Sport Sciences for Health (2018) 14:275–282
https://doi.org/10.1007/s11332-017-0424-z

ORIGINAL ARTICLE

A wearable-enhanced fitness program for older adults, combining fitness trackers and gamification elements: the pilot study fMOOC@Home

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Received: 8 June 2017 / Accepted: 29 December 2017 / Published online: 10 January 2018

Abstract

Purpose Besides nutrition, physical activity is one of the most important prerequisites for healthy aging. The public funded R&D project fMOOC (Fitness MOOC—interaction of older adults with wearable fitness trackers in a Massive Open Online Course), aimed at encouraging older adults to increase their physical activity with the help of a senior-friendly wearable enhanced training system composed of a smartphone training-app coupled with an activity-tracking device.

Methods In a pilot study, we evaluated the training system in the home environment of older adults—20 older adults, used the smartphone app and the activity-tracking device for 4 weeks. We investigated the usability of the system using validated usability tests and asked the participants about use patterns and acceptance. We also examined the effectiveness of the training by measuring changes in strength, physical activity, balancing ability and endurance.

Results The analysis of the data shows that the majority of the participants (60%) engaged in the training program on a regular basis. Among the various technical components of the training program, the fitness tracking devices were used most frequently (90% on a daily basis). An interesting result is that even within a short training period of 4 weeks, and within the small sample of 20 participants, the data showed significant health improvements regarding the duration of daily physical activity ($T(19) = -2.274$; $p < 0.05$) and the balancing ability ($T(19) = -3.048$; $p < 0.01$).

Conclusion A wearable-enhanced fitness training program, can motivate older adults to be more physically active.

Keywords Older adults · Physical activity · Wearables · Usability

Background

The World Health Organization (WHO) defines physical activity (PA) as "any bodily movement produced by the skeletal muscles that requires energy expenditure" [1]. Regular PA reduces the risks of several health problems such as cardiovascular diseases, type II diabetes and metabolic syndrome [2, 3]. Intervention strategies to increase PA, and to quantify the rate and magnitude of change in risk factors, are important. Intervention studies have shown that already in a short exercise training of 4–6 weeks positive changes, e.g. in lowering blood pressure can be achieved [4]. The impact of fitness components increases when people age; regular PA is particularly important for older adults to maintain their mobility and to reduce the risk of falls, as well as injury from falls [5]. Theories on enhancing PA behavior and maintenance suggest that during the development of strategies, individual psychosocial processes, such as goal-setting, motivation and self-efficacy, must be considered [6, 7].

Motivational aspects, such as predictors of regular participation in PA and barriers, which hinder people from being active, have been well studied in the older population. Even though a lower age correlates with PA, and having an early history of PA has also been described as a predictor of future PA, age does not seem to be a strong predictor of

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11332-017-0424-z) contains supplementary material, which is available to authorized users.

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PA. Current studies show that it is more difficult to motivate men compared to women to be active in later life [8]. Characteristics like high self-efficacy, greater social support, better knowledge of perceived benefits and a positive attitude toward PA are proven to have a strong influence on a person's being physically active [9, 10]. In relation to internal barriers, studies point out that for older adults, their health or changing health statuses are inhibiting factors, as well as the lack of time, fear of injury, lack of knowledge and lack of self-discipline [11, 12]. One factor that is too often neglected is the experience of "fun". The results of a PA intervention study for obese persons could show that enjoyment in PA was often a by-product for all participants and could become a sought-after endpoint [13]. Psychosocial reasons (e.g., enjoying group interaction and meeting with friends) are important motivators and could be easily integrated into PA interventions [14]. There is a need for methods to increase adherence (e.g. taking the prescribed medicine), especially for the elderly user. A strategy that has recently emerged to address this problem is gamification, where new technologies have already shown their high value [15].

Mobile health (mHealth) is defined as the utilization of mobile phones, smartphones, wearables and tablets to provide timely and increased accessibility to interactive healthcare resources in order to help manage chronic or acute diseases and to promote health [16]. mHealth applications are widely used not only for self-monitoring, but also in prevention and rehabilitation programs, e.g., for weight control [17], asthma control [18] and especially in diabetes [19]. Current studies have shown that mobile apps are able to empower this older target group by providing a means for PA profiles, goal-setting, feedback, social support and online expert consultation [20]. Here, other sensors could support mHealth applications. When offering PA training to older adults, qualitative studies reveal that tangible feedback from accelerometers might be an interesting approach for motivation [21]. The popularity of activity-tracking devices has increased in the last few years and many different products are on the market. The producers of these devices promise a continued, long-term adherence. However, these motivational devices lack long-term motivation and usability. In a comparison of five fitness trackers, we measured low usability and handling difficulties by older adults [22]. That may be one reason that, 6 months after buying or receiving an activity-tracking device, one-third of US consumers stop using the device [23]. Studies show that stand-alone solutions are not capable of keeping participants motivated in being physically active over a long period. Combined individual mHealth solutions might be an interesting approach, especially for older adults. Studies show that the combination of a smartphone app for self-monitoring, real-time feedback and social networking, in addition to counselling for obese adults, resulted in more weight loss than in adult groups that only had access to the smartphone app or counselling [24]. One limitation of previous research with mHealth applications is that the majority of studies on PA and its benefits have not undergone initial and systematic feasibility testing. Therefore, it is often not clear whether high dropout-rates and limited effectiveness could also be caused by poor usability and low acceptance of the technical assistive system.

With the aim of promoting sustained engagement of older adults for healthy aging, a novel wearable-enhanced mHealth system was developed in the German funded project fMOOC. The pilot study fMOOC@Home was conducted to further understand the willingness of older adults to use a combined system of a Garmin activity-tracking device and a smartphone app developed within the fMOOC project and how older adults can be motivated to be more active. The aim of the current study was to investigate which features participants were using and how often. We wanted to gain an insight into usage behavior, usability barriers and personality-related factors associated with older adults' use.

Methods

Approach

Within a user-centered design approach, a technical system, which combines wearable, mobile and learning technologies to capture and share fitness data and content such as training plans and exercise videos, was designed [25]. The fMOOC user interface of the smartphone app has been designed for older adults (aged 60+), taking into account their specific handling requirements. To fulfill these needs, the key usability principles derived from multidisciplinary usability research regarding text, navigation and language characteristics were implemented into the design process of the fMOOC user interface [25, 26]. The Garmin wearable activity tracker (Garmin vívofit) was used to track and monitor PA and the smartphone app was installed on either a Nexus 5 or Samsung Galaxy 5 (Fig. 1).

We developed three difficulty levels with the possibility to increase the frequency, intensity, or duration of exercise, following the principles of evidence-based training concepts. All exercises with older adults were recorded in a short video (Fig. 2). Within a training session participants watched the short video (20–30 s), where the exercise was explained. After that, participants were shown the number of repetition or rather the duration (a watch was integrated in the app) of the exercise for their individual difficulty level. When an exercise was completed, participants started the next short video introduction. The individual difficulty levels, as well as specific motor limitations (e.g.,

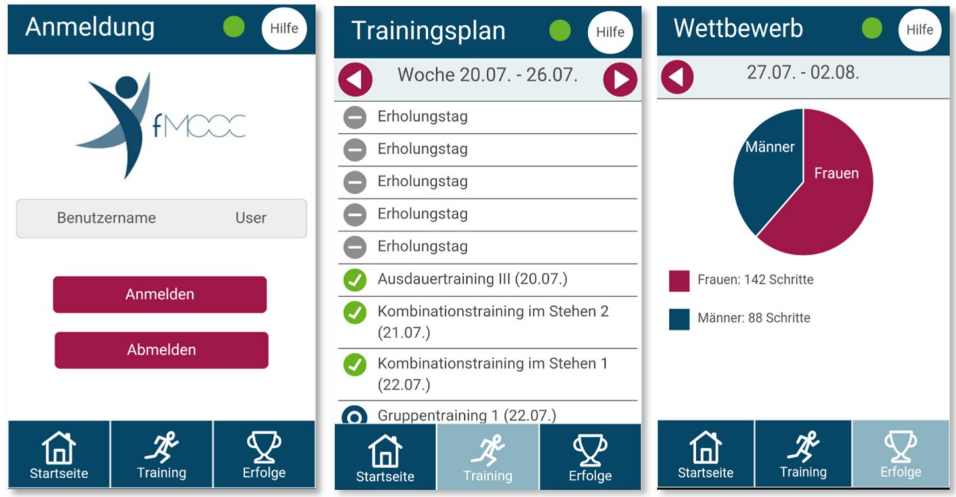

Fig. 1 Design of the smartphone app

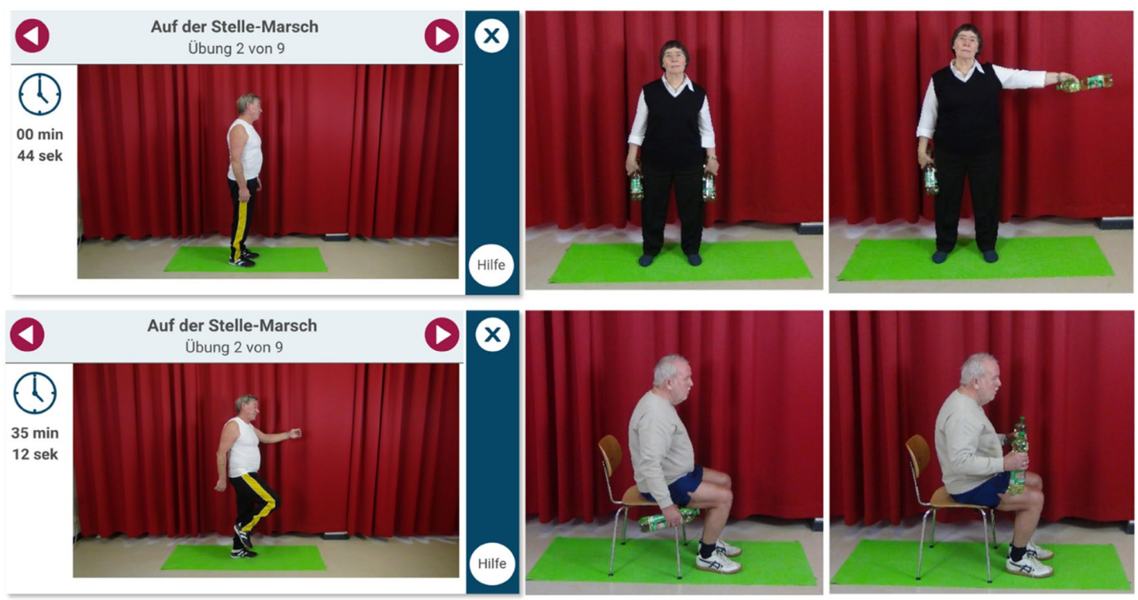

Fig. 2 Screenshots of different video-based exercises

not being able to perform exercises on the floor), were chosen in consultation with the participant and the principal investigator. The level of difficulty was determined by the number of repetitions of the different exercises—a low number of exercise repetitions (e.g. two rounds 10 squats each) and therefore overall shorter duration represented a lower level of difficulty and a higher number of repetitions (e.g. three rounds 15 squats each) and therefore longer duration represented a higher level of difficulty. The difficulty level was chosen by the participants individually on basis of their perceived fitness level. In each case four participants chose the easiest or rather the most difficult level. Twelve participants completed the training on a medium level. The 4-week training program consisted of three training days and four recovery days per week. Each training session lasted approximately 45 min and consisted of endurance, strength and balancing exercises.

Measures and procedure

In total 20 older adults took part in the pilot study. The participants were recruited from the panel of user studies of the geriatrics' research group. Inclusion criteria were defined as being $\geq$ 60 years of age. Exclusion criteria were undertaking sporting activities on a regular basis, experience with an activity-tracking device, having a high risk of falling (< 14 points on the short-fall efficacy scale [27] and having an implanted defibrillator (due to bioelectrical impedance analysis). The presented pilot study included two study visits with durations of approximately 1.5 h in the laboratory of Geriatrics Research Group. After an initial telephone screening, all participants were checked for inclusion and exclusion criteria and received an informed written consent document. In the first study visit, 20 older adults, who were not engaged in regular physical exercise, were asked several questions regarding socio-demographic data (age, sex, marital status, household size, highest educational level), digital literacy/technology usage (How often do you use a computer/tablet/smartphone/the Internet?), technology commitment [28], PA (PAQ 50+ [29]), self-assessment of motor skills (FFB-Mot [30]), resilience (RS 11 [31]), health behavior, sleep quality and their subjective fitness level. Hand and leg strength, endurance (a six-minute walk test [32]), balance (Fullerton Advanced Balance Scale [33]) and body composition (BIA mBCA 515) were assessed by the study's personnel. Furthermore, participants received the smartphone and the fitness tracker. The essential functions of the smartphone, the fitness tracking device and the smartphone app were explained in group training. Moreover, study participants received a senior-friendly handbook and a technical support phone number. Within the clinical trial, the participants were asked to carry the fitness tracker device for the next 4 weeks on a daily basis, and regularly carry out their training with the smartphone app. This short training period was chosen for different reasons. Studies have shown that physical effects can already be seen after a 4-week training period. The usability and acceptance of participants towards a technical system can already be seen after a much shorter time. Furthermore, the duration of the project fMOOC was only 1 year including requirement analysis, conception of the training, development of the app and finally the evaluation, therefore only a short evaluation period was possible. Visit 2 was the final examination during which participants were asked to repeat all tests of the first study visit and also to fill out a questionnaire regarding app usage, to rate the tracker, the overall system (System Usability Scale (SUS) [34]; User Experience Questionnaire (UEQ) [35]) and their subjective motor change. In a group discussion, each participant could express both positive and negative experiences with the system and suggest improvements for the fMOOC training program (Fig. 3).

The data were analyzed using IBM SPSS Statistics 21.0. Tests on normal distribution and variance homogeneity were conducted. Due to the data's non-normal distribution, non-parametric Mann–Whitney *U* tests, the Kruskal–Wallis test or the Wilcoxon signed-rank test were conducted (e.g., for subjective fitness levels or knowledge about activity-tracking devices). In other cases (e.g., endurance and balancing ability), *t* tests were applied.

Results

Sample

Twenty participants aged over 60 years took part in the study (10 females, 10 males, mean age 69 years, age range 62–75 years). The sample had a high digital literacy with the majority of study participants using digital technologies like smartphones (70%), computers (90%) and the Internet (90%) frequently. A tablet was used by only 30% of the participants. Participants accomplished, on average, 46 points on a 12–60 point technology commitment scale, which shows high technology commitment. This high digital literacy is owed by the free choice of the older adults to participate in the study.

Physical training compliance

In total 12 training sessions were included in the 4-week training—six sessions regarding strength and six sessions regarding endurance. Before and after each training session (strength and

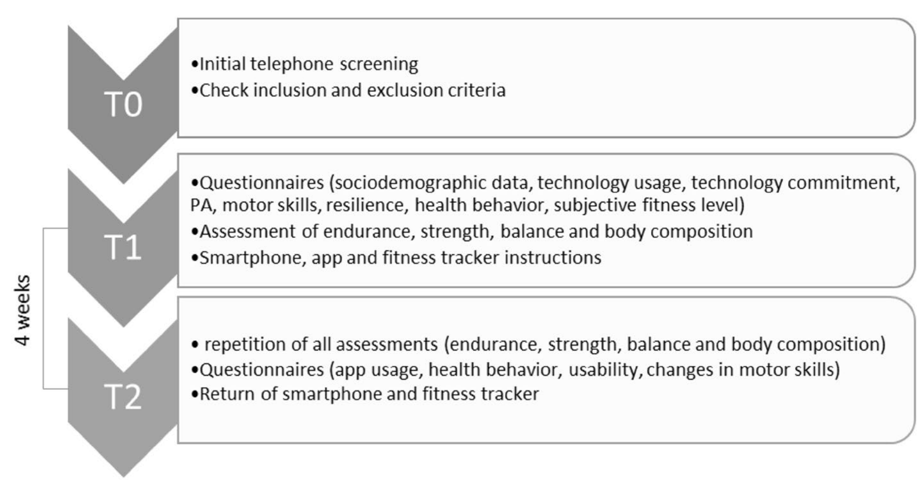

Fig. 3 Methodological approach of the study

endurance) a warm-up and cool down phase was conducted. To analyze the number of conducted exercises, subjective data as well as electronic logging data were evaluated. Three quarters of the participants stated that they conducted all exercises regarding strength. The logging data showed a lower number of participants who conducted all exercises (Table 1). 40% of the participants reported that they did not conduct the training on a regular basis. The reasons for this were lack of time ($n = 2$), health problems ($n = 2$), lack of motivation ($n = 1$) and technical problems ($n = 4$). Four of the 20 participants stated that they conducted the training together with their partner/spouse. The majority of the participants considered the exercises as rarely challenging; however, 80% considered the level of difficulty as being appropriate. The computer-generated logging data show that 55% of the participants finished all of the training units. Furthermore, 20% conducted 10 of the 12 training units. The logging data showed that the three most inactive participants were female.

Usage of the training system

The analysis of electronic logging data showed that the usage of the smartphone application varied a lot. Within the 4-week study period, participants opened the app 44 times on average (14–90). To synchronize the data of the activity-tracking device with the smartphone app, many attempts were often necessary. On average, each participant synchronized the device 128 times.

Almost all participants (18 out of 20) stated that they used the smartphone training app on a daily basis. Only two female participants used the app less than once a week. These participants were not considered as drop out, because in terms of usage of a technical device for physical training, these data are also of importance. The participants stated that they used the fitness tracking device most frequently (90% on a daily basis), followed by the display of data (50% daily) and the display of badges (35% daily). The comment function within the training app was used the least. The participants were asked if they would use the training app and/or the fitness tracking device after the trial: 55% answered "yes the training app and the activity tracking device", 10% would only use the app with the exercises and 15% would only use the activity-tracking device. As a reason to stop using the device, the training participants offered: "I don't like doing gymnastics" (♂, 67 years) and "I don't want to do any kind of sports" (♂, 70 years). Three quarters of the participants stated that it was fun to use the training system (combination of smartphone app and activity-tracking device).

Changes after intervention

At the beginning of the study, the average value of physical activity, measured by the PAQ 50+, was 140 points; 4 weeks later, it increased to 193. Thus, the PA of the test participants increased significantly ($T(19) = -2.274$; $p < 0.05$). There were no significant differences in terms of gender ($T(18) = 0.769$; $p = 0.452$). Even the descriptive data show hand and leg strength, measured by a dynamometer, increased by at least 1 kg and the endurance increased by 8 m, but there are no statistical significant differences (Table 1).

The balancing ability, measured using the FAB, increased significantly from 33.2 to 34.9 points ($T(19) = -3.048$; $p < 0.01$). The body composition was measured via bioelectrical impedance analysis. At the second visit, there were no differences in BMI, fat mass or fatless mass. Neither for hand or leg strength nor for endurance or balance significant differences in terms of gender were found (Table 2).

Participants were also asked about subjective changes in terms of health and fitness. There were no differences in ratings of the subjective heath status ($z = -0.378$, $p = 0.273$), but participants rated their fitness level after the intervention significant higher ($z = -2.828$; $p < 0.01$). In particular, the endurance was assessed better after the 4-week training ($z = 2.081$; $p < 0.05$).

The self-assessment of motoric skills (measured by FFB-Mot) showed no differences before (Ø 89.8) and after (Ø 90.6) the intervention ($T(19) = -0.552$; $p = 0.588$). Changes were found again in the subcategory endurance from 20.3 to 21.7 points ($T(19) = -2.316$; $p < 0.05$). Furthermore, the number of participants rating their fitness level as "good" increased significantly from 25 to 45% ($T(19) = 3.199$; $p < 0.01$).

Table 1 Physical training compliance—difference between subjective and objective data

		Subjective data (%)	Logging data (%)
Number of participants who conducted all training sessions	Endurance	70	50
	Strength	75	55

Table 2 Differences in hand and leg strength and balancing ability after the intervention

	Before	After	p
Hand strength, right (kg)	28.3 ± 8.0	29.0 ± 8.9	n.s.
Hand strength, left (kg)	26.5 ± 8.1	28.0 ± 10.7	n.s.
Leg strength, right (kg)	44.3 ± 10.7	46.3 ± 10.9	n.s.
Leg strength, left (kg)	41.4 ± 10.4	45.4 ± 10.3	n.s.
Endurance (meters in 6 min)	563.1 ± 76.3	571.4 ± 82.7	n.s.
Balance (points)	33.2 ± 4.0	34.9 ± 3.7	< 0.01

In each case, four participants reported improved sleep quality (fall asleep, full night's sleep). Eight participants stated that they moved more confidently. More than half of the participants ($n = 11$) reported improved motivation to be active in their daily living and to take car care of their health.

Usability and acceptance

Participants rerated the usability of the system with SUS and the UEQ. On average the system scored 71 of 100 points, which complies with a medium-to-high level of usability (52–72 = ok; > 72 = good).

The UEQ allowed a more differentiated view. The training system (combination of smartphone app and activity-tracking device) was rated in all items (8) of the both dimensions stimulation and perspicuity positively (Fig. 4). Particular participants rated the comprehensibility and the learnability positively.

When rating the different functions of the training systems participants assessed the fitness tracking device, the strength exercises and the displaying of training results best (90% "good" or "very good"). The instructions and the warm-up/cool down exercises were rated "good" or "very good" by 70% of the participants.

Discussion

This pilot study showed, that older adults are willing to use a learning solution combining the Massive Open Online Course (MOOC) approach with an embodied learning experience enhanced by an activity-tracking device, provided that certain conditions are fulfilled. The comparison of the presented results with other studies is difficult because of the specific technical system used in the study. The fitness tracking device, especially, was used frequently by the participants. A reason for that might be the high technical experience of the participants in the study. In the presented study 90% of the participants used a computer and the Internet and 70% of the participants used a smartphone frequently. In general population only 53%, or rather 38% of the 60- to 69-year-old people are using a laptop or computer. In 2016, a smartphone was used by 51% of the older adults [36]. Furthermore, the technology commitment of participants was high. Participants with a high technical affinity are usually more willing to participate in studies with modern technologies like fitness tracking devices or smartphones than participants without any technology experience.

The evidence-based training was rated by the older adults as "very motivating" in contrast to other motivational elements like badges. In connection to the results of [15], badges do not seem to be a good approach to motivate older adults to engage in physical training. However, the approach of Simmonds et al., assumes that tangible feedback from accelerometers may enhance motivation. This can be confirmed with the results of the present study [21]. In addition, a combination of feedback, social networking and a smartphone app for self-monitoring seemed to motivate older adults to use a technically supported training system [24]. The study of Klompstra et al. showed that men are more difficult to motivate into being active in later life, but the participants who did not complete the training in the present study were female [8]. A reason for the higher training adherence of men in the study might be the higher digital competence of men in general. In the usage of information and communication technologies there is a significant difference between men and women. While only 75% of women are internet users, 85% of men use the Internet [36]. The difference remains in older adults. In this age group (> 64 years), 55.9% of men and 36.3% of women are internet users [37]. In conclusion, the fMOOC@Home study showed that it is possible to improve participants' health and wellbeing through evidence-based training, and using a PA tracker

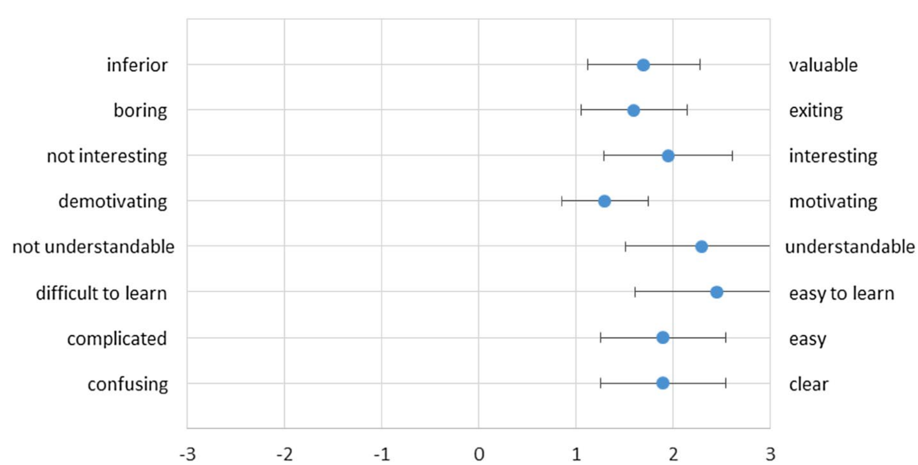

Fig. 4 Results of the user experience questionnaire

and additional learning elements. Despite a short training period and small sample, the balancing ability of the participants and further subjective parameters (sleep, fitness level, endurance) improved. Considering this, physicians or physiotherapists can recommend such a combination of training to motivate older adults into being more physically active or to continue therapeutic or rehabilitation exercises at home. Such an approach can be also offered at sport clubs.

In the present pilot study, we investigated only a small homogenous sample, which included primarily well-educated and study-experienced older adults and only a 4-week intervention. Because of the homogeneity of the sample, it is possible that our findings will not apply to samples that are more heterogeneous. Furthermore, a generalization of the findings is not possible because of the use of the specific fMOOC Platform. The most important prerequisite for helping older adults to conduct physical training in their home environment seems to be an evidence-based balanced training, taking into account training duration, intensity and frequency. In addition, older adults have a need to feel safe when conducting the training, so the issue of individual performance (e.g., regarding balancing ability) has to be considered in order to address a large population. A customizable and adjustable training program can bring many more benefits. Regarding technical devices such as a smartphone app or an activity-tracking device, a high degree of usability and reliability must be ensured, especially for older adults.

For further studies and developments, a greater understanding of older adults' motivations and experiences with respect to PA is required, in order to develop interventions that resonate with the target population. To learn more about additional factors that hinder or promote PA among older adults, future research with larger samples, a longer training period and a control group with randomized treatment are needed.

Funding This article was produced as part of a project which was supported by the German Federal Ministry of Education and Research under Grant Number 16SV7100. Responsibility for the contents of this publication lies with the authors.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the ethic review board at the Charité and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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