In a randomized clinical trial on 710 participants with coronary heart disease (aged 58 ± 9.2 years), predominantly (85%) insufficiently active, a six-month

FIT-OLD
This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

intervention (4 text messages per week – motivational, advise or supportive, selected according to participants' characteristics) yielded a significant post-intervention increase in physical activity, assessed with the *Global Physical Activity Questionnaire* (Bull, Maslin, & Armstrong, 2009) (+345 metabolic equivalent (MET)-min/week, 95% CI 195-495, $p < .001$) (Chow, et al., 2015; Thakkar, Redfern, Thiagalingam, & Chow, 2016). The intervention group showed increased leisure-time physical activity (471 vs. 307 MET-min/week in the control group, $p = .001$) and transport-domain activity (230 vs. 128 MET-min/week, $p = .002$), and decreased sedentary times (494 vs. 587 min, $p < .001$) (Thakkar, Redfern, Thiagalingam, & Chow, 2016).

An SMS-intervention in a sample of 43 persons (age mean ± SD, 63.3 ± 4.5 years) living in an upper-middle-income country (Malaysia), who underwent a three-month intervention with the intervention group receiving an exercise booklet and five messages per week, while the control group received only the booklet, was effective in short-term exercise frequency promotion, but did not affect physical activity level (Müller, Khoo, & Morris, 2016). While after the intervention the experimental group had a significantly higher weekly exercise frequency than the control group (mean difference 1.21 times, not maintained at the follow-up assessment at six months), physical activity (MET-minutes) and sitting time (hours), assessed by the *International Physical Activity Questionnaire* (short form) (Craig, et al., 2003), were not affected by the intervention (Müller, Khoo, & Morris, 2016).

In comparison to our study, Kim and Glanz (2013) performed a shorter and more intensive intervention, including a higher weekly number of messages as well as providing participants with pedometers and walking manuals, although no conclusions on the influence of intervention on different levels of physical activity could be drawn. Chow et al. (2015) performed a 6-month intervention on a patient population, including semipersonalized messages on different lifestyle factors (smoking, diet, activity and general cardiovascular health) with a higher number of messages and subjectively measured physical activity. Müller et al. (2016) did not see any positive results in a shorter intervention combining text-messaging and a booklet.

With regard to the type of intervention, Ostrander, Thompson, & Demiris (2014) reviewed the effectiveness of using targeted messaging in promotion of physical activity of the elderly, documenting increase in physical activity in duration of up to a year, regardless of whether the message contents were tailored. The authors singled out the use of environmentally-mediated messages and taking into account participants' stage of behavioral change as intervention characteristics possibly leading to better results (Ostrander, Thompson, & Demiris (2014). The lack of positive results in our study could surely be attributed to different factors, possibly cultural differences of participants from different countries (although messages were translated and culturally adapted) and insufficient intensity of intervention of only two messages per week and no additional content – arguably, a hybrid intervention of a higher intensity would have resulted in a stronger result. Another important factor could be the impact of seasonality. The initial measurement was performed during spring, while the post-intervention measurement took place in the autumn months. The significant impact of seasonality on physical activity behavior has been shown to be consistent across studies, regardless of the methods used to assess physical activity, participants' countries of origin or their pathologies (Garriga, Sempere-Rubio, Molina-Prados, & Faubel, 2021). Significant differences in the levels of physical activity were reported between seasons more suitable for activities (higher levels of physical activity during spring and summer) and less favorable seasons (lower levels of activity in autumn and winter), with the opposite trend detected for sedentary behavior (Garriga, et al., 2021). The trends of the seasonal activity change of participants in our study are consistent with these observations. The significant increase in sedentary activity in both groups of our participants in the follow-up measurement could also be attributed to seasonal changes, with group allocation explaining a very low proportion (0.9%) of the variance in the follow-up sedentary time. Seasonal impact on objectively-measured prolonged sedentary activity in colder

FIT-OLD
This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

months has already been confirmed in a large U.S. cohort of middle-aged and older persons (Diaz, et al., 2016).

Fitness test results in our study did not follow this pattern. Both groups performed significantly better in the follow-up fitness test. Regarding seasonality, this finding is in line with the results of Bezerra et al. (2018), who observed no seasonal impact on physical fitness (muscle strength and aerobic capacity), regardless of physical activity levels and habitual exercise behavior (exercisers/non-exercisers) of 371 elderly participants (78.4 ± 5.3 years; 74.1% females), monitored during a one-year period. The finding of the increased fitness and the concurrent decreased physical activity in the follow-up assessment in both groups in our study was rather unexpected. Previous studies reported a positive correlation between objectively measured moderate- to vigorous physical activity and aerobic endurance in the Portuguese elderly ($r = 0.397$; $p = .000$), emphasizing the importance of physical activity promotion for improvement of fitness (Silva, et al., 2019). The positive association between physical activity level and different components of functional fitness, including aerobic endurance, was also observed in a sample of 623 older persons from Taiwan (Syue, et al., 2022). The aerobic capacity in our study was assessed by the 2-min step test, that was proved valid and reliable for different populations of elderly persons, including people with peripheral artery disease and knee osteoarthritis (Chow, Fitzgerald, & Rand, 2023; Braghieri, et al., 2021; de Morais, et al., 2022). Possible explanations, although somewhat speculative, for the improved fitness-test results of our participants include better motivation and familiarization with the test protocol.

Finally, the significant between-group difference in the post-intervention level of vigorous activity, in favor of the intervention group, may be considered of no practical importance, since the mean time spent in vigorous activities per day was very short (less than a minute per day) and both groups even experienced a decrease in the higher-intensity activity during the studied period.

Several limitations of this study should be mentioned. The overall sample is rather small considering it comprises elderly persons from five different countries. As already mentioned, cultural differences might have influenced the results. The intervention lasted six months and was based only on mobile-phone text messages sent two times per week. Although SMS texting was previously found to be an acceptable intervention method for promoting messages on physical activity, a higher frequency of messaging might have positively influenced the outcome (Hall, Cole-Lewis, & Bernhardt, 2015). The frequency of the text messages was decided by the project partners in order not to saturate the SMS receivers. Also, tailored messaging combined with other intervention strategies (e.g., phone calls; intermediate personal meetings with the participants; motivational interviews) might have produced more positive results. To avoid the effect of seasonality and to influence and detect longer-term changes, interventions of longer duration with follow-up measurements in different seasons should be carried out.

In conclusion, a six-month SMS-based intervention (two messages per week) for promotion of physical activity in 172 community-dwelling people aged 60+ from five European countries, randomly allocated to either intervention or control group, did not produce significant changes in light-, moderate- or vigorous physical activity at the 6-month post-intervention assessment. There was an insignificant trend of increase in light activity of the intervention group and both groups performed significantly better in the follow-up fitness test. Also, a significant increase in sedentary time was detected for both groups in the follow-up assessment, attributed to the effect of seasonality. Future studies should consider interventions of longer duration, combined interventions of higher intensity and accounting for the possible seasonality impact.

FIT-OLD

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Acknowledgments

The current study has been designed as a part of the project "Interventions in the Elderly's Mobility Modes for Promotion of their Physical Activity and Fitness"- Fit-Old. (project number 622623-EPP-1-2020-1-DE-SPO-SCP) funded by the ERASMUS+ program of the European Commission. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors are grateful to the participants, survey staff, who contributed to management of the survey in the selected settings, guiding participants about the questions, and/or translating the questionnaires from English to local languages and preparing them for distribution.

Funding

The current study has been designed as a part of the project "Interventions in the Elderly's Mobility Modes for Promotion of their Physical Activity and Fitness"- Fit-Old. (project number 622623-EPP-1-2020-1-DE-SPO-SCP) funded by the ERASMUS+ program of the European Commission.

Conflict of Interest

The authors declare no financial or other conflicts of interests.

References

Bezerra, P., Rodrigues, L.P., Ayan, C., & Cancela, J.M. (2018). The influence of winter and summer seasons on physical fitness in aged population. *Archives of gerontology and geriatrics, 76*, 80-84. doi: 10.1016/j.archger.2018.02.008

Braghieri, H.A., Kanegusuku, H., Corso, S.D., Cucato, G.G., Monteiro, F., Wolosker, N., Correia, M.A., & Ritti-Dias, R.M. (2021). Validity and reliability of 2-min step test in patients with symptomatic peripheral artery disease. *Journal of vascular nursing, 39*(2), 33-38. doi: 10.1016/j.jvn.2021.02.004

Bull, F.C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., et al. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. British journal of sports medicine, 54(24), 1451-1462. doi: 10.1136/bjsports-2020-102955

Bull, F.C., Maslin, T.S., & Armstrong, T. (2009). Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *Journal of physical activity & health, 6*(6), 790-804. doi: 10.1123/jpah.6.6.790

Hall, A.K., Cole-Lewis, H., & Bernhardt, J.M. (2015). Mobile text messaging for health: a systematic review of reviews. *Annual review of public health, 36,* 393-415. doi: 10.1146/annurev-publhealth-031914-122855.

Chow, C.K., Redfern, J., Hillis, G.S., Thakkar, J., Santo, K., Hackett, M.L., Jan, S., Graves, N., de Keizer, L., Barry, T., Bompoint, S., Stepien, S., Whittaker, R., Rodgers, A., & Thiagalingam, A. (2015). Effect of Lifestyle-Focused Text Messaging on Risk Factor Modification in Patients With Coronary Heart Disease: A Randomized Clinical Trial. *JAMA, 314*(12), 1255-1263. doi: 10.1001/jama.2015.10945

Chow, J.J.L., Fitzgerald, C., & Rand, S. (2023). The 2 min step test: A reliable and valid measure of functional capacity in older adults post coronary revascularisation. *Physiotherapy research international,* 28(2), e1984. doi: 10.1002/pri.1984

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and science in sports and exercise, 35*(8), 1381–1395. doi: 10.1249/01.MSS.0000078924.61453.FB

de Morais Almeida, T.F., Dibai-Filho, A.V., de Freitas Thomaz, F., Lima, E.A.A., & Cabido, C.E.T. (2022). Construct validity and reliability of the 2-minute step test in patients with knee osteoarthritis. *BMC musculoskeletal disorders, 23*(1), 159. doi: 10.1186/s12891-022-05114-1

Diaz, K.M., Howard, V.J., Hutto, B., Colabianchi, N., Vena, J.E., Blair, S.N., & Hooker, S.P. (2016). Patterns of Sedentary Behavior in US Middle-Age and Older Adults: The REGARDS Study. *Medicine and science in sports and exercise, 48*(3), 430-438. doi: 10.1249/MSS.0000000000000792

Elavsky, S., Knapova, L., Klocek, A., & Smahel, D. (2019). Mobile Health Interventions for Physical Activity, Sedentary Behavior, and Sleep in Adults Aged 50 Years and Older: A Systematic Literature Review. *Journal of aging and physical activity, 27*(4), 565-593. doi: 10.1123/japa.2017-0410

European Commission. (2022). *Special Eurobarometer 525 – Sport and physical activity.* Brussels, Belgium: European Commission.

Eurostat. (2023). *Population structure and ageing.* /on-line/. Retrieved June 23, 2023 from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_structure_and_ageing

Garriga, A., Sempere-Rubio, N., Molina-Prados, M.J., & Faubel, R. (2021). Impact of Seasonality on Physical Activity: A Systematic Review. *International journal of environmental research and public health, 19*(1), 2. doi: 10.3390/ijerph19010002

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Kim, B.H., & Glanz, K. (2013). Text messaging to motivate walking in older African Americans: a randomized controlled trial. *American journal of preventive medicine, 44*(1), 71-75. doi: 10.1016/j.amepre.2012.09.050

Maresova, P., Javanmardi, E., Barakovic, S., Barakovic Husic, J., Tomsone, S., Krejcar, O., & Kuca, K. (2019). Consequences of chronic diseases and other limitations associated with old age - a scoping review. *BMC Public Health, 19*(1), 1431. doi: 10.1186/s12889-019-7762-5

Michie, S., van Stralen, M.M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation science,* 6, 42. doi: 10.1186/1748-5908-6-42

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M.P., Cane, J., & Wood, C.E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of behavioral medicine, 46*(1), 81-95. doi: 10.1007/s12160-013-9486-6

Müller, A.M., Khoo, S., & Morris, T. (2016). Text Messaging for Exercise Promotion in Older Adults From an Upper-Middle-Income Country: Randomized Controlled Trial. *Journal of medical internet research, 18*(1), e5. doi: 10.2196/jmir.5235

Ostrander, R.E., Thompson, H.J., & Demiris, G. (2014). Using targeted messaging to increase physical activity in older adults: a review. *Journal of gerontological nursing, 40*(9), 36-48. doi: 10.3928/00989134-20140324-03

Pedersen, B.K., & Saltin, B. (2015). Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scandinavian journal of medicine & science in sports, 25 Suppl 3*, 1-72. doi: 10.1111/sms.12581

Rikli, R.E., & Jones, C.J. (1999). Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*, *7*(2), 129–161. Doi: 10.1123/japa.7.2.129

Rikli, R.E., & Jones, C.J. (2013). Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. *The Gerontologist, 53*(2), 255-267. doi: 10.1093/geront/gns071

Silva, F.M., Petrica, J., Serrano, J., Paulo, R., Ramalho, A., Lucas, D., Ferreira, J.P., & Duarte-Mendes, P. (2019). The Sedentary Time and Physical Activity Levels on Physical Fitness in the Elderly: A Comparative Cross Sectional Study. *International journal of environmental research and public health, 16*(19), 3697. doi: 10.3390/ijerph16193697

Syue, S.H., Yang, H.F., Wang, C.W., Hung, S.Y., Lee, P.H., & Fan, S.Y. (2022). The Associations between Physical Activity, Functional Fitness, and Life Satisfaction among Community-Dwelling Older Adults. *International journal of environmental research and public health, 19*(13), 8043. doi: 10.3390/ijerph19138043

Thakkar, J., Redfern, J., Thiagalingam, A., & Chow, C.K. (Patterns, predictors and effects of texting intervention on physical activity in CHD - insights from the TEXT ME randomized clinical trial. *European journal of preventive cardiology, 23*(17), 1894-1902. doi: 10.1177/2047487316664190

Troiano, R.P., Berrigan, D., Dodd, K.W., Mâsse, L.C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and science in sports and exercise, 40*(1), 181-188. doi: 10.1249/mss.0b013e31815a51b3

Warburton, D.E.R., & Bredin, S.S.D. (2017). Health benefits of physical activity: a systematic review of current systematic reviews. *Current opinion in cardiology, 32*(5), 541-556. doi: 10.1097/HCO.0000000000000437

World Health Organization (WHO). (2020). *WHO guidelines on physical activity and sedentary behaviour.* Geneva, Switzerland: WHO.

FIT-OLD

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Journal Paper 3

Yerrakalva, D., Yerrakalva, D., Hajna, S., & Griffin, S. (2019). Effects of Mobile Health App Interventions on Sedentary Time, Physical Activity, and Fitness in Older Adults: Systematic Review and Meta-Analysis. *Journal of Medical Internet Research, 21*(11), e14343. doi: 10.2196/14343

Zubala, A., MacGillivray, S., Frost, H., Kroll, T., Skelton, D.A., Gavine, A., Gray, N.M., Toma, M., & Morris, J. (2017). Promotion of physical activity interventions for community dwelling older adults: A systematic review of reviews. *PLoS One, 12*(7), e0180902. doi: 10.1371/journal.pone.0180902

Tables

Table 1. Sample characteristics

	Females (N = 117)		Males (N = 55)	
	Mean±SD	Range	Mean±SD	Range
Age (years)	71.5±6.2	61-92	71.8±5.8	60-85
Body height (cm)	162.0±9.8	144-190	169.2±8.2	153-187
Body weight (kg)	70.3±12.2	47-120	75.0±10.3	55-96

FIT-OLD
This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table 2. Physical and sedentary activity and fitness measured pre- and post-intervention, by group, and test for normality distribution for the total sample

	Intervention group (N = 90)		Control group (N = 82)		Total sample (N = 172)	
	Mean±SD	Range	Mean±SD	Range	K-S*	*p*
Initial measurement						
Light activity (minutes/day)	212.1±54.7	79.1-376.5	216.5±60.9	70.5-359.4	0.078	.013
Moderate activity	30.8±25.4	1.3-159.6	37.4±28.5	1.4-161.3	0.114	<.001
(minutes/day)					0.426	<.001
Vigorous activity	0.5±2.3	0.0-15.0	0.4±1.2	0.0-9.3	0.036	.200
(minutes/day)	525.5±70.5	353.8-	515.3±78.3	344.1-	0.046	.200
Sedentary activity	79.1±16.4	675.5	82.4±16.9	677.8		
(minutes/day)		44-126		45-130		
Two-minute step test (N of					0.048	.200
steps)	220.6±56.9		210.5±53.3		0.129	<.001
	27.3±16.9	46.4-400.8	32.5±27.7	98.7-353.3	0.400	<.001
Follow-up measurement	0.2±0.7	1.0-96.7	0.2±0.9	0.9-160.2	0.046	.200
Light activity (minutes/day)	573.8±76.6	0.0-6.6	555.2±81.5	0.0-7.1	0.103	<.001
Moderate activity	114.4±33.4	311.8-	115.1±35.9	365.6-		
(minutes/day)		795.2		831.2		
Vigorous activity		55-226		61-252		
(minutes/day)						
Sedentary activity						
(minutes/day)						
Two-minute step test (N of						
steps)						

*Kolmogorov-Smirnov test

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table 3. Results of the Wilcoxon Signed-Rank Test for pre-post within group differences in the measured variables

Intervention group				
Post-pre difference	Two-minute step test	Light activity/day	Moderate activity/day	Vigorous activity/day
Z	-7.560	-1.555	-1.541	-1.075
p	<.001	.120	.123	.282
Control group				
Post-pre difference	Two-minute step test	Light activity/day	Moderate activity/day	Vigorous activity/day
Z	-6.573	-1.269	-1.870	-1.843
p	<.001	.204	.061	.065

FIT-OLD

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Journal Paper 3

Table 4. Independent-Samples Mann-Whitney U Test between intervention and control group

	Mean Rank				
	Intervention group (N=90)	Control Group (N=82)	Mann-Whitney U	z-score	p
Initial measurement					
Light activity (minutes/day)	85.4	87.8	3793	0.316	.752
Moderate activity (minutes/day)	80.4	93.2	4237	1.675	.094
Vigorous activity (minutes/day)	81.4	92.1	4151	1.458	.145
Two-minute step test (N of steps)	81.2	92.4	4171	1.475	.140
Follow-up measurement					
Light activity (minutes/day)	90.7	81.9	3315	-1.151	.250
Moderate activity (minutes/day)	85.3	87.8	3794	0.319	.750
Vigorous activity (minutes/day)	93.7	78.6	3040	-2.038	.042
Two-minute step test (N of steps)	86.5	86.5	3686	-0.012	.990

FIT-OLD

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table 5. Results of the one-way ANCOVA on between-group differences in post-intervention sedentary time, while controlling for initial sedentary time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	264878.88[a]	2	132439.44	27.64	<.001	.246
Intercept	297934.47	1	297934.47	62.17	<.001	.269
Pre-intervention sedentary time	249949.16	1	249949.16	52.16	<.001	.236
Group allocation*	7686.35	1	7686.35	1.60	.207	.009
Error	809855.93	169	4792.05			
Total	55967921.38	172				
Corrected Total	1074734.81	171				

[a]R Squared = .246 (Adjusted R Squared = .238) *intervention/control group

FIT-OLD This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table 6. Paired Samples T-test for within-group pre-post differences in sedentary activity

	Paired Differences					t	df	Two-Sided p
	Mean (min/ day)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Intervention group								
Initial sedentary activity Follow-up sedentary activity	-48.3	77.3	8.2	-64.5	-32.1	-5.93	89	<.001
Control group								
Initial sedentary activity Follow-up sedentary activity	-39.8	78.5	8.7	-57.1	-22.6	-4.60	81	<.001

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

DISCLAIMER

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

This project has been funded by the Erasmus+ Programme of the European Union (Grant Agreement No 613171-EPP-1-2019-1-DE-SPO-SCP. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.