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Feasibility and effectiveness of eHealth interventions for the promotion of physical activity in socially disadvantaged populations

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Abstract

Physical inactivity is a public health concern as it is continually increasing and represents one of the major risk factors for the etiology and progression of non-communicable diseases. The World Health Organization demands system-based approaches to reduce physical inactivity by 15% by 2030 worldwide. Physical activity is a modifiable but complex behavior influenced by individual, social, and environmental factors which need to be taken into account in intervention research. Conventional interventions to promote physical activity are increasingly being replaced by eHealth interventions for reasons of cost efficiency and reach. The original research included in this dissertation investigates the feasibility and effectiveness of eHealth interventions for the promotion of physical activity in socially disadvantaged populations. In pilot study I the feasibility of a smartphone app-supported physical and cognitive training was examined in older individuals. Subsequently, a scoping review was conducted to summarize the evidence on the feasibility and effectiveness of existing social media-based physical activity interventions. The results were used to design pilot study II which aimed to examine the feasibility of a social network-based intervention targeting vocational school students. The smartphone app-supported, combined program turned out to be feasible and appropriate for older individuals. The scoping review revealed that the incorporation of *Facebook* was prevailing in interventions and had positive effects on physical activity, as well as other physical health outcomes. However, it was not appropriate for promoting physical activity and secondary health outcomes in vocational school students in pilot study II. The findings highlight that participatory efforts are needed involving target populations and engaging multi-level stakeholders in design and implementation of interventions to generate robust evidence that can be disseminated and will ultimately inform policy-makers on how to create physical activity-promoting programs for socially disadvantaged populations that incorporate the social and built environment.

Zusammenfassung

Die stetig zunehmende körperliche Inaktivität ist eine Herausforderung für die öffentliche Gesundheit, da sie eine der Hauptrisikofaktoren für nicht übertragbarer Krankheiten darstellt. Die Weltgesundheitsorganisation fordert systembasierte Ansätze, um körperliche Inaktivität bis zum Jahr 2030 weltweit um 15 % zu reduzieren. Körperliche Aktivität ist ein modifizierbares, jedoch komplexes Verhalten, dass durch individuelle, soziale und umweltbedingte Faktoren beeinflusst wird. Diese Einflussfaktoren gilt es im Rahmen der Interventionsforschung zu berücksichtigen. Konventionelle Maßnahmen zur Förderung körperlicher Aktivität werden aus Gründen der Kosteneffizienz und der Reichweite zunehmend durch eHealth Maßnahmen ersetzt. Die in der Dissertation enthaltenen Forschungsarbeiten untersuchen die Machbarkeit und Wirksamkeit von eHealth Interventionen zur Förderung körperlicher Aktivität bei sozial benachteiligten Bevölkerungsgruppen. In Pilotstudie I wurde die Machbarkeit eines Smartphone App-unterstützen, körperlichen und kognitiven Trainings bei älteren Menschen überprüft. Anschließend wurde ein Scoping Review durchgeführt, der die Evidenz zur Machbarkeit bestehender sozialer Medien-basierter Interventionen und deren Wirksamkeit auf körperliche Aktivität zusammenfasst. Dessen Ergebnisse dienten dem Design der Pilotstudie II, in der die Machbarkeit einer sozialen Netzwerk-basierten Intervention bei Berufsschüler:innen getestet wurde. Das Smartphone App-unterstützte, kombinierte Programm erwies sich als machbar und geeignet für ältere Menschen. Der Scoping Review zeigte, dass *Facebook* in Interventionen am häufigsten eingesetzt wurde und positive Auswirkungen auf körperliche Aktivität sowie andere physische Parameter hatte. Zur Verbesserung der körperlichen Aktivität und anderer Gesundheitsparameter bei Berufsschüler:innen, in der Pilotstudie II war es jedoch ungeeignet. Die Ergebnisse zeigen, dass partizipatorische Bemühungen erforderlich sind, die Zielgruppen und Akteure verschiedener Ebenen in die Gestaltung und Umsetzung der Maßnahmen einbinden, um belastbare Erkenntnisse zu gewinnen, die verbreitet und letztlich die Politik darüber informieren, wie bewegungsförderliche Programme unter Einbezug der sozialen und baulichen Umgebung für sozial benachteiligte Bevölkerungsgruppen geschaffen werden können.

Abbreviations

BCTs	Behavior Change Technique(s)
BMI	Body Mass Index
MRC	Medical Research Council
MVPA	Moderate to Vigorous Physical Activity
NCDs	Non-Communicable Diseases
PA	Physical Activity
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
QoL	Quality of Life
RCTs	Randomized Controlled Trials
SEM	Social Ecological Model
SES	Socio-Economic Status
TIDieR	Template for Intervention Description and Replication
WHO	World Health Organization

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1 Introduction

1.1 Background

Physical inactivity is a public health concern, as it is continuously increasing, particularly in high-income countries. According to estimates, 27.5% of all adults worldwide revealed low levels of physical activity (PA) in 2016 compared to only 23.3% in 2010 (Guthold et al., 2018). This prevalence is even more pronounced in adolescents aged 11-17 years of whom, in 2016, 80% were deemed physically inactive globally (Guthold et al., 2020).

These trends are perturbing, considering that physical inactivity is one of the main risk factors for the etiology and progression of non-communicable diseases (NCDs), including cardiovascular diseases, certain cancers, and diabetes mellitus (Lee et al., 2012; Wahid et al., 2016). NCDs account for 91% (Institute for Health Metrics and Evaluation [IHME], 2021) of all deaths in the European Union (EU) and proportionately cause 30% of all premature deaths (World Health Organization [WHO], 2021). The financial and structural burden of NCDs is enormous and driven by an aging population and the dissemination of unhealthy lifestyles. Vandenberghe and Albrecht (2020) found that cardiovascular diseases, cancers, type 2 diabetes, and chronic respiratory diseases impose indirect costs of nearly 2% of EU gross domestic product due to a loss of productivity. Additionally, NCDs contribute to approximately 25% of the total health spending of the EU.

The containment of physical inactivity is also a social matter. In line with this, the WHO demands in an updated global action plan a system-based approach adaptable to each country to ensure that all individuals, regardless of their social and ethnic background, geographical origin, age, gender, and health status have equal chances for a health enhancing active lifestyle. The recent global target is a 15% relative reduction of physical inactivity by 2030 worldwide (WHO, 2018)

1.2 Outline

1.2.1 Theory-based considerations for the design and research of interventions for PA promotion

Fortunately, PA is a modifiable behavior which can be addressed in interventions or programs to move large segments of the world's population from inactivity to activity to reach the PA target outlined above. In the following section, predictors for PA behavior change based on theoretical frameworks and complex intervention research are described.

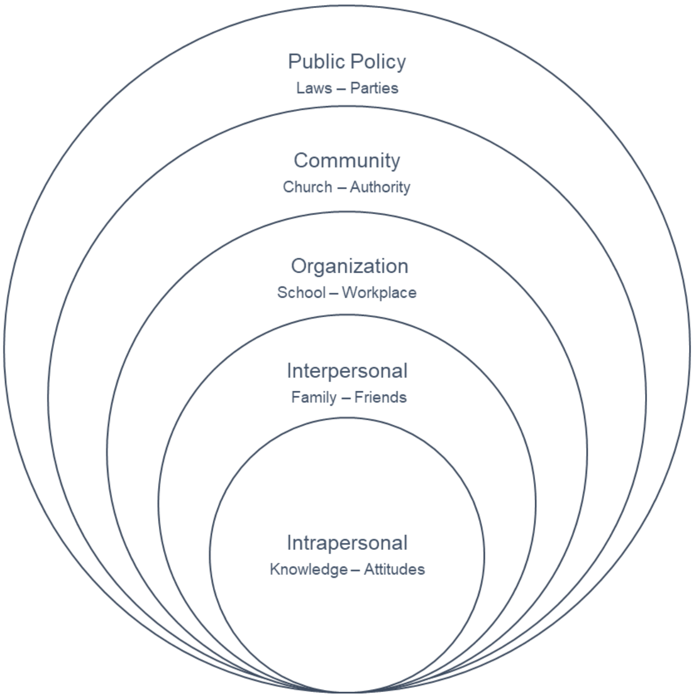
The current WHO guidelines provide a suitable framework for the design and implementation of PA interventions, as they consider different populations and provide practical recommendations. The recommendation for children and adolescents is to engage in 60 minutes of moderate to vigorous physical activity (MVPA) per day and strengthening, as well as vigorous aerobic exercises, on at least three days per week, in order to gain substantial health benefits. Adults are advised to engage in 150-300 minutes of PA at moderate intensity or 75-150 minutes at vigorous intensity per week. Moderate or intense strengthening exercises of the major muscle groups on at least two days per week lead to additional health benefits in adults. Older individuals above the age of 65 years should additionally include multidimensional, functional activities to improve balance and strength (e.g. dancing), on a minimum of three days per week in their exercise regimen (WHO, 2020).

A sufficient level of PA according to these recommendations has more benefits than only reducing the risk for the onset of chronic diseases. It ameliorates physical fitness, such as cardiorespiratory fitness, improves e.g. muscle and bone health, and is associated with maintained physical functioning in older age enabling individuals to participate in daily life (2018 Physical Activity Guidelines Advisory Committee, 2018; Lee et al., 2012). While evidence for positive effects on dementia is scarce, study results indicate that PA can delay cognitive decline in healthy individuals and individuals with mild cognitive impairment (Blondell et al., 2014; WHO, 2019). Especially aerobic exercise has been shown to improve executive function, significantly more in women than in men (Barha et al., 2017; Salas-Gomez et al., 2020). Regular PA can also affect other mental disorders in a therapeutic or preventive manner. Previous research suggests that PA prevents and reduces symptoms of depression and schizophrenia (Belvederi Murri et al., 2019; Rosenbaum et al., 2014), and minimizes signs of anxiety and stress (Kandola et al., 2018; Stubbs et al., 2017). Sufficiently active individuals are more likely to be mentally healthy and to report better well-being (Chekroud et al., 2018; Sampasa-Kanyinga et al., 2020; Stubbs et al., 2018). Recent results suggest that especially moderate PA leads to improvements in sleep quality among every age group (Wang & Boros, 2021).

Despite these well-known benefits, the adoption of health enhancing PA is complex and influenced by an interplay of individual, social, and environmental factors. A framework for better understanding the underlying mechanisms of individuals' PA behavior is the socio ecological model (SEM) by McLeroy and colleagues (1988). This model posits that human behavior is determined by (a) intrapersonal factors, (b) interpersonal processes, (c) institutional factors, (d) community factors, and (e) public policy. On an intrapersonal level, PA interventions should aim to address characteristics of an individual, whereas on an interpersonal level, they should focus on social norms regarding PA of existing social networks of an individual. PA interventions addressing factors at the institutional level are supposed to reinforce organizational cultures that are PA or health enhancing. On a community level, programs should strive to build collaborations between community stakeholders and use this powerful linkage to offer PA promoting services accessible to all population groups. Interventions addressing the public policy level should shape policy-making processes (McLeroy et al., 1988). Figure 1 illustrates the model and figure 2 shows an adapted version outlining targets and intervention strategies for PA.

Figure 1

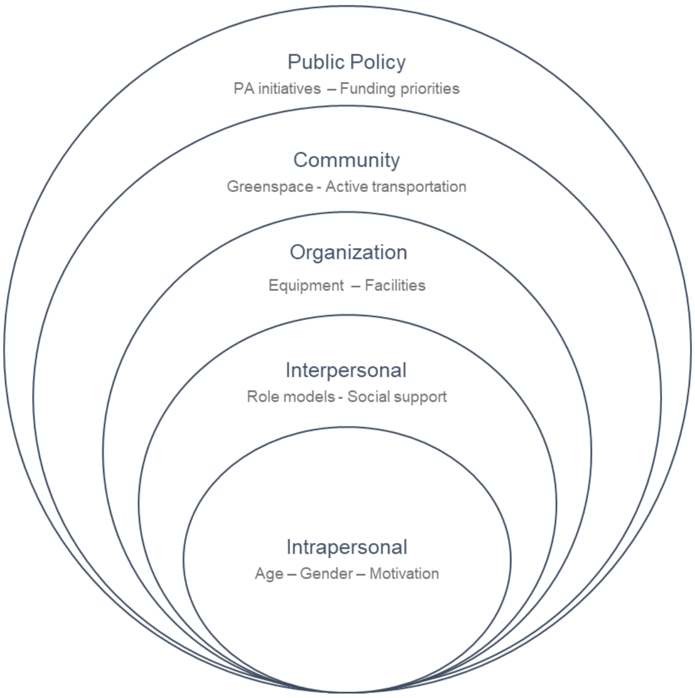
The socio ecological model



Adapted from McLeroy et al., 1988

Figure 2

The socio ecological model including targets and intervention strategies for PA



Adapted from McLeroy et al., 1988

Note. PA = physical activity

In the large European joint research program *Determinants of Diet and Physical Activity* (*DEDI-PAC*), factors affecting the uptake and maintenance of PA across the lifespan were investigated from the socio-ecological perspective. On the (inter)personal level, the early uptake of PA and free-range conditions that allow for active transportation and parent-independent activities were found to be beneficial for an active lifestyle during childhood. In adults, time-consuming life events, such as the transition to university or job entry, turned out to be barriers for PA engagement (Condello et al., 2017). Social support from relevant others seemed promising for facilitating improvements in PA among all age groups (Jaeschke et al., 2017). At the community level, attractive environments that are safe, easily accessible, well-connected and have a balanced infrastructure were positively associated with PA. Evidence about effective implementation practices and policies, however, is still lacking (Puggina et al., 2017). To conclude, the results of *DEDIPAC* suggest social relationships to play a major role in PA behavior change. This mechanism can be explained by Albert Bandura's social cognitive theory (SCT). It states that most human behavior is acquired through observational learning from others, because it is effortless and preservative of capabilities. Especially individuals we feel connected to can have a meaningful influence on our behaviors (Bandura, 1986). In his subsequent work, Bandura (2004) found that social support and guidance contribute to sustainable changes in health behavior, if they are employed during early stages of the adoption process and conducive to self-beliefs in individual success.

Michie and colleagues (2013) developed a taxonomy summarizing evidence of theory-based behavior change techniques (BCTs). In total, 93 BCTs are included in the taxonomy which can serve as effective components (or “active ingredients”) of interventions intended to change behavior, including PA. They are hierarchically clustered into sixteen categories with the third category being social support which is subdivided into ‘unspecified’, ‘practical’, and ‘emotional’. Notwithstanding that, the BCTs self-monitoring (BCT 2.3, BCT 2.4) and goal setting (BCT 1.1) in PA interventions (e.g. walking interventions), are indispensable and widely utilized, social support has been shown to be a valuable BCT. Olander and colleagues (2013) demonstrated that social support effectively promotes PA and self-efficacy in obese individuals. Little evidence was found regarding the benefit of social support for the promotion of PA behavior in individuals with dementia (Nyman et al., 2018) and, in a systematic review, all interventions that were favorable regarding PA in adolescents and adults with chronic cardiorespiratory conditions, included the BCT social support (Sawyer et al., 2019). Furthermore, social contacts and social support are particularly relevant at certain stages of life. A qualitative analysis revealed that in the majority of studies reviewed, older participants appreciated the social connectedness and support resulting from PA (Franco et al., 2015). In adolescence, peers have been shown to have an essential impact on the uptake and maintenance of PA, where inactivity is most prevalent, by means of social support and role modelling (Lawler et al., 2020).

Complex interventions to address the variety of underlying facets of human PA behavior are ubiquitous in PA research, but there is no consensus in the literature on what constitutes complex interventions. Contrary to the original Medical Research Council (MRC) guidance (Craig et al., 2013), an intervention is no longer considered complex just because it relies on multiple intervention components, addresses multiple behaviors or groups or targets multiple levels. A review identified three dimensions of complexity described in the existing literature: characteristics of intervention stakeholders, multimodality of an intervention, and the intervention context (Trompette et al., 2020). Following the updated framework of the MRC guidance for developing and evaluating complex interventions, an intervention is considered to be complex because of both, its components or its interaction with the context in which it is embedded (Skivington et al., 2021). Thus an intervention can either be complex because, it addresses, for example, dietary and PA behavior which requires interdisciplinary expertise of a nutritionist and coach and is designed to be delivered online or in the real world setting or it can be complex, because of its effective implementation in primary care practices and outpatient diabetes facilities. The research of complex interventions is divided into four phases: development or identification of an intervention; assessment of feasibility; evaluation of the intervention; implementation. It can be started in any phase, depending on the key questions regarding the intervention, as long as the core elements context, program theory, engaged stakeholders, key uncertainties, intervention refinements, and economic considerations are scrutinized before proceeding to the next phase (Skivington et al., 2021).

For example, in the *Peer-Led physical Activity iNtervention for Adolescent girls* (*PLAN-A)*, pre-nominated pupils promoted PA among their female classmates aged 12-13 years via peer-supported training. After feasibility testing, the process evaluation revealed that a peer-led school-based intervention was acceptable, fidelity regarding the use of the intervention materials was high, and its preliminary effectiveness was to be evaluated on a larger scale (Sebire et al., 2019). In the complex, community-based intervention *10,000 steps Ghent*, a significant increase of the average daily steps in the intervention community was found after one year (De Cocker et al., 2009). Consequently, the intervention was disseminated regionally which resulted in an increased perception of the intervention in 90% of organizations in the implementation region, but did not lead to an equally high rate of implementation of the intervention (Van Acker et al., 2011). Thus, understanding human PA behavior, requires complex intervention research, recognizing the role of the built and social environment and determining not only whether an intervention is effective, but rather focusing on whether it is, for example, acceptable, time- and cost-efficient, transferrable, while running through the four phases of the renewed framework for developing and evaluating complex interventions.

1.2.2 Development of eHealth and its consequences

Interventions to support healthy lifestyle behaviors, such as PA, can be delivered in various ways. Traditional print-based or face-to-face interventions are increasingly being replaced by interventions using new technologies, better known as eHealth interventions, due to their rapid development and easy availability (Moller et al., 2017; Short et al., 2011). In the following section, eHealth is defined and its advantages as well as disadvantages are highlighted.

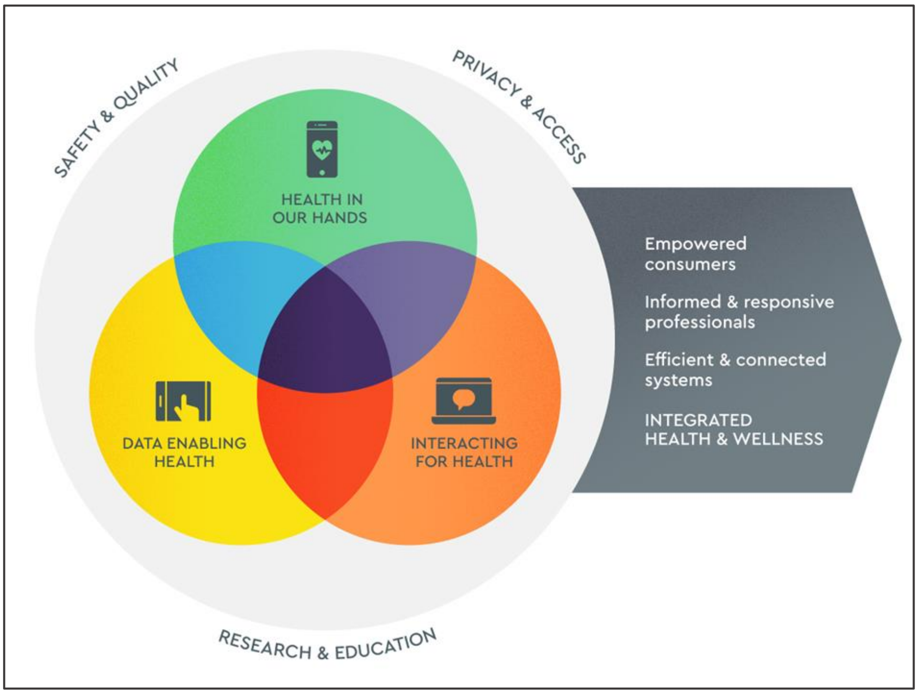
The evolution of the term eHealth in academic research goes back to the early 1990s. First publications in this area appeared on *PubMed* in 1992 and the body of evidence grew rapidly with more than 1,600 articles in 2013 using the term eHealth (Boogerd et al., 2015). The most commonly used definition of eHealth is the one by Gunther Eysenbach (2001):

e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology. (Eysenbach, 2001, p.1)

Since then, a number of definitions have appeared, most of them referring to the terms health and technologies, but no consensus has been reached, which has led to an inconsistent use of various terms in the scientific literature (Oh et al., 2005). This dissertation is based on the conceptual model by Shaw and colleagues (2017), who define three eHealth domains: (1) health in our hands, (2) interacting for health, and (3) data enabling health. They conclude that, according to these three domains, the utilization of digital technologies for health purposes has three overlapping functions: (1) to track, monitor, and inform about health (2) to communicate about health, and (3) to extract and process health data (see figure 3).

Figure 3

The conceptual eHealth model



From Shaw et al., 2017, p. 9

Applicable information and communication technologies (ICTs) that can be employed in eHealth interventions are manifold, because of the rapid technological progress over the past few decades. During the COVID-19 pandemic, this development gained even more momentum. Beyond social online networks and mobile health or fitness applications, artificial intelligence chatbots were adopted to provide information on COVID-19 or for screening purposes. In China, robotic technologies were used to care for patients in isolation units and in rural areas of the United States (U.S.), medical apps were used to connect patients to a remote doctor in case of emergencies (Bokolo, 2021).

EHealth is a promising public health approach, because it can reach a large number of people simultaneously and provide primary or secondary prevention or disease management programs at relative low costs (Bennett & Glasgow, 2009). In the EU, 91% of households had access to the World Wide Web in 2020 (Statista Research Department, 2022) and the proliferation of smartphones is expected to continue to increase reaching 84% by 2025 (Degenhard, 2021). The internet is progressively accessed via mobile devices due to the rising importance of mobile apps in consumer behavior. From 2020 to 2022, the number of downloads increased by 21.6% and in addition to gaming apps, the use of social media apps is widespread in the EU (Ceci, 2021). This demonstrates the enormous reach of new technologies and their ease of use on demand and remotely.

The promotion of PA using new technologies has become the focus of research in the last two decades (Mueller et al., 2018) and appears to be effective (Cotie et al., 2018; Davies et al., 2012). There are numerous advantages to employing technology in PA interventions. New technologies have the potential to support PA in real time and with interactive feedback, including individually tailored advice (Krebs et al., 2010; Nahum-Shani et al., 2015). In addition, BCTs shown to foster PA in descending order of effectiveness can be incorporated in eHealth interventions: feedback, goal setting, competition, social sharing with acquaintances and social sharing with strangers (Hosseinpour & Terlutter, 2019). In fitness apps, two trends have emerged to support an active lifestyle, one is gamification, the other is enabling social interactions and exchange. For example, *Fitbit* released a pedometer version, where steps were converted into rewards that feed a virtual pet, while with *Strava* or *Runtastic*, fitness activities can be shared with friends or like-minded people and linked to the online social network *Facebook*. Tu and colleagues (2018) compared the effects of a gamified app to an app that promoted social interactions and found that participants in both groups displayed improved walking behavior, but participants in the social condition intended to continue using the app after the intervention period.

However, digitalization also has its disadvantages. Thus far, it reinforced social inequalities and led to a so-called digital divide, which means that individuals with a low socio-economic status (SES) use the digital progress less to their advantage (Robinson et al., 2015). Moreover, the digital divide has evolved from absent material resources (e.g., access to the internet or technologies=primary digital divide; Latulippe et al., 2017) towards disparities in skills to use them (secondary digital divide; Van Deursen & Van Dijk, 2014) and difficulties transferring the accessed information into favorable behavior (tertiary digital divide; Van Deursen & Helsper, 2015). This is also evident in the use of eHealth services, which is influenced by the social determinants age, social status, and gender. It is known that users are generally younger, better educated than non-users (Cornejo Mueller et al., 2020), and more likely female (Kontos et al., 2014). These social differences in user behavior are mainly attributed to a low eHealth literacy (Cornejo Mueller et al., 2020), i.e. little / lack of competence to access, understand, and rate health information from electronic sources and utilize it to address a health problem (Norman & Skinner, 2006). The health disparities caused or reinforced by eHealth have to be thoughtfully examined and eHealth solutions, sensitive to different social and ethnic groups that are disadvantaged regarding health need to be implemented and tested (Kontos et al., 2014; Viswanath & Kreuter, 2007).

1.2.3 Definition of socially disadvantaged populations in the context of this dissertation

The term socially disadvantaged individuals has long been present in social and health policies. It is often used synonymously with the term vulnerable individuals or underserved populations. For a better understanding, the terms are defined below and their meaning in the context of this dissertation is highlighted.

Vulnerable individuals are characterized by an elevated risk for chronic diseases due to a physical or mental condition or a social situation (e.g., pregnant women, homeless, or individuals that have been exposed to any kind of violence; Robert Koch-Institut [RKI], 2008).

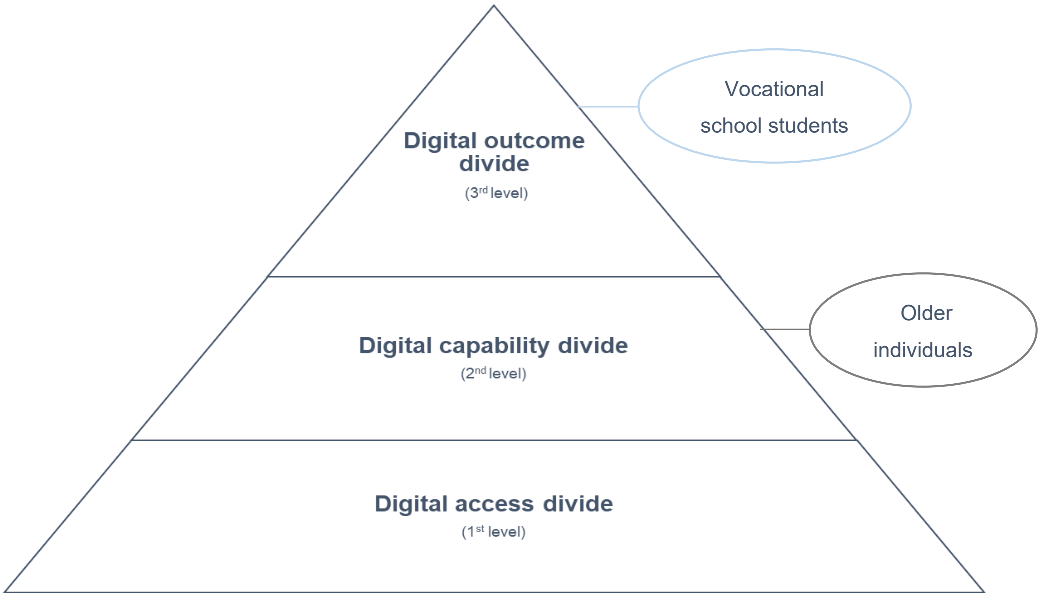
Socially disadvantaged individuals do not necessarily suffer from any of the above conditions, but they are affected by social inequalities, for example health inequalities. At the population level, a skewed distribution of health chances and risks of disease is known to be associated with three factors: education, job position, and income. Individuals with lower levels of education, a lower salary, and a poor job position are more likely to become ill (Geyer, 2008; Siegrist, 2021). These individuals are defined as vertically disadvantaged due to a low SES (Kaba-Schönstein & Kilian, 2018). Other factors that are often times the focus of health initiatives because of their potential to cause health inequalities are age, gender, or migration background. Health inequalities are particularly evident during middle age, where common diseases, such as diabetes or cancer, manifest (Geyer, 2021). Gender inequalities have been found for prevalence's of various diseases. For example, men are more likely to suffer from myocardial infarction (MI) during earlier stages of their lives compared to women (Geyer et al., 2018). With increasing age or lifestyle- associated risk factors, such as smoking, the incidence of MI between males and females equalizes (Millett et al., 2018). Women, on the other hand, are at a higher risk for depression (Salk et al., 2017). Per definition, individuals in these population groups are considered to be horizontally disadvantaged (Kaba-Schönstein & Kilian, 2018)

Underserved populations generally suffer from scarce resources. They have limited access to different services and societal goods, such as education, healthcare, and means of transportation or living space (Bantham et al., 2021). Individuals who are considered underserved in traditional health care include elderly, gay, lesbian, bisexual, and transgender individuals, individuals with a non-white ethnic background and low SES, disabled individuals and those from low- and middle-income countries (Weitz et al., 2001). In public health research, this term refers to populations that are underrepresented in clinical and health studies. It is well documented that women, ethnic minorities or individuals with a low SES are often times not adequately represented in samples (Rogers, 2004). Further, in PA studies, individuals with physical disabilities are frequently even excluded (Mendoza-Vasconez et al., 2016).

In the context of this dissertation, I studied two populations that are socially disadvantaged regarding health: older individuals (Gomes et al., 2017; Harvey et al., 2015) and vocational school students (Elgar et al., 2015; Reik et al., 2010). On the one hand, both populations are more likely to be physically inactive and therefore have an increased risk for NCDs. On the other hand, it can be assumed that both populations experience disparities in the use of new technologies for health purposes, thus are affected by the digital divide and, therefore, are considered as socially disadvantaged. It is well documented that older individuals suffer from digital exclusion (Heponiemi et al., 2020, Kaihlanen et al., 2022). Data from Germany on media use of the internet show that 87% of younger individuals (14-29 years old) use the internet for the reception of content. In the group of the 50-69 year-olds, it is only 38% and among individuals above the age of 70 years 18% (ARD/ZDF-Forschungskommission, 2021). The lower user rates among older adults allow for the assumption that they lack abilities to use the web to gain information and that they are affected by the digital capability divide (see fig. 4). Contrary to that, younger users seem to have sufficient skills for information retrieval. However, students enrolled in a vocational school with an intermediate to low level of education might be less likely to transfer the knowledge, suggesting that this population may be affected by the digital outcome divide. To conclude, both populations are affected at different levels of the digital divide as illustrated in figure 4, however evidence is lacking.

Figure 4

The three levels of the digital divide



Adapted from Wei et al., 2011

1.2.4 Previous research on the effects of eHealth interventions in the two target populations

As explained in the previous section, older adults and younger adults with lower levels of education are considered socially disadvantaged and affected by different levels of the digital divide. Therefore, the role of eHealth interventions for promoting PA in these populations was chosen as the focus of this dissertation. In this section, the existing evidence regarding the feasibility and effects of such interventions for these two populations is summarized briefly.

A recent systematic review synthesized the results from 38 randomized controlled trials (RCTs) and found that eHealth interventions increased the time spent on PA, the energy expenditure, and the amount of steps among individuals 50 years and older. Digital PA coaching via e.g. text messaging platforms, websites, DVDs, as well as PA tracking plus feedback via wearables were the most commonly employed methods (Kwan, Salihu, et al., 2020). In a rapid review of reviews, inconclusive results were found with three reviews indicating that web-based programs and activity monitors effectively promoted PA in older individuals, whereas one review revealed only positive trends. The quality of evidence stemming from these studies is considered low to moderate (McGarrigle & Todd, 2020).

Zubala and colleagues (2017) found that the mode of delivery, in general, was not a mediating variable for positive intervention effects on PA among community dwelling older adults, but rather professional and tailored guidance, social and environmental support, as well as enjoyment were motivators for PA. The most beneficial intervention components remain unclear to date. The authors suggest more complex interventions taking contextual factors into account and longitudinal studies with follow-ups beyond two years to identify strategies for the maintenance of PA.

Evidence regarding the role of eHealth interventions for PA among vocational school students, to date, is very scarce. In the multilevel intervention *Let's move it* from Finland, vocational school students and their teachers were taught how to increase PA and reduce sitting time during class using BCTs. A website with guidance on goal-setting and motivational boosts via social media was offered to students. Acceptability of the intervention and the uptake of BCTs was high and associated with an increase of objectively measured PA, but the target group barely used the offered website (Hankonen et al., 2017). As part of the *PRALIMAP-INÈS* nutritional trial, socially disadvantaged overweight adolescents from middle- and high-schools in north-eastern France were encouraged to participate in a *Facebook* challenge to increase their PA. Despite high initial interest, only 21 of the initial 262 participants enrolled in the challenge, where they had to perform a weekly amount of jumps. Evidence regarding the effectiveness of this intervention component is therefore missing (Saez et al., 2018). Another study revealed that telephone- and online-based support services for multiple health risk behaviors were barely used by Australian vocational school students. In the target group which was proactively offered access to the *10,000 steps* program and *Get Healthy Information and Coaching Service (GHICS)* to reduce their high rates of physical inactivity, only 12.7% signed up for the available services (Atorkey et al., 2021).

As illustrated above, a limited amount of research addressing vocational school students has been conducted so far. In contrast, the quantity of studies examining older individuals is higher, but the evidence is only partly robust, because results are inconsistent. Furthermore, attempts to digitally promote PA in older adults generally seem to rely on websites and PA monitors, thus, incorporating more conventional Web 2.0 and not the latest technologies.

1.3 Research aims

The overarching aim of this dissertation is to investigate the feasibility and effectiveness of eHealth interventions for the promotion of PA in socially disadvantaged populations. First, the feasibility of a smartphone app-supported intervention was examined in a sample of older individuals. Then, the current evidence on the feasibility and effectiveness of social media-based PA interventions was reviewed and summarized in order to subsequently design and pilot a more contemporary intervention approach incorporating social media and targeting vocational school students.

The following questions are addressed in this dissertation:

1. Is a smartphone app-supported, combined PA and cognitive intervention targeting older individuals appropriate for promoting PA behavior and improving additional secondary health outcomes?
2. What is the feasibility and impact of social media use in PA interventions on PA behavior and secondary health outcomes?
3. Is a social network-based PA intervention targeting vocational school students appropriate for promoting PA behavior and improving additional secondary health outcomes?

For investigating the first and third research questions, two pilot studies were conducted (herein referred to as pilot study I respectively pilot study II). To answer the second research question, a scoping review was carried out (herein referred to as scoping review). The underlying sub-questions are shown in table 1.

Table 1

Sub-questions addressed in the three published original articles

Article reference	Study type	Sub-questions
Thiel et al., 2022 (see 3.1)	Pilot study I	a) Which resources are necessary for recruitment, assessments, and implementation of intervention components? b) How satisfied are the instructors and participants (measured by retention rate) with the intervention? c) What are the lessons learned during the set-up of the intervention? d) Are the outcome parameters adequate? e) What is the magnitude of potential effects on the outcome parameters? f) Is the intervention safe (in terms of adverse events)? g) What are implications for further research?
Guenther et al., 2021a (see 3.2)	Scoping Review	a) Which social media platforms are used in interventions to promote PA? b) Does the use of social media have positive effects on PA? c) Which other dimensions of health are captured? d) Does the use of social media affect other dimensions of health? e) Are social media-based PA interventions feasible in terms of acceptability, use, and usability?
Guenther et al., 2022 (see 3.3)	Pilot study II	a) Is the intervention feasible in terms of processes? b) Is the intervention feasible in terms of the required resources? c) Which challenges occur during the set-up and implementation of the intervention? d) Which challenges occur during data processing? e) Are the Web 2.0 platforms used and accepted by the target group? f) What are reasons for non-use of the Web 2.0 platforms? g) What is the magnitude of potential effects on the outcome parameters?

Note. PA= physical activity; BMI= body mass index; QoL= Quality of Life

1.4 Ethical approval

Pilot study I (Thiel et al., 2022) was approved by the Ethics Committee of the German Society of Physiotherapy (Deutscher Verband für Physiotherapie, 2016-06) and was retrospectively registered at the German Clinical Trials Register (DRKS00010595). Pilot study II (Guenther et al., 2022) was approved by the Ethics Committee of the Medical Faculty of the Heinrich-Heine-University Duesseldorf, Germany, on June 4th, 2020 (Study-No.: 2020-860). Both studies were conducted in accordance with the ethical principles of the Declaration of Helsinki (World Medical Association [WMA], 2013).

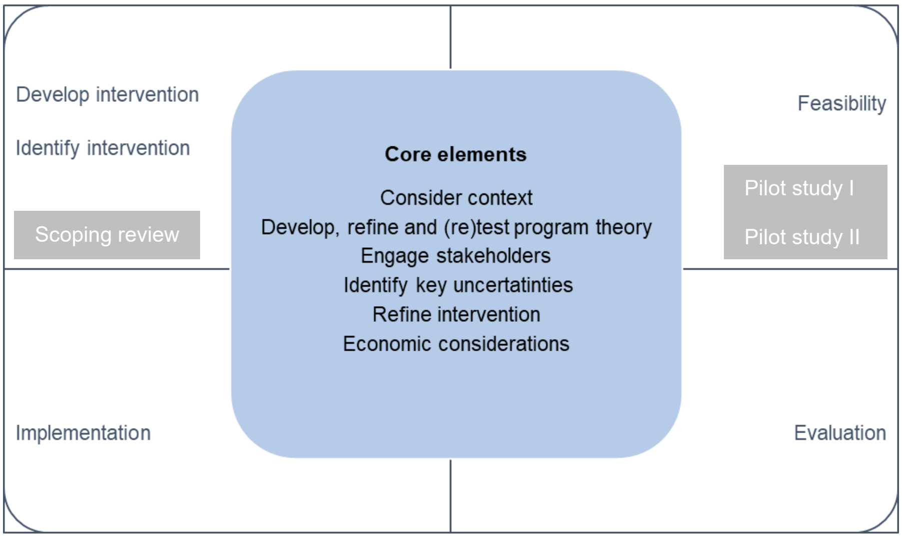
2 Methods

2.1 Pilot studies

A pilot study is a study preceding a full-fledged resource-intensive controlled intervention trial that examines the feasibility of an intervention on previously defined aspects, for example safety and dose of an intervention or treatment, recruitment potential or adequacy of measurement tools. A pilot study does not intend to provide evidence on the efficacy of an intervention, but serves as a basis for deciding whether to continue a study, in general, with or without modifications based on previously specified feasibility criteria. Pilot studies resolve uncertainties, provide lessons-learned, and can spare resources in future RCTs (Thabane et al., 2010; Thabane et al., 2016). Considering the updated framework of the MRC guidance (Skivington et al., 2021), feasibility testing is one necessary step in an iterative process for the development and evaluation of complex interventions. Figure 5 illustrates the current framework and shows where the three underlying studies of this dissertation are to be placed.

Figure 5

Placement of the three studies into the framework for developing and evaluating complex interventions



Adapted from Skivington et al., 2021

2.1.1 Pilot study I

As outlined in section 1.2, studies on eHealth interventions targeting older populations predominantly evaluated the use of websites or PA monitors, e.g. pedometers (McGarrigle &

Todd, 2020; Kwan, Salihu, et al., 2020). Complex programs combining smartphone app-supported training of physical and cognitive functions, embedded in the living space of elderly, are rare and have seldomly been tested scientifically. Therefore, such a complex intervention first had to be piloted before examining it at a larger scale. The data of pilot study I were collected as part of the funding line SILQUA-FH 03FH008SA5 by the German Federal Ministry for Education and Research (BMBF). The complex intervention *Quartier Agil* took place in an urban district of Bochum and was piloted in two consecutive intervention cycles à six month (from January to June 2017 and August 2017 to January 2018). Thirty-nine community-dwelling adults aged 63 years and older were offered a combined, physical and cognitive training once a week by two tutors. Social and group activities in the neighborhood were arranged every other week. Additional home-based physical or cognitive exercises were provided using a specific designed smartphone app for the study. A *WhatsApp* group was used for organization and communication of events. A manual with the actual training program is made available online (https://doi.org/10.5281/zenodo.6998000; Guenther, Osterhoff, et al., 2022).

The program's feasibility was evaluated in terms of processes, resources, and lessons learned (project level) and in terms of feedback of participants and tutors (individual level). PA, physical and cognitive fitness, quality of life (QoL) were quantitatively assessed and qualitative measures for social participation, were used to determine the magnitude of potential intervention effects. Data were collected before (baseline) and after each of the two intervention cycles (follow-up). To perform intragroup comparisons of the quantitatively assessed outcome parameters, the Wilcoxon-Wilcox test was used. The reporting adheres to the *Template for Intervention Description and Replication (TIDieR)* checklist (Hoffmann et al., 2014) and more detailed information on the methods is provided in the original article (see section 3.1).

2.1.2 Pilot study II

The intervention examined in pilot study II was based on the *Active Team* intervention by Maher and colleagues (2015). This effective online social network PA intervention, originally tested in a sample of inactive adults was adapted for young adults enrolled in a vocational school. Referring to the updated framework for complex interventions (Skivington et al., 2021) described above, the adaptation to a new population requires an evaluation of the program's feasibility within the new target group first.

Fourteen students between the ages of 16 and 27 years from one vocational school in the city of Duesseldorf were enrolled. They were motivated to walk 10,000 steps per day by self-monitoring of their steps and social comparison to other classmates via the pedometer app *Pacer* and a *Facebook* group. The intervention *WALK2gether* lasted six weeks and took place between November 2021 and January 2022. It was designed as a resource-friendly, standalone, digital intervention and incorporated already existing platforms. Processes pertaining to the development and implementation of the intervention as well as problem solving strategies and required resources were documented as parameters for feasibility. Quantitatively assessed data on PA, subjective health status, QoL, exercise motives, and participants' feedback was captured at baseline (T0) and six-week follow-up (T1) and analyzed with a *t*-test to determine the magnitude of potential intervention effects. Reporting was done following the checklist of Thabane and colleagues (2010) and more details on the methodology are included in the original article (see section 3.3).

2.2 Scoping Review

A scoping review is a synthesis of all knowledge on a subject without assessing the quality. Accordingly, a scoping review does not intend to answer a precise research question, but scrutinizes the extent, nature, and range of evidence on a research topic. It can be compared to a map showing all the research done on one subject, no matter how heterogeneous it is and identifying the gaps that need to be addressed. Thus, it serves the decision-making for subsequent, more elaborate systematic reviews (Tricco et al., 2016; von Elm et al., 2019).

The rationale for conducting a scoping review in the context of this dissertation was to obtain a comprehensive overview of the latest effective social media interventions examined in PA research. The use of social media is a relatively new, but quickly evolving field, as the mode of delivery for eHealth interventions has changed in the past seven years from predominantly tele-based to web-based platforms (Duan et al., 2021). This was the first scoping review that considered all relevant social media platforms from 2014–2020 and included a broad search of all interventions promoting PA via any of these platforms. In addition to scoping the existing evidence, the results were intended to inform the design of the intervention in pilot study II. The scoping review was conducted and prepared in accordance with the *Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)* guidelines for scoping reviews (Tricco et al., 2018). A protocol for conducting the scoping review was developed previously and is accessible on *Open Science Framework (OSF*; https://osf.io/v9dxj; Guenther & Pischke, 2021). Two authors searched the electronic databases *Scopus* and *Medline* with an a-priori peer-reviewed search strategy and selected the sources of evidence in two phases. First, they screened titles and abstracts of all records independently followed by the screening of all full texts that were deemed relevant after screening phase one for eligibility was completed. Discrepancies at any stages of the screening process were resolved via discussion with a third author.

Data on general information of the source, participant characteristics, and flow, the intervention, outcome (measurements), results, and key conclusions were charted independently by the two reviewers in a prior developed sheet. Random samples of the extracted data were checked for congruence. Both, the search strategy and the extracted data, are published open access and were included as a supplement of the published original article for better comprehensibility (https://www.mdpi.com/article/10.3390/ijerph182413018/s1; Guenther et al., 2021b). Results are reported along the objectives of the scoping review, displaying the most commonly used social media platforms, effects on PA, and frequently examined secondary health outcomes, as well as findings pertaining to feasibility. A detailed description of the methodological approach can be found in the original article, see 3.2.

3 Results (Published Original Articles)

3.1 Feasibility of smartphone-supported, combined physical and cognitive activities in the neighborhood for stimulating social participation of the elderly. Thiel, C., Guenther, L., Osterhoff, A., Sommer, S., & Grueneberg, C. BioMed Central Geriatrics, 22(1):629. (2022)

Thiel *et al. BMC Geriatrics* (2022) 22:629
https://doi.org/10.1186/s12877-022-03303-0

BMC Geriatrics

RESEARCH ARTICLE — Open Access

Feasibility of smartphone-supported, combined physical and cognitive activities in the Neighbourhood for stimulating social participation of the elderly

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Abstract

Background: Combining smartphone-assisted group activities in the neighbourhood and training in physical and cognitive skills may offer the potential to promote social participation and connectedness of older adults. This non-controlled proof-of-concept, retrospectively registered study aimed to determine the feasibility of such an intervention approach, including its evaluation.

Methods: In two consecutive six-month intervention cycles, 39 community-dwelling adults were provided with weekly smartphone, physical and cognitive training by two tutors. Using a specifically designed app, the participants were also encouraged to join and later self-organise physically and cognitively stimulating activities related to hot spots in their Bochum neighbourhood. Indicators of feasibility were documented.

Results: The recruitment and assessments took 3 hours per participant. Excluding smartphone support, the preparation and the implementation of the intervention amounted to nine person-hours per week.

Six participants dropped out, and 13 did not complete one or more assessments. The participants attended 76 ± 15% of the weekly training sessions. The instructors deemed the programme feasible, but familiarisation with the smartphone and the app was very time-consuming.

Twenty-seven of 29 participants reported high overall satisfaction, and 22 agreed that the programme helped them to establish social contacts. The smartphones attracted substantial interest and were used frequently, despite mixed satisfaction with the project-specific app. From baseline to follow-up, the six-minute walking distance, lower extremity strength and moderate to vigorous physical activity, as well as quality of life, were preserved at a high level, while balance performance was significantly improved. Of the 11 tests related to cognitive functioning, 4 tests (a memory test, the Stroop test and 2 tests of verbal fluency) indicated significant improvement. No moderate or serious adverse events occurred in relation to the assessments or the intervention.

Conclusions: The multimodal approach seems safe and feasible and offers the potential to promote social connectedness, bonds in the residential neighbourhood and smartphone competency, as well as to preserve or improve

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physical and cognitive functions. Adaptations of the intervention and of the outcome assessments may contribute to better assessment and exploitation of the potential of this approach in a future study involving socially, physically and cognitively less active elderly persons.

Keywords: Combined cognitive and physical activity, Smartphone support, Neighbourhood, Social participation, Community-dwelling adults

Background

Social participation and the role of the neighbourhood in the ageing population

Most older adults like to engage in social activities [1]. Pursuing meaningful activities in a community and cultivating relationships may indeed constitute an important component of successful ageing [2]. However, later life often comes with decreased physical and cognitive performance and deteriorating health [3], which might reduce social engagement [4]. The relations between social participation, physical and cognitive functions, and health in the ageing population are likely complex and bidirectional and may operate through multiple pathways [5, 6].

While social participation is of high relevance to older adults, the proportion of older people living alone has increased worldwide [7]. The family structure and living arrangements have fundamentally changed, providing less informal opportunities for social interaction and increasing the risk of disability in basic activities of daily living [8], as well as of deteriorating physical and mental health [9]. In this context, the neighbourhood has become more important as a framework for social relationships and participation in society [10]. At the same time, older adults identify with the neighbourhood as their residential environment and wish to remain in their own homes as long as possible [11].

The constituents of this neighbourhood may vary, and definitions can operate on various dimensions (e.g., geographical, physical, administrative, perceptual and activity-related). According to Rüßler and Stiel [12], a neighbourhood can be regarded as a social environment that emerges from social interaction, is socially formed, has manifold social functions, is easily graspable and primarily relates to daily life, has an impact on its inhabitants' perceptions and actions, and offers the potential for identification and empathy.

Interventions that directly or indirectly contribute to ageing individuals' ability to maintain or expand their social participation and social relations in their neighbourhood will likely improve the conditions and the quality of their lives [10]. Physically and cognitively stimulating activities that involve group interaction and are related to daily life in the neighbourhood may offer opportunities for social interaction, as well as promote its physical and cognitive prerequisites. When designing programmes that provide such interventions, the needs and preferences of the individuals involved, as well as their view on participation issues, should be considered [13, 14]. To increase their appeal and accessibility, such group-based programmes should be complemented with individual support and training elements, reflecting the older age group's enormous heterogeneity in their constitutions, needs and habits [8].

Physical and cognitive activities and training for social participation

Physical activity may be a meaningful leisure pursuit and group activity that can be done in the neighbourhood. Equally important, it also helps reduce age- and health-related impairments in everyday life and slows down or even reverses the decrease in strength, endurance and flexibility. Regular activities, such as walking, dancing or light gardening work [15, 16], may improve physical performance, function and mobility. Specific exercise training may trigger greater benefits, as long as its form, intensity, duration and frequency are individually adapted to the participants' physical functions and needs [17–19].

Exercise is also effective for older people with mobility limitations [20]. Several training programmes, such as the Otago Exercise Program, Weight-Bearing Exercise for Better Balance (WEBB), Functional Task Exercise (FUNTEX), High Intensity Functional Exercise (HIFE) and Lifestyle Functional Exercise Program (LIFE), continue to spread internationally because of their good scientific evidence [21–23], including economic benefits related to fall prevention in some cases (Otago, WEBB and LIFE) [24–26]. Nonetheless, transfer effects on everyday mobility (in the sense of distance covered and radius of action) and even more importantly, on social participation, are still unclear. Physical activities are generally regarded as more enjoyable if done in a group [27], which may result in new social connections. However, a review and meta-analysis of 16 randomized trials with 2315 participants presenting with a wide range of chronic diseases and mobility limitations shows that physical activity per se does not automatically improve older people's participation in social life ($SMD = 0.03$; 95% $CI = -0.10$ to 0.16) [28]. Only exercise interventions lasting 12 months or longer were slightly beneficial (SMD = 0.15; 95% CI = 0.02 to 0.28). In their conclusion, the authors argue for the development of more complex interventions which go beyond physical activity, and which address both participation and its various determinants [28].

Cognitive training is another intervention that can be organised as a meaningful group activity and can be related to the neighbourhood. There is sufficient evidence of the effects of cognitive training on outcomes such as neuroplastic changes in the brain assessed by neuroimaging [29], patient self-esteem [30] or executive function [31]. The effects are larger for task-specific skills, that is, if the exercise closely matches the target real-life task [32, 33]. Cognitive training can enhance the management of the tasks that are relevant for participation in everyday life. For instance, the training in cognitive processing speed can improve the management of instrumental activities of daily life, such as shopping, using public transportation, managing finances and taking responsibility for one's own medication [34], as well as gait performance [35].

When interlaced in multimodal programmes, physical and cognitive activities or training promise better effects on the functions with high relevance for social participation than solitary interventions [36]. Programmes such as 'Maintaining and supporting Independent Living in Old Age' (SimA) [37] or 'NeuroVitalis' [38] provide evidence-based approaches to cognitive training for older people. SimA is a multimodal programme including competence training (general strategies of coping with age-related changes and everyday problems of the elderly), and memory training. SimA has shown long-lasting effects in domains that are important for independent living, as well as actual (self- and externally assessed) independence [37]. NeuroVitalis, another cognitive training programme aimed at older people, has shown small but promising effects [39–41]. It includes exercises to improve focus and attention, memory, and executive function. Both SimA and NeuroVitalis involve individual as well as dialogue-based and group exercises at various levels of difficulty, and can be complemented by physical training. Among stroke patients, cultural and social activities that comprise physical and cognitive stimulation, supplemented by specific individual support for physical and cognitive fitness, have been shown to contribute to the preservation and promotion of autonomy and participation [42].

Exercise training and a physically, intellectually and socially active lifestyle also contribute to the prevention or the delayed onset of a range of cardiovascular, metabolic, neoplastic and mental diseases [43, 44].

Digital support for participation

Digital information and communication systems may facilitate social participation related to physical and cognitive activities in the neighbourhood [45, 46]. Smartphones or tablets offer community functions, as well as access to social media and to information on events in the neighbourhood. Such devices may also provide general information on health-enhancing behaviour and physical or cognitive exercises, as well as individual activity tracking [47]. According to a survey among the German-speaking population released in November 2020, 82% of Germans aged 60-69 years, and 52% of Germans 70 years and older have used a smartphone at least from time to time [48].

However, choosing the appropriate device, application and setup may pose a significant obstacle for technically inexperienced people [49]. Discovering the functions and learning how to handle a tablet or a smartphone are cognitively stimulating, but the familiarisation process may require considerable time and motivation [50, 51]. Among other factors, complex menu navigation, small font sizes and the requirement for fine-tuned movements can present further barriers to tablet or smartphone use by older people [49–51]

Taken together as a simplified theory of change, combining technology-assisted group activities and training in physical and cognitive functions in the neighbourhood may offer various pathways to promote social participation and connectedness of older adults. Such a multimodal programme might include various components [52] and adhere to certain principles, as follows:

1. *Provide and enable social interaction.* The intervention should be aimed at stimulating social interaction, as well as enhancing cognitive and physical resources that are relevant for everyday life and social participation [53, 54].
2. *Take place in the neighbourhood.* Activities should be related to the neighbourhood, based on what the participants perceive as their hot spots, that is, nearby places to which they can relate and that are meaningful to them [55, 56].
3. *Involve participants.* While supported by instructors throughout the programme, the participants should be invited to contribute to and act as co-producers of the interventions [57].
4. *Use digital resources.* The participants should carefully be introduced and have easy access to new digital devices and technologies (e.g., smartphones and specific apps) [52].

Such multimodal approaches are rare and have scarcely been tested scientifically.

Objectives

This proof-of-concept study focuses on the promotion of social participation of older people without or with only slight physical and cognitive impairments. It aims to test whether the components and the principles listed in the preceding section could be included and adhered to in a comprehensive programme called *Quartier Agil* (literally, Agile Quarter), as well as to determine the magnitude of potential effects in two exploratory intervention cycles. While analysing the programme's feasibility [58], the following aspects should be covered:

1. Report the resources necessary for the recruitment and assessments, as well as for the implementation of the intervention's various components.
2. Report the arrangement of the intervention, and analyse participant and instructor satisfaction, as well as retention rate. Report important lessons learned during the process of setting up *Quartier Agil* (problems that occurred, adaptations made, solutions found).
3. Reflect on the adequacy of the outcome parameters.
4. Estimate the possible magnitude of the effects on social participation, physical function, physical activity and cognitive-linguistic performance and functionality, as well as the safety of the intervention (adverse events).
5. Decide whether a larger study, which can more comprehensively investigate the *Quartier Agil* approach, seems warranted, as well as whether there should be changes to the study setup, intervention or assessments.

Methods

This non-controlled proof-of-concept study comprised a preparation period and two six-month intervention cycles (January to June 2017, and August 2017 to January 2018) in a selected neighbourhood. For each intervention cycle, the plan was to recruit 20 participants by placing advertisements in local newspapers, distributing flyers and putting up posters on relevant sites of the neighbourhood (e.g., churches, cafés frequented by seniors), as well as to solicit the support of community stakeholders in social services and charitable institutions.

No sample size calculation was performed. No interim analyses were planned, and no stopping guidelines were in place. After study commencement, apart from a pre-planned refinement of the intervention after the first cycle, no further changes were made to the study design, methods or outcomes.

The inclusion criteria were as follows:

- community-dwelling in the selected neighbourhood,
- minimum age of 63 years and
- written declaration of consent (> 24 hours after verbal and written information).

The exclusion criteria were as follows:

- receiving home care or residential care,
- absolute contraindications regarding physical activity or exercise, according to the American College of Sports Medicine [59] or the German Society of Sports Medicine and Prevention [60], including, but not limited to, significant cardiac diseases such as decompensated heart failure, unstable angina, critical aortic stenosis, resting systolic BP > 200 mmHg, or resting diastolic BP > 110 mmHg; cancer with extreme nausea, fatigue or severe hematologic condition (such as thrombocytes < 20.000 µl); severe neurologic conditions such as ataxia; acute systemic illness or fever; uncontrolled type 2 diabetes or type 2 diabetes with severe foot ulcers; end-stage pulmonary disease such as COPD GOLD 4; musculoskeletal conditions that would prohibit exercise such as a severe rheumatoid arthritis flare; and
- cognitive deficits exceeding a mild cognitive impairment (ICD-10-Code: F06.7) as assessed by the Montreal Cognitive Assessment (MoCA) [61, 62]

No exclusion criteria relating to social interaction and cognitive or physical activity were defined. For this exploratory study, it was deliberately accepted that the participants were volunteers who might already show a high level of activity in any of these domains, thereby possibly diminishing potential intervention effects. The research team hoped that these volunteers would become better co-producers of the multimodal intervention and might also be able to better assist other (less active and experienced) group members. Further, participants with high levels of activity might serve as positive examples and improve motivation and group cohesiveness. Therefore, considerable intragroup heterogeneity was also accepted.

This study had been approved by the Ethics Committee of the German Society of Physiotherapy (Deutscher Verband für Physiotherapie, 2016-06) and was retrospectively registered in the German Clinical Trials Register (DRKS00010595). It followed the ethical principles of the World Medical Association's Declaration of Helsinki in its most recent version of Fortaleza. As far as applicable, the reporting adheres to the Consolidated Standards of Reporting Trials (CONSORT) guidelines and to the Template for Intervention Description and Replication (TIDieR) checklist and guide [63]. Funding was provided by the German Federal Ministry for Education and Research (BMBF SILQUA-FH 03FH008SA5).

Intervention

The intervention occurred in the city of Bochum in the Ruhr metropolitan area (situated in the state of North Rhine-Westphalia in Germany). With its six municipalities, each subdivided into several urban districts, Bochum is particularly affected by population aging [10]. In two initial project meetings, a consortium consisting of the leading project team and representatives from the cooperating organisations – the University of Applied Sciences Ruhr West, the Municipality of Bochum (Social and Health Departments), the Diakonie Bochum (regional welfare association), the Municipality of Bottrop (urban development) and the Fraunhofer Institute for Software and Systems Engineering – selected an eligible municipality. Based on its geographic characteristics, sociodemographic structure, options for and access to activities, the urban district of Bochum-Altenbochum (4.3 km^2, 12,100 inhabitants) was chosen to host the *Quartier Agil* intervention.

Potential participants were informed about the project's aim, the time scope, as well as the six components and principles of the intervention. The research team announced that attending the weekly group meeting was mandatory, but the degree to which they would attend further individual and group activities and exercises was completely up to them.

After providing their informed consent, the participants received a Google Nexus 5X Android smartphone, running with a prepaid SIM card and an app specifically designed for *Quartier Agil*, which they were free to use until the end of the intervention cycle. In the first few weeks, the participants received detailed instructions on how to use the smartphone and the *Quartier Agil* app. To be able to align cognitive and physical group activities with the participants' preferences and habits, relevant and highly frequented sites in the neighbourhood (hot spots) were planned to be identified within the first month based on a group discussion with the participants during the weekly multimodal group training described further below, backed up by tracking their smartphone GPS signals.

The programme was envisaged to exploit the complex and bidirectional relations between social participation, physical and cognitive functions and health through multiple pathways [5, 6] by the implementation of physical, cognitive and social activities, guided by participation tutors (hereafter, tutors). These tutors were charged with instructing and guiding the participants towards the goal of maintaining and enhancing their social participation. The tutors were intended to be healthcare professionals capable of coaching older adults. In this trial, the two tutors comprised a physiotherapist/sport scientist (Master of Arts in Sports Gerontology) and a clinical linguist (Master of Arts).

The tutors should be able to implement and deliver the programme, as well as guide and support the participants through the range of activities. Beyond their professional expertise, they were required to have didactic skills, know effective networking strategies and be experienced with older adults. Their role and their relationship with the participants were planned to vary, depending on the programme component. For complex and challenging physical exercise and cognitive training sessions or for the individual assessment of cognition or physical function, they should provide clear professional guidance and expert advice. For sessions that particularly focused on social interaction or on the participatory advancement of the *Quartier Agil* programme, they should hold back and take a moderating role.

Quartier Agil offered six components, from which each participant could choose his/her individually preferred combination (Table 1). The combination of physical and cognitive contents, social activities and smartphone support was supposed to arouse the participants' interest and ensure a variety of options for them.

The multimodal group training was scheduled to be held for 1.5 hours once a week on the same day and place. It served to organise the group, introduce the members to the smartphone and the app, gather feedback, perform (dual-task) exercises, and to provide context as to how physical and cognitive abilities change with age and which strategies might be applied to slow down physical and cognitive decline. On the hot spots identified earlier in the process, group activities (e.g., a visit to the weekly market) were scheduled every second week, ideally at the suggestion of the participants as the experts in their own neighbourhood. Additional social and sociocultural group activities (e.g., preparing a meal together, playing bocce in the park) were arranged by the tutors early in each intervention cycle. The group members were then encouraged to take over and self-organise their activities or challenge one another to join public activities, freely choosing the frequency and duration, content and place.

For an additional option, some participants were offered to hold smartphone-supported home-based physical or cognitive training sessions using the respective features of the specifically designed and programmed *Quartier Agil* smartphone app, involving exercise training instructions (videos with strength and

Table 1 Components of the *Quartier Agil* intervention

	Key elements	Objective	Setting	Tutors' role	Location	Resources
Multimodal group training	Combined physical and cognitive (dual task) training, education	Improve cognitive and physical resources for relevant everyday functions; promote an (inter-)active lifestyle	Group	Instructing	Gym of the local sports club	Smartphones, training equipment
"Hot spot" activities	Activities in exploring the local environment	Be active; meet people in the neighbourhood; (re-)discover one's habitat, strengthen link to (social) neighbourhood	Group	Accompanying	"Hot spots" in the neighbourhood	Smartphones, local environment and facilities
Group challenge tasks	Tasks created by group members, posed to (sub-)groups	Be active; create curiosity; improve self-efficacy	Group	Stimulating	Neighbourhood	Dependent on task; mostly smartphones, local environment and facilities
Solitary physical training	Individually tailored physical exercises	Improve physical function	Individual	Supporting	Home	Smartphones, app
Solitary cognitive training	Individually tailored cognitive exercises	Improve cognitive function	Individual	Supporting	Home	Smartphones, app
Personal challenge tasks	Individual cognitive or physical tasks embedded in everyday activities	Be active; create curiosity; improve self-efficacy	Individual	Stimulating	Neighbourhood, home	Dependent on task; mostly smartphones, local environment and facilities

balance exercises) and cognitive games (e.g., memory exercises, anagram, Stroop tasks, and word search puzzle). These physical or cognitive tasks were linked to the calendar feature of the *Quartier Agil* app, and the participants were reminded via text messages. Other features of the *Quartier Agil* app included communication (chat feature), and the option to locate other participants in the quarter (which could be turned off by the participants). The individual content and progression of the physical and cognitive training features were managed by the tutors using a web interface. This interface also allowed the tutors to set up quizzes based on QR codes. Lastly, the participants were encouraged to set themselves personal challenge tasks relating to (everyday) physically or cognitively challenging activities, considering their individual needs and aims (e.g., walking instead of driving to the baker's shop, keeping the shopping list in mind instead of writing it down).

A particular focus of the intervention was the promotion of social participation through the maintenance and/or improvement of (instrumental) activities of daily living, physical mobility and autonomy. If requested, the tutors gave limited advice on possible primary or secondary care based on their therapeutic background and experience, but they did not provide any curative or therapeutic care.

Based on the recommendations by the American College of Sports Medicine [64], the following weekly physical activities and exercises and progression were recommended to most of the participants:

- Aerobic activities: 1 × 20 minutes (first month) ➔ 2–3 × 30–60 minutes (sixth month)
- Resistance training: 1 × 4–6 exercises, 1 × 10–15 repetitions, each with low to moderate resistance (first month) ➔ 1–2 × 4–6 exercises, 3 × 8–12 repetitions with high resistance (sixth month)
- Balance training: 1 × 4 static exercises, 2 × 15–30 seconds each (first month) ➔ 2 × 6 static and dynamic exercises, 4 × 30–60 seconds each or 10–15 repetitions, respectively (sixth month)
- Stretching according to individual needs

During the multimodal group training, for each of these domains, exemplary activities and exercises were performed together, and individual feedback was provided to the participants. Participants were instructed to try out various ways to accumulate the recommended dose of physical activity in each domain throughout every week. In doing so, they were free to choose "hot spot" activities, group challenge tasks, solitary physical training (smartphone-supported), or personal challenge tasks or any preferred combination of these (see Table 1). If participants already met or surpassed the recommended dose of physical activity, they were suggested to slowly increase the intensity or difficulty level, or the total amount of activities.

Cognitive-linguistic training was partially based on existing training programmes (SimA, NeuroVitalis)

[37, 38] and progressed according to the following scheme:

- First–sixth month: at least 10 minutes/day, self-paced cognitive training (attention, working memory, executive control, verbal ability), according to individual needs
- First–second month: 30 minutes/week, attention and focus (psychoeducation, group activity)
- Third–fourth month: 30 minutes/week, executive control (psychoeducation, group activity)
- Fifth–sixth month: 30 minutes/week, sensory systems and visual perception (psychoeducation, group activity)

To introduce the cognitive-linguistic exercises, these were first performed in the multimodal group training. Similar to the physical activities, participants could then choose their preferred way to achieve the recommended cognitive-linguistic training dose, e.g. real-life group activities or group challenges; individual, smartphone-supported cognitive training; and/or setting up personal challenge tasks.

During the 6 months of implementation, the content of the training sessions became more complex, and physical and cognitive-linguistic elements were linked. For example, initially, during a stepping task, the participants were asked to adjust their stepping pace and direction according to the appearance of cue words in a story read to them. At the end, the participants practised a rather complex line dance.

Individual tailoring

During the group training sessions, common criteria were applied to individually tailor the intervention, such as rating of perceived exertion, lack of concentration, as well as signs of exhaustion, pain and/or dizziness. The participants were instructed to reduce the intensity or take a break accordingly. Variations of exercises were offered (e.g., varying the initial body position, number of repetitions) to prompt individual adjustments. If the nature of the task permitted it, the participants were encouraged to help their peers.

The level of difficulty of the app-based cognitive tasks was automatically regulated by individual performance.

Data collection/assessments

The programme's feasibility was evaluated at the project level (process, resources and lessons learned) and the participant level (clinical data: physical and cognitive fitness, activity/mobility, participation). Defined sets of quantitatively measured outcome parameters for physical and cognitive fitness, as well as qualitative and self-estimated measures for social participation were used to estimate the magnitude of the effects. Because of the exploratory nature of the study and because of the expectation of a relatively high initial level of physical, cognitive and social activities of the participants, outcomes were not pre-defined as primary, secondary, or tertiary (deviating from the CONSORT statement).

The data on physical functionality and physical capacity, cognitive functionality and cognitive capacity, physical activity, quality of life and social participation were collected before (baseline) and after each of the two six-month cycles of intervention by the tutors (follow-up). The feedback of the participants and the tutors was gathered every fourth week and towards the end of each intervention cycle. The latter included requests and suggestions for upcoming sessions. During the programme, the attendance rate for the various components was recorded by the tutors.

It was planned that the *Quartier Agil* smartphone app also included a documentation feature, capturing login, sensor and self-report data. It should allow the participants (and by extension in an aggregated form, the tutors) to log the frequency and duration of app usage, as well as the frequency, amount, type and intensity of the solitary physical training and physical leisure activities, while safeguarding individual participant privacy and fully adhering to the data security requirements in Germany.

Physical function and capacity

The six-minute walk test (6MWT) was used to estimate aerobic (endurance) capacity. The 6MWT measures the maximum distance that the participants are able to walk on a flat surface within 6 minutes. While it has been described as sufficiently reliable, valid and responsive (minimum clinically important change: 20 m), ceiling effects do occur in persons with a high aerobic capacity [65].

The Berg Balance Scale (BBS) was used to assess balance and risk of falling. The BBS involves a standardised rating of the duration and quality of the performance in 14 balance-related tasks [66].

Leg strength was assessed by measuring the maximum isometric force of the knee extensors of the dominant leg, according to the Physiological Profile Assessment (PPA), using a digital force gauge attached to the subject's leg in a standardised seating position (90° knee and hip flexion). The greatest force out of three trials was recorded [67].

Cognitive function and capacity

The Montreal Cognitive Assessment (MoCA) was used to screen memory recall abilities, visuospatial abilities, multiple aspects of executive function, attention, concentration, working memory, language and orientation to time and place [62]. It also served to assess exclusion criteria.

The Nürnberger-Alters-Inventar (NAI; Nuremberg Gerontopsychological Inventory) served to evaluate cognitive functions, such as attention, memory and inhibition [68].

The Regensburg Word Fluency Test (RWT) was used to assess cognitive-linguistic performance through word-generation tasks for the evaluation of executive functioning and word fluency [69].

Physical activity

For the assessment of habitual physical activity, the participants wore an accelerometer (Actigraph wGT3X) during their waking hours for 1 week. The device was positioned on the hip to register triaxial acceleration at 100 Hz. The data collection and evaluation followed published recommendations [70], using cut-off points for moderate to vigorous physical activity (MVPA), according to Freedson et al. [71]. During that week, the participants were additionally asked to complete a handwritten activity diary and to subjectively estimate their average daily physical activity.

Quality of life

The participants rated their health-related quality of life (HRQOL) using the well-established Short Form 12 (SF-12) questionnaire. Based on the 12 questions on the SF-12, physical and mental component summary scores were calculated, each between 0 and 100 (respectively for the lowest and the highest levels of HRQOL) [72].

Additionally, the participants were asked to answer questions relating to their autonomy (AUT); past, present and future activities (PFF); and social participation (SOP) using the respective facets of the World Health Organization Quality of Life–OLD (WHOQOL-OLD) questionnaire [73]. For each facet, the transformed scale score, ranging from 0 to 100, was calculated.

Adverse events

Throughout the programme, adverse events, such as falls, cardio-respiratory complications, dizziness/vertigo and injuries of the musculoskeletal system, were documented and classified according to the degree of severity (minor, moderate, serious). Potential causality between the intervention or the assessments and moderate or serious events was analysed post hoc by examining the course of events and circumstances and looking for a plausible link.

Social participation

After the six-month intervention, the participants were asked to rate the change of their social participation using self-developed questions. Before and after the six-month intervention, for one week each, the participants were requested to record the number of persons with whom they had contact, the frequency of going outside their homes, the number of social contacts meaningful to them and the number of social contacts with whom they were satisfied.

Feedback of participants and tutors

At the end of each cycle, the participants provided structured feedback on the organisation of the programme and their overall satisfaction with it. Feedback was obtained by a questionnaire containing open-ended and closed-ended questions at the follow-up assessments, and a group discussion in one of the last multimodal group training sessions led by the tutors during which the key statements were summed up and noted. The tutors recorded their own impressions regarding the programme's feasibility and social effects, as well as the participants' active involvement and behaviour throughout the programme. They were also asked to reflect on the group size and constellation, resources for and barriers to the implementation of the various components, usability and maintenance of the smartphone and apps, as well as the intervention content and scheduling.

Statistical analysis

For the analysis of the clinical data, an intention-to-treat (ITT) approach was followed, with the last value carried forward in case a participant missed the follow-up test (assuming that the data were missing at random). To perform intragroup comparisons of clinical outcome measures before and after the intervention, the Wilcoxon-Wilcox test was used (IBM SPSS 22). No adjustments were made for covariates. The effect size (ES) r was calculated as $r = \frac{Z}{\sqrt{N}}$, where Z is derived from the Wilcoxon-Wilcox W test statistic, and N denotes the number of included observations [74].

Results

Participants

Of the potential participants recruited through newspaper advertisements, flyers on relevant sites in the neighbourhood (e.g., cafés or shops), community stakeholders and word-of-mouth recommendations, 19 and 20 persons met the inclusion criteria and were respectively included in Cycles 1 and 2 of the study (Fig. 1).

Descriptive sociodemographic data are presented in Table 2.

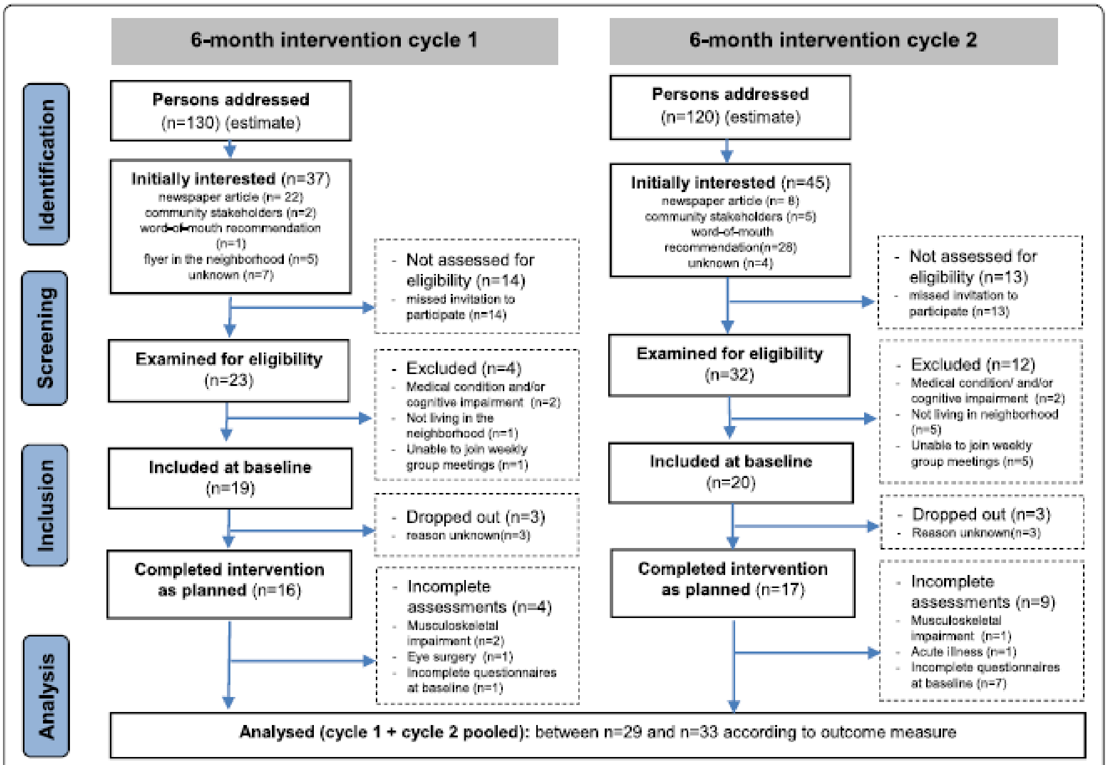

Fig. 1 STROBE flow of participants in the subsequent Cycles 1 and 2

Table 2 Characteristics of the study sample at baseline (that is, at the start of each 6-month intervention cycle)

	Total (*n* = 39) **Mean (Standard Deviation) or absolute number**	**Cycle 1** (*n* = 19) **Mean (Standard Deviation) or absolute number**	**Cycle 2** (*n* = 20) **Mean (Standard Deviation) or absolute number**
Age, years	73.1 (6.8)	71.9 (7.1)	73.6 (6.3)
Body mass index, kg/m^2	24.7 (4.4)	25.4 (3.2)	24.4 (3.7)
Gender (female)	33	16	17
Fall episode within last 1.5 years	24	17	7
Medical conditions present			
- neoplasms	3	2	1
- endocrine, nutritional and metabolic	11	3	8
- nervous system	3	2	1
- eye	3	0	3
- blood and circulatory system	15	9	6
- musculo-skeletal system	24	11	13

Data are presented as mean ± standard deviation or in absolute numbers

At baseline, the participants accumulated 158 ± 43 minutes of light activity and 30 ± 25 minutes of MVPA per day, with 13 of 32 participants following physical activity recommendations (> 30 minutes of MVPA/day) [75]. With a mean of 493 ± 74 meters, 25 of 33 participants performed better in the 6MWT than the age- and gender-specific norm at baseline [76]. Seventeen of 33 participants scored higher in the BBS than their age- and gender-specific norm value at the baseline [77]. MoCA scores indicated no clinically relevant case of cognitive impairment [61] in the sample (Table 4).

Recruitment

The two tutors spent a total of 20 work hours on making preparations and recruiting participants (31 minutes per successfully recruited participant). The eligibility criteria were highly applicable, and there were no unclear cases. The eligibility criteria did not seem too restrictive, with an estimated recruitment rate (proportion of persons included at baseline from the persons initially addressed – see Fig. 1) above 10%.

Assessments

The two tutors spent a total of 26 hours on making preparations and organising the baseline and follow-up assessments (20 minutes per participant). Actually, conducting the assessments took 164 hours in total (approximately 2 hours per participant). For various reasons, the assessments were partly incomplete for 13 of 33 participants (Fig. 1).

Attendance during intervention

In total, six participants dropped out during the intervention period (Fig. 1). The average attendance rate in the weekly group training (offered 24 times per cycle) was 76 ± 15%. In each cycle, almost half of the participants performed 10 additional activities at hot spots (e.g., a photo safari, during which individually meaningful landmarks were to be photographed and then shared with the group; a bike ride along the "Springorum" bicycle path on a former mine railway track; a teatime quiz at the well-known traditional "Wickenburg" bakery) and 3 group challenge tasks (e.g., playing bocce or Kubb; "mental walks" where routes were first to be imagined, and then actually walked).

Intervention: resources and implementation

The two tutors were both present at all the group sessions and in most additional activities that they had organised, except for holidays and solitary individual training. They each spent approximately 6 hours per week during Cycle 1 and 3 hours per week during Cycle 2 on the conception and implementation of all activities (excluding smartphone support).

For the weekly multimodal group training serving as an anchor, the gym of a local sports club was rented. This facility provided a broad range of sports equipment and training materials (Swiss ball, stepper, small sandbags, mats, etc.), which were complemented by weight bands and board and throwing games.

The amount of time that was initially planned for smartphone training in the weekly group sessions turned out to be too short and had to be extended. Furthermore, it had to be supplemented by individual support. Introducing the smartphones to the participants and supporting them, adjusting settings, assisting in solving technical problems and coordinating further problem solving with the technical partners required an extra 3 hours in the initial weeks of each cycle and approximately 1 hour towards the end of each cycle for each tutor.

The hot spot activities and the group challenge tasks were offered in the neighbourhood as planned. The smartphone was employed as an essential element of many of these activities. The exercise training and QR code scanner features of the Android app specifically designed for *Quartier Agil* were deemed useful, whereas its communication feature turned out to be of little use. Therefore, the latter feature was soon replaced with a standard app (WhatsApp), which was widely used for intragroup communication during and after each intervention cycle.

Intervention: example

An example of the actual programme offered in a typical week of *Quartier Agil* (week 13 of 25) is shown in Table 3. More detailed information will be made available in German on https://www.hs-gesundheit.de/forschung/abgeschlossene-projekte/quartier-agil.

Intervention: modifications

Based on the participants' feedback and on the tutors' experiences, as planned, the intervention was modified after completing Cycle 1.

Because of the challenges and the time expenditure related to the smartphone training and support, this was trimmed down to cover only the most relevant functions. Basic features, such as the messaging app or the contact information of other group members, were pre-installed. Furthermore, the tutors offered a fixed, clearly limited time slot prior to each group session for the introduction to specific functions, individual consultation and troubleshooting. The tutors also paired advanced smartphone users with less experienced ones and asked the participants to support one another. The time gained was utilised for physical and cognitive exercises, as well as

Table 3 Sample week of the *Quartier Agil* programme

Day	Monday	Tuesday	Wednesday	Thursday
Component	**Solitary cognitive training**	**Solitary physical training**	**Multimodal group training**	**Hot spot activities**
Content	Cognitive game Anagram via app	Six strength exercises via app	Greeting administration Cognitive game Homonym Obstacle course + cognitive task outlook	Paper chase: "On the trail of …" hike through botanical garden, combined with a smartphone-based quiz
Duration	5 minutes	30 minutes	90 minutes	60 minutes
Time	At the discretion of each participant	At the discretion of each participant	10:30–12:00	Self-organised by a number of participants
Location	Home	Home	Local sports club	Botanical garden
Mentoring	–	–	2 tutors	–
Resources	Smartphone, app	Smartphone, app	Word list, cones, hoop, balance pads	Smartphone, quiz
Organised by	1 tutor	1 tutor	2 tutors	2 tutors

In this example, no activity was scheduled from Friday to Sunday. The content of the multimodal group training and the actual hot spot activities usually changed from week to week

for facilitating group activities and getting to know one another.

For a further change in Cycle 2, the tutors included more didactic elements to promote group processes and social networking. They applied more games for familiarisation, promoted practising in small groups or in pairs and frequently changed seating arrangements. They also repeatedly let the group reflect on and discuss the project aims. Exercises, activities and app features that were rated 'poor' after Cycle 1 were replaced by other items. For example, instead of a modified ball game, a net-stepping task was provided to the participants of Cycle 2.

Most of the recurring technical issues with the smartphones were resolved by either the technical partners or the tutors using non-digital workarounds. This can be illustrated by the smartphone tracking module that was intended to identify highly frequented sites in the neighbourhood (hot spots) and to interconnect participants in real time (i.e., while they were moving around in the neighbourhood). Due to problems with the GPS signal processing and filtering, this tracking and interconnection module did not work as intended. As a workaround, hot spots were then identified based on a simple paper-and-pencil alternative and on a discussion with all participants to align group activities with their preferences and habits.

Intervention: participants' feedback

The participants' feedback indicated good overall satisfaction with the programme, and most participants asked for an extension of the intervention period. Of 29 participants, 27 stated that their expectations had been fulfilled. Twenty-two of 29 participants clearly felt that the programme had indeed helped them make new contacts and expand their social network, as well as actively participate in the social life of their neighbourhood. While this was not formally evaluated, the participants' smartphone competency seemed considerably improved.

Of the group activities, the QR code-based quiz in the nearby botanical garden, a relay of 100 questions and the throwing game Kubb were rated most positively. Modified ball games and other sports games were less popular.

The smartphone videos to guide individual strength and balance training were initially regarded as helpful but were actually used to varying degrees. Cognitive challenges offered via the *Quartier Agil* app were appreciated and used after some time. The overall satisfaction with the specifically designed app varied between participants because of both dispensable and missing features. However, after the initial barriers had been overcome, the smartphone itself and the conventional messaging app were lauded and used quite frequently.

Intervention: tutors' feedback

Generally, the tutors rated *Quartier Agil* as a feasible programme. However, they addressed some limiting factors. Extensive differences in cognitive and physical capabilities among the participants, as well as varying extrinsic motivators and expectations, made it difficult to design and deliver an intervention that was suitable and interesting for everyone. Due to this heterogeneity, the group size (20 persons) was regarded as the maximum, which still enabled safe and tailored supervision by the two tutors. The smartphone introduction and support were perceived as the greatest challenge to this project. Abundant minor and major technical problems

Table 4 *Quartier Agil* intervention effects

		Baseline		Follow-up		Wilcoxon-Wilcox test (W)		Effect size
	n	*Median (Range)*		*Median (Range)*		*z*	*p*	*r*
Berg Balance Scale (score)	33	54 (41–56)		55 (44–56)		−2.33	.020	.41
	n	*Mean (Standard Deviation)*	*95% CI*	*Mean (Standard Deviation)*	*95% CI*	*z*	*p*	*r*
Six-minute walk test (m)	33	493 (74.3)	467–519	500 (82.9)	470–529	−1.05	.295	.18
Isometric strength: knee extension (kg)	33	21.6 (7.32)	19.0–24.2	22.2 (9.00)	19.0–25.4	- 0.38	.705	.07
Light physical activity (% of wear time)	32	18.8 (5.44)	16.8–20.8	18.7 (5.16)	16.9–20.6	−0.11	.909	.02
Moderate to vigorous physical activity (% of wear time)	32	3.94 (3.34)	2.74–5.14	3.80 (2.95)	2.74–4.87	−0.07	.943	.01
MoCA (score)	33	25.7 (2.20)	24.9–26.5	25.7 (2.47)	24.8–26.6	−0.14	.890	.02
NAI subtest: figure test (*n* remembered items)	33	5.27 (1.01)	4.92–5.63	5.64 (0.78)	5.36–5.91	−2.03	.042	.35
NAI subtest: wordlist (sum *n* copied and recognised items)	33	5.73 (2.11)	4.98–6.48	6.12 (1.73)	5.51–6.73	−1.09	.274	.19
NAI subtest: numbers connection test (RT in s)	33	25.3 (12.1)	21.1–29.7	22.5 (5.94)	20.4–24.6	−0.47	.638	.08
NAI subtest: numbers symbol test (score)	33	47.9 (9.66)	44.4–51.3	48.42 (9.47)	45.1–51.8	−0.52	.603	.09
NAI subtest: Stroop (interference score, RT in s)	33	23.5 (11.9)	19.3–27.7	20.2 (9.17)	17.0–23.5	−2.18	.030	.38
NAI-Subtest: latent learning (*n* remembered items)	33	6.09(1.40)	5.59–6.59	6.24 (1.09)	5.86–6.63	−0.47	.641	.08
RWT subtest: formal lexical verbal fluency	33	62.4 (21.4)	54.8–70.0	70.4 (23.5)	62.0–78.7	−1.64	.100	.29
RWT subtest: formal lexical verbal fluency change	33	63.1 (24.6)	54.4–71.8	75.9 (21.0)	68.4–83.3	−3.25	.001	.57
RWT subtest: semantic verbal fluency	33	75.8 (24.1)	67.3–84.3	83.5 (20.0)	76.4–90.6	−2.75	.006	.48
RWT subtest: semantic verbal fluency change	33	72.2 (24.0)	63.8–80.7	74.0 (24.0)	65.0–82.0	−0.74	.462	.13
SF-12	31							
PCS		48.1 (7.63)	45.3–50.9	46.3 (10.8)	42.4–50.3	−1.05	.296	.19
MCS		24.3 (9.24)	20.9–27.6	24.9 (7.83)	22.0–27.8	−0.04	.970	.01
WHOQOL-OLD	*32*							
AUT		*78.9 (13.7)*	74.0–83.9	*78.9 (13.3)*	74.1–83.7	−0.09	.929	.02
PPF		*74.4 (16.8)*	68.4–80.5	*74.1 (17.0)*	67.8–80.2	−0.22	.830	.04
SOP		*76.2 (16.0)*	70.4–81.9	*77.3 (19.4)*	70.3–84.4	−0.75	.456	.13
	n	*Absolute number*		*Absolute number*		*z*	*p*	*r*
Activity diary	29							
Contact persons/week						*0*	1.0	*0*
0 persons		0		0				
1–3 persons		6		4				
4–7 persons		16		20				
8+ persons		7		5				
Left home/week						*−1.41*	.157	*.26*
0 times		1		0				
1–3 times		25		25				
4–7 times		3		4				
8+ times		0		0				
Meaningful contacts/ week						*−0.71*	.48	*.13*
0 contacts		0		0				

Table 4 (continued)

1–3 contacts	17	17			
4–7 contacts	12	10			
8+ contacts	0	2			
Satisfaction with contacts			*0*	1.0	*0*
very high	9	9			
high	15	14			
moderate	4	6			
low	1	0			
not satisfied	0	0			

Abbreviations: *MoCA* Montreal Cognitive Assessment, *NAI* Nuremberg Gerontopsychological Inventory, *RT* reaction time, *n* quantity, *RWT* Regensburg Word Fluency Test, *PCS* physical component summary score, *MCS* mental component summary score, *AUT* Autonomy, *PPF* past, present and future activities, *SOP* social participation

and delays consumed the time spent with the group and required intensive cooperation with the technical partners, relating to the front-end, back-end and data processing components. Finally, albeit to a lesser degree in Cycle 2, the tutors thought that the participants were hesitant to show initiative in co-producing their activities. While they became familiar with each other and got involved over the course of each cycle, they were still slow to get active themselves. So, even towards the end, they relied on the participation tutors to bring in ideas instead of designing the individual and the group challenges on their own.

Adverse events

There were neither moderate nor serious adverse events during the investigation period that could be traced back to the intervention or assessments of the *Quartier Agil* project.

Preliminary estimate of effects

Most outcome measures (except improved balance) related to physical function and physical activity did not significantly differ between baseline and follow-up (Table 4). Because of problems with the data collection using the *Quartier Agil* app and because of a large number of inconsistent entries in the activity diary, the actual types of activities could not be analysed.

Cognitive testing revealed a significantly improved short-term memory from baseline to follow-up and an increased inhibition, as well as a significant improvement of executive functions and word fluency, displayed by two of the word generation tasks of the RWT (Table 4). All other cognitive parameters showed a trend towards consistent or more efficient cognitive functioning but did not reach significance.

Quality of life and indicators of social participation did not significantly differ between baseline and follow-up (Table 4).

Discussion

According to this exploratory proof-of-concept study, the *Quartier Agil* approach to promote older people's social participation in their neighbourhood seems feasible and safe. Its core components and principles (provide and enable social interaction, take place in the neighbourhood, involve participants and use digital resources) can be included and followed, albeit to varying degrees and at different costs. Adaptations in the intervention and in the assessments may contribute to better assessment and exploitation of the potential of the *Quartier Agil* approach.

Resources needed

More resources than anticipated were necessary for the recruitment and assessments, as well as for the implementation of some components of the intervention.

The high number of programme components and the consideration of perspectives from multiple disciplines, such as sociogerontology and psychogerontology, prevention sciences, and sports and therapy science, strengthen the programme and contribute to a truly bio-psycho-social approach. However, in practice, this increases the complexity and the resources needed, which becomes particularly apparent in developing and organising the smartphone support.

Recruitment

The recruitment was sufficiently feasible. For future studies, it is interesting to note that in the first cycle, at a time when we did not have any personal connections to stakeholders or potential participants in the neighbourhood, most participants were recruited via newspaper advertisement. Later, as soon as some personal relationships were established (Cycle 2), most participants were recruited by word-of-mouth recommendations. The smartphone support was an important attractor for programme participation. This also had an impact on how the group was composed and what the preferences of the participants were later in the programme. It is unclear if less cognitively, physically and/or socially active persons (which would be the actual target group in a future larger study) could be recruited with similar ease. This may require different recruitment strategies.

Intervention

Overall, with the changes introduced for Cycle 2 (as listed under the sub-heading Intervention: Modifications), the intervention was feasible. Nonetheless, several adaptations could be considered to strengthen it.

Introducing the smartphone and apps to the participants turned out to be very time-consuming for the tutors. In this situation, more and better organised interactions among group members may improve less experienced users' adoption of the new technology. Taking advantage of the heterogeneous group constellation by pairing experienced and inexperienced users in Cycle 2 turned out to be useful, together with restricting time for smartphone lessons. For the experienced participants, helping and instructing less skilled group members seemed to solidify their own knowledge, while the less experienced participants indeed seemed to increase their digital competency because of this help [78, 79]. For the future, another option might be to involve digital natives (e.g., younger relatives, such as grandchildren).

Assessments

Baseline and follow-up assessments could be performed safely and were generally feasible, but some participants had incomplete data. The total number of assessments may have overwhelmed these participants, as further discussed in the subsection "Adequacy of outcome parameters". In the future, the relevance of these assessments (and of the completeness of the data) could be explained more carefully to the participants (e.g., by additionally providing them with a video), and all data should be immediately checked for completeness and plausibility (enabling further enquiry if needed).

Participant satisfaction and lessons learned

Overall, *Quartier Agil* was well received, with few dropouts. Specific adjustments may be useful based on the feedback of the participants and the tutors, as listed in the Results section. The most important adjustments likely concern the smartphone app and the participants' views on their own role in the project.

The app was specifically designed and programmed for *Quartier Agil*, intended to ease or enable goal and incentive setting, and offering home-based physical or cognitive training sessions. Another planned feature was the documentation of physical training, activities and visited locations, and most importantly, older people's social interaction itself. However, some of the features of the app were not well received by the participants. Further, some of the documentation features were not (completely) programmed because of the limited resources available, while other features did not function properly, or were unreliable. We had underestimated the iterative process of app development and the recurring bugs that could not to be resolved quickly. Underlying problems included the front-end, back-end and data processing components of the sensing system.

For future interventions, the research team would aim to either select established and user-tested apps well before the start of the project (commercial, open-source, prototype) or plan to use paper-and-pencil alternatives. As an example, WhatsApp successfully initiated brisk communication among the participants far beyond the *Quartier Agil* intervention. Studies on instant messaging (e.g., WhatsApp) provide some evidence of a positive relation between computer-mediated communication and perceived social support and connectedness among community-dwelling older adults [80]. With ongoing technological development, smartphone apps will offer more options and may better adhere to standards for mobile health-related apps. However, it will still be challenging to identify suitable, affordable and easy-to-use applications for specific means, such as goal setting, describing behavioural patterns over time (documentation of activities/ visited locations) and examining social network systems.

Researchers could attempt to better explain the nature of social interaction to the participants and to further gather and discuss their individual perceptions of social participation. This would consume more time early on and might require better use of didactic strategies, but it could result in a greater or a more specific commitment of the participants and allow them to co-produce the intervention instead of just perceiving themselves as recipients. Encouraging participants' exchange on the specific objectives of the project could be more explicitly extended to the underlying concept of enhancing activity and cognitive function as a means to enable participation, while stressing the relation between physical-cognitive functions and (perceived) social participation as individual and varying among persons. Researchers could also better illustrate to participants that (training) activities are not only means of maintaining health but equally represent a form of autonomy, participation and social interaction themselves.

Adequacy of outcome parameters

The data collection and testing provided valuable information on several parameters relevant for social participation. The participants perceived it as quite extensive, so the researchers did not add any assessments in Cycle 2. However, the outcomes may not have fully covered the scope of the interventions (e.g., concurrent motor and cognitive task training, and smartphone education and training) and the aims of *Quartier Agil* (e.g., to prevent both physical decline and social isolation in the neighbourhood, and to increase health behaviour competence). Outcomes such as dual-tasking abilities [81], perceived competence and confidence to handle and use a smartphone [82], the size of the personal life space [83] and physical activity-related health competence [84] might offer advantages over some of the rather clinical and functional outcomes chosen for this feasibility study. Dual-tasking abilities, smartphone competence, life space and health behaviour competence might better reflect the multidimensionality of the researchers' approach, have higher relevance for or be more closely linked to participation and be more sensitive to the actual intervention.

Such outcomes should not simply be added to the current set but would need to replace existing functional outcomes. The choice of parameters to assess both the process and the outcomes should ultimately be guided by a refined theory of change (logic model) of the *Quartier Agil* intervention, while strengthening the focus on social participation. The social relationships of the present study's participants should be characterised in more detail to be able to reflect on and understand the implications of their different nature and type. For example, in previous studies, friendship ties were found to be more closely related to late-life physical activity than family ties [85].

In this context, the utility of a detailed quantitative collection of social interactions, daily activities and mobility patterns – with the goal of actually guiding the intervention – needs to be discussed critically. While using (big data) analytical techniques might help expose relevant behaviour patterns and (inter-)relations with social participation during the intervention, the sole reliance on objective data might detract participants from finding and communicating their own perspectives and solutions. As a technological solution, sensor data might be used to trigger context-contingent, ecological momentary assessments [86], which could later be used for scientific analysis, as well as assist in individual and group reflections. For example, when a participant changes his/her location in the neighbourhood (obtained via GPS data), an app might immediately deliver related questions (e.g., "Why are you here?" "Whom are you with?" "Do you feel that you are socially participating?"). Participant incentives might be necessary to encourage the use of the sensing app for long periods of time.

Focus group discussions, semi-structured interviews and photovoice should complement the quantitative assessments. Apart from producing scientific findings, these qualitative assessments could also be viewed as a participatory method and part of the intervention, since these might contribute to triggering more thorough reflection and communication processes regarding social participation, the participants' role in the project and their neighbourhood, among others.

Magnitude of effects

According to this study's results, *Quartier Agil* may safely contribute to the preservation of physical functioning and the improvement of cognitive functioning that are relevant for participation and health in an already physically and cognitively active population. While some of these effects' relevance for older persons can hardly be underestimated, and some individuals informally reported considerable real-life impacts, these functional effects had a limited magnitude on a group level. Due to the broad inclusion criteria resulting in a relatively fit yet heterogeneous group, and because of the accentuated multimodal nature of the programme, this finding was somewhat expected.

Unfortunately, the actual amount of individual training and activity throughout the six-month intervention remains unclear, since the self-reported extent and intensity of the solitary physical training, as well as the usage/login data for the *Quartier Agil* app features including the cognitive training were either not available in time, or were apparently not logged correctly. Using more reliable and user-friendly logging technology may allow researchers to analyse possible dose-response relations in future studies.

Future study

A larger controlled study to more comprehensively investigate the *Quartier Agil* approach seems warranted. However, in order to be able to actually detect effects, this future study should focus on older adults who are considerably less active than the participants in the current trial. Further, the intervention and the outcome assessments should be revised according to the suggestions offered in the preceding sections.

Limitations

This study was deliberately not set up to have high internal and external validity. Its purpose was to systematically gather information on the feasibility of both the *Quartier Agil* intervention approach and a study to evaluate this approach. This study's limitations include its non-controlled design; the small, selective convenience sample, which is not representative of the actual target group; and the relatively high number of incomplete assessments. The lack of exclusion criteria regarding current physical and cognitive activities should be considered as a particularly significant limitation.

Conclusions

Overall, the *Quartier Agil* approach to promote autonomy and social participation of older people living in the same neighbourhood through combined physical and cognitive training, supported by technical devices, such as smartphones, appears feasible. Even for the physically and cognitively active and capable population, modest improvement or at least the preservation of physical and cognitive functions relevant for participation could be observed. Likewise, the approach offers older people, who have different interests and motives, the opportunity to have a sense of achievement and to gain experience on a variety of levels (social participation, digital participation, technical competence, physical function, cognitive capacity and connectedness to the neighbourhood). Increasing solidarity and exchange among neighbourhood residents may contribute to community-building and enhanced neighbourhood cohesion.

The variety of overlapping social, digital, cognitive and physical activities may contribute to making this unique programme interesting and attractive to diverse participants. However, such a broad range of intervention components necessarily comes at a price, that is, the portion of each component and its effect on the corresponding domain may be limited. Furthermore, the multimodal nature of the project and the use of smartphones (including the app) require a significant organisational effort and tie up considerable resources for its supervision.

Based on the results presented in this paper, a future larger study to assess the effects of a refined *Quartier Agil* intervention on social participation as a primary outcome, and revised secondary outcomes among socially, physically and cognitively less active elderly persons seems worthwhile.

Meantime, this study's approach and the lessons learned have generated substantial interest among the people involved in the project and other municipalities and neighbourhoods. Even in its current (preliminary) conceptualisation, the project may provide interesting options for sports clubs, municipalities, local charities, churches, welfare organisations and other social institutions to extend the existing engagement and their presence in the neighbourhood. The recent concept of the BMBF-funded project *Quartier Agil* is described in more detail in a German manual, which will be made available (for application in other neighbourhoods) at https://www.hs-gesundheit.de/forschung/abgeschlossene-projekte/quartier-agil.

Abbreviations

6MWT: six-minute walk test; AUT: autonomy facet of the WHOQOL-OLD questionnaire; BBS: Berg Balance Scale; BMBF: Federal Ministry of Education and Research; FUNTEX: Functional Task Exercise; HIFE: High Intensity Functional Exercise; HRQOL: health-related quality of life; ITT: intention-to-treat; LIFE: Lifestyle Functional Exercise Program; MoCA: Montreal Cognitive Assessment; MVPA: moderate to vigorous physical activity; NAI: Nuremberg Gerontopsychological Inventory; PFF: past, present and future activities facet of the WHOQOL-OLD questionnaire; PPA: Physiological Profile Assessment; RWT: Regensburg Word Fluency Test; SF-12: Short Form 12; SIMA: Maintaining and supporting Independent Living in Old Age; SOP: social participation facet of the WHOQOL-OLD questionnaire; TIDieR: Template for Intervention Description and Replication; WEBB: Weight-Bearing Exercise for Better Balance; WHOQOL-OLD: World Health Organization Quality of Life–OLD.

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Authors' contributions

Study concept and design: CG, SaSo, CT. Data acquisition: LG, AO. Data analysis: LG, AO, CT. Data interpretation: LG, AO, CT, SaSo, CG. Drafting the manuscript: CT, LG. Manuscript revision for important intellectual content: LG, AO, CT, SaSo, CG. All authors have read and approved the final manuscript.

Authors' information

This study's preliminary results have been presented at the "8th Conference of HEPA Europe 2017" in Zagreb, Croatia; the "Gerontologie-Geriatrie-Kongress 2018" in Cologne, Germany; and the "Forschungssymposium Physiotherapie 2019" in Hildesheim, Germany and published in the journal *Bewegungstherapie & Gesundheitssport* 2019; 35: 235–245, doi https://doi.org/10.1055/a-0968-1359.

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Availability of data and materials

The datasets used and analysed in this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study had been approved by the Ethics Committee of the German Society of Physiotherapy (Deutscher Verband für Physiotherapie, 2016-06). A mental health expert (SaSo) had ruled that all adult persons interested in participating had been deemed capable of ethically and medically consenting for their participation in the research presented in this manuscript. All participants provided their written informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References
1. Adams KB, Leibrandt S, Moon H. A critical review of the literature on social and leisure activity and wellbeing in later life. Ageing Soc. 2011;31:683–712. https://doi.org/10.1017/S0144686X10001091.
2. Rowe JW, Kahn RL. Successful aging. Gerontologist. 1997;37:433–40. https://doi.org/10.1093/geront/37.4.433.
3. Cornwell B, Laumann EO, Schumm LP. The social connectedness of older adults: a National Profile*. Am Sociol Rev. 2008;73:185–203. https://doi.org/10.1177/000312240807300201.
4. Ma L, Sun F, Tang Z. Social frailty is associated with physical functioning, cognition, and depression, and predicts mortality. J Nutr Health Aging. 2018;22:989–95. https://doi.org/10.1007/s12603-018-1054-0.
5. Douglas H, Georgiou A, Westbrook J. Social participation as an indicator of successful aging: an overview of concepts and their associations with health. Aust Health Rev. 2017;41:455–62. https://doi.org/10.1071/AH16038.
6. Lifshitz-Vahav H, Shrira A, Bodner E. The reciprocal relationship between participation in leisure activities and cognitive functioning: the moderating effect of self-rated literacy level. Aging Ment Health. 2017;21:524–31. https://doi.org/10.1080/13607863.2015.1124838.
7. National Institute of Aging, WHO. Global health and aging; 2011. https://www.who.int/ageing/publications/global_health/en/. Accessed 15.3.20
8. Saito T, Murata C, Aida J, Kondo K. Cohort study on living arrangements of older men and women and risk for basic activities of daily living disability: findings from the AGES project. BMC Geriatr. 2017;17:183. https://doi.org/10.1186/s12877-017-0580-7.
9. de Souza A, Pelegrini TDS, Ribeiro JHM, Pereira DS, Mendes MA. Concept of family insufficiency in the aged: critical literature analysis. Rev Bras Enferm. 2015;68:1176–85. https://doi.org/10.1590/0034-7167.2015680625i.
10. Heinze RG, Naegele G. EinBlick in die Zukunft: Gesellschaftlicher Wandel und Zukunft des Alterns im Ruhrgebiet. Münster: LIT; 2010.
11. Farber N. Aging in place: a state survey of livability policies and practices. Denver: National Conference of State Legislatures; AARP Public Policy Institute; 2011.
12. Rüßler H, Stiel J. Im quartier selbstbestimmt älter werden; 2013. http://www.sozialraum.de/im-quartier-selbstbestimmt-aelter-werden.php. Accessed 15 Feb 2018
13. Fuchs R, Schlicht W, editors. Seelische Gesundheit und sportliche Aktivität. Göttingen, Bern, Wien: Hogrefe; 2012.
14. Martin M, Tesch-Römer C, Kliegel M. Psychologische Grundlagen der Gerontologie. 4th ed. s.l: W. Kohlhammer Verlag; 2014.
15. Hwang PW-N, Braun KL. The effectiveness of dance interventions to improve older Adults' health: a systematic literature review. Altern Ther Health Med. 2015;21:64–70.
16. Roberts CE, Phillips LH, Cooper CL, Gray S, Allan JL. Effect of different types of physical activity on activities of daily living in older adults: systematic review and meta-analysis. J Aging Phys Act. 2017;25:653–70. https://doi.org/10.1123/japa.2016-0201.
17. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc. 2011;43:1334–59. https://doi.org/10.1249/MSS.0b013e318213fefb.
18. Angulo J, El Assar M, Álvarez-Bustos A, Rodríguez-Mañas L. Physical activity and exercise: strategies to manage frailty. Redox Biol. 2020;35:101513. https://doi.org/10.1016/j.redox.2020.101513.
19. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54:1451–62. https://doi.org/10.1136/bjsports-2020-102955.
20. VanSwearingen JM, Perera S, Brach JS, Wert D, Studenski SA. Impact of exercise to improve gait efficiency on activity and participation in older adults with mobility limitations: a randomized controlled trial. Phys Ther. 2011;91:1740–51. https://doi.org/10.2522/ptj.20100391.
21. Sunde S, Hesseberg K, Skelton DA, Ranhoff AH, Pripp AH, Aarønæs M, et al. Effects of a multicomponent high intensity exercise program on physical function and health-related quality of life in older adults with or at risk of mobility disability after discharge from hospital: a randomised controlled trial. BMC Geriatr. 2020;20:464. https://doi.org/10.1186/s12877-020-01829-9.
22. Weber M, Belala N, Clemson L, Boulton E, Hawley-Hague H, Becker C, et al. Feasibility and effectiveness of intervention Programmes integrating functional exercise into daily life of older adults: a systematic review. Gerontology. 2018;64:172–87. https://doi.org/10.1159/000479965.
23. de Vreede PL, Samson MM, van Meeteren NLU, Duursma SA, Verhaar HJJ. Functional-task exercise versus resistance strength exercise to improve daily function in older women: a randomized, controlled trial. J Am Geriatr Soc. 2005;53:2–10. https://doi.org/10.1111/j.1532-5415.2005.53003.x.
24. Carande-Kulis V, Stevens JA, Florence CS, Beattie BL, Arias I. A cost-benefit analysis of three older adult fall prevention interventions. J Saf Res. 2015;52:65–70. https://doi.org/10.1016/j.jsr.2014.12.007.
25. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012:CD007146. https://doi.org/10.1002/14651858.CD007146.pub3.
26. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2019;1:CD012424. https://doi.org/10.1002/14651858.CD012424.pub2.
27. Graham LJ, Connelly DM. "any movement at all is exercise": a focused ethnography of rural community-dwelling older adults' perceptions and experiences of exercise as self-care. Physiother Can. 2013;65:333–41. https://doi.org/10.3138/ptc.2012-31.
28. Beauchamp MK, Lee A, Ward RF, Harrison SM, Bain PA, Goldstein RS, et al. Do exercise interventions improve participation in life roles in older adults? A systematic review and meta-analysis. Phys Ther. 2017;97:964–74. https://doi.org/10.1093/ptj/pzx082.
29. ten Brinke LF, Davis JC, Barha CK, Liu-Ambrose T. Effects of computerized cognitive training on neuroimaging outcomes in older adults: a systematic review. BMC Geriatr. 2017;17:139. https://doi.org/10.1186/s12877-017-0529-x.
30. Schultheisz TSDV, de Aquino RR, Alves ABF, Radl ALM, Serafim AP. Effect of cognitive stimulation workshops on the self-esteem and cognition of the elderly a pilot project. Dement Neuropsychol. 2018;12:421–6. https://doi.org/10.1590/1980-57642018dn12-040013.
31. Mowszowski L, Lampit A, Walton CC, Naismith SL. Strategy-based cognitive training for improving executive functions in older adults: a systematic review. Neuropsychol Rev. 2016;26:252–70. https://doi.org/10.1007/s11065-016-9329-x.
32. Bherer L. Cognitive plasticity in older adults: effects of cognitive training and physical exercise. Ann N Y Acad Sci. 2015;1337:1–6. https://doi.org/10.1111/nyas.12682.
33. Reijnders J, van Heugten C, van Boxtel M. Cognitive interventions in healthy older adults and people with mild cognitive impairment: a

systematic review. Ageing Res Rev. 2013;12:263–75. https://doi.org/10.1016/j.arr.2012.07.003.
34. Wolinsky FD, Vander Weg MW, Howren MB, Jones MP, Dotson MM. The effect of cognitive speed of processing training on the development of additional IADL difficulties and the reduction of depressive symptoms: results from the IHAMS randomized controlled trial. J Aging Health. 2015;27:334–54. https://doi.org/10.1177/0898264314550715.
35. Marusic U, Verghese J, Mahoney JR. Cognitive-based interventions to improve mobility: a systematic review and meta-analysis. J Am Med Dir Assoc. 2018;19:484–491.e3. https://doi.org/10.1016/j.jamda.2018.02.002.
36. Joubert C, Chainay H. Aging brain: the effect of combined cognitive and physical training on cognition as compared to cognitive and physical training alone - a systematic review. Clin Interv Aging. 2018;13:1267–301. https://doi.org/10.2147/CIA.S165399.
37. Oswald WD, Gunzelmann T, Rupprecht R, Hagen B. Differential effects of single versus combined cognitive and physical training with older adults: the SimA study in a 5-year perspective. Eur J Ageing. 2006;3:179. https://doi.org/10.1007/s10433-006-0035-z.
38. Baller G, Kalbe E, Kaesberg S, Kessler J. NeuroVitalis. Köln: ProLog; 2013.
39. Kaesberg S, Kalbe E, Mayer A, Baller G, Sack A, Kessler J. NEUROvitalis®: effects of a new neuropsychological training in healthy elderly individuals as well as patients suffering from mild cognitive impairment and early-stage Alzheimer's disease. Alzheimer's Dement. 2009;5:332.
40. Rahe J, Becker J, Fink GR, Kessler J, Kukolja J, Rahn A, et al. Cognitive training with and without additional physical activity in healthy older adults: cognitive effects, neurobiological mechanisms, and prediction of training success. Front Aging Neurosci. 2015;7:187. https://doi.org/10.3389/fnagi.2015.00187.
41. Rahe J, Petrelli A, Kaesberg S, Fink GR, Kessler J, Kalbe E. Effects of cognitive training with additional physical activity compared to pure cognitive training in healthy older adults. Clin Interv Aging. 2015;10:297–310. https://doi.org/10.2147/CIA.S74071.
42. Mayo NE, Anderson S, Barclay R, Cameron JI, Desrosiers J, Eng JJ, et al. Getting on with the rest of your life following stroke: a randomized trial of a complex intervention aimed at enhancing life participation post stroke. Clin Rehabil. 2015;29:1198–211. https://doi.org/10.1177/0269215514565396.
43. Pedersen BK, Saltin B. Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. Scand J Med Sci Sports. 2015;25(Suppl 3):1–72. https://doi.org/10.1111/sms.12581.
44. Holmes WR, Joseph J. Social participation and healthy ageing: a neglected, significant protective factor for chronic non communicable conditions. Glob Health. 2011;7:43. https://doi.org/10.1186/1744-8603-7-43.
45. Welch V, Petkovic J, Pardo Pardo J, Rader T, Tugwell P. Interactive social media interventions to promote health equity: an overview of reviews. Health Promot Chronic Dis Prev Can. 2016;36:63–75. https://doi.org/10.24095/hpcdp.36.4.01.
46. Baker S, Warburton J, Waycott J, Batchelor F, Hoang T, Dow B, et al. Combatting social isolation and increasing social participation of older adults through the use of technology: a systematic review of existing evidence. Australas J Ageing. 2018;37:184–93. https://doi.org/10.1111/ajag.12572.
47. Seifert A, Schlomann A, Rietz C, Schelling HR. The use of mobile devices for physical activity tracking in older adults' everyday life. Digit Health. 2017;3:2055207617740088. https://doi.org/10.1177/2055207617740088.
48. Koptyug E. Share of smartphone users in Germany in 2020, by age group; 2021. https://www.statista.com/statistics/469969/share-of-smartphone-users-in-germany-by-age-group/. Accessed 1 Jun 2021
49. Plaza I, Martín L, Martin S, Medrano C. Mobile applications in an aging society: status and trends. J Syst Softw. 2011;84:1977–88. https://doi.org/10.1016/j.jss.2011.05.035.
50. McGaughey RE, Zeltmann SM, McMurtrey ME. Motivations and obstacles to smartphone use by the elderly: developing a research framework. IJEF. 2013;7:177. https://doi.org/10.1504/IJEF.2013.058601.
51. Osterhoff A, Günther L, Thiel C, Grüneberg C, Sommer S. ICF-based analysis of barriers and facilitators for smartphone usage in an app-supported training program for health and well-being of older users. In: Gao Q, Zhou J, editors. Human aspects of IT for the aged population. Healthy and active aging: 6th international conferenceITAP 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II. 1st ed; 2020. p. 343–53.
52. Poscia A, Stojanovic J, La Milia DI, Duplaga M, Grysztar M, Moscato U, et al. Interventions targeting loneliness and social isolation among the older people: an update systematic review. Exp Gerontol. 2018;102:133–44. https://doi.org/10.1016/j.exger.2017.11.017.
53. Cattan M, White M, Bond J, Learmouth A. Preventing social isolation and loneliness among older people: a systematic review of health promotion interventions. Ageing Soc. 2005;25:41–67. https://doi.org/10.1017/S0144686X04002594.
54. Rubio E, Lázaro A, Sánchez-Sánchez A. Social participation and independence in activities of daily living: a cross sectional study. BMC Geriatr. 2009;9:26. https://doi.org/10.1186/1471-2318-9-26.
55. Chaudhury H, Campo M, Michael Y, Mahmood A. Neighbourhood environment and physical activity in older adults. Soc Sci Med. 2016;149:104–13. https://doi.org/10.1016/j.socscimed.2015.12.011.
56. Saito LT. How low-income residents can benefit from urban development: the LA live community benefits agreement. City Community. 2012;11:129–50. https://doi.org/10.1111/j.1540-6040.2012.01399.x.
57. Farrance C, Tsofliou F, Clark C. Adherence to community based group exercise interventions for older people: a mixed-methods systematic review. Prev Med. 2016;87:155–66. https://doi.org/10.1016/j.ypmed.2016.02.037.
58. Thabane L, Ma J, Chu R, Cheng J, Ismaila A, Rios LP, et al. A tutorial on pilot studies: the what, why and how. BMC Med Res Methodol. 2010;10:1. https://doi.org/10.1186/1471-2288-10-1.
59. Thompson WR, Gordon NF. American College of Sports Medicine guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins; 2013.
60. Deutsche Gesellschaft für Sportmedizin und Prävention. S 1- Leitlinie Vorsorgeuntersuchung im sport; 2007. https://www.dgsp.de/seite/278046/. Accessed 15 Mar 2020
61. Carson N, Leach L, Murphy KJ. A re-examination of Montreal cognitive assessment (MoCA) cutoff scores. Int J Geriatr Psychiatry. 2018;33:379–88. https://doi.org/10.1002/gps.4756.
62. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53:695–9. https://doi.org/10.1111/j.1532-5415.2005.53221.x.
63. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ. 2014;348:g1687. https://doi.org/10.1136/bmj.g1687.
64. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc. 2009;41:1510–30. https://doi.org/10.1249/MSS.0b013e3181a0c95c.
65. Du H, Newton PJ, Salamonson Y, Carrieri-Kohlman VL, Davidson PM. A review of the six-minute walk test: its implication as a self-administered assessment tool. Eur J Cardiovasc Nurs. 2009;8:2–8. https://doi.org/10.1016/j.ejcnurse.2008.07.001.
66. Berg KO, Maki BE, Williams JI, Holliday PJ, Wood-Dauphinee SL. Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil. 1992;73:1073–80.
67. Lord SR, Menz HB, Tiedemann A. A physiological profile approach to falls risk assessment and prevention. Phys Ther. 2003;83:237–52.
68. Oswald WD, Fleischmann UM. Nürnberger-alters-Inventar: (NAI) ; NAI-Testmanual und -Textband. 4th ed. Göttingen: Hogrefe Verl. für Psychologie; 1999.
69. Aschenbrenner S, Tucha O, Lange KW. RWT Regensburger Wortflüssigkeitstest. Göttingen: Hogrefe; 2000.
70. Thiel C, Gabrys L, Vogt L. Registrierung körperlicher Aktivität mit tragbaren Akzelerometern. Dtsch Z Sportmed. 2016;67:44–8. https://doi.org/10.5960/dzsm.2016.220.
71. Freedson PS, Melanson E, Sirard J. Calibration of the computer science and applications Inc. accelerometer. Med Sci Sports Exerc. 1998;30:777–81.
72. Ware J, Kosinski M, Keller SD. A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. Med Care. 1996;34:220–33. https://doi.org/10.1097/00005650-199603000-00003.

73. Power M, Quinn K, Schmidt S. Development of the WHOQOL-old module. Qual Life Res. 2005;14:2197–214. https://doi.org/10.1007/s11136-005-7380-9.
74. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. J Exp Psychol Gen. 2012;141:2–18. https://doi.org/10.1037/a0024338.
75. Rütten A, Pfeifer K. Nationale Empfehlungen für Bewegung und Bewegungsförderung; 2016. https://www.bundesgesundheitsministerium.de/service/begriffe-von-a-z/b/bewegungsempfehlungen.html. Accessed 1 Aug 2018
76. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. Am J Respir Crit Care Med. 1998;158:1384–7. https://doi.org/10.1164/ajrccm.158.5.9710086.
77. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: six-minute walk test, Berg balance scale, timed up & go test, and gait speeds. Phys Ther. 2002;82:128–37. https://doi.org/10.1093/ptj/82.2.128.
78. Bubolz-Lutz E. Geragogik: Bildung und Lernen im Prozess des Alterns ; das Lehrbuch. 1st ed. Stuttgart: Kohlhammer; 2010.
79. Kim YS. Reviewing and critiquing computer learning and usage among older adults. Educ Gerontol. 2008;34:709–35. https://doi.org/10.1080/03601270802000576.
80. Fuss BG, Dorstyn D, Ward L. Computer-mediated communication and social support among community-dwelling older adults: a systematic review of cross-sectional data. Australas J Ageing. 2019;38:e103–13. https://doi.org/10.1111/ajag.12703.
81. Osuka Y, Kojima N, Sakurai R, Watanabe Y, Kim H. Reliability and construct validity of a novel motor-cognitive dual-task test: a Stepping Trail making test. Geriatr Gerontol Int. 2020;20:291–6. https://doi.org/10.1111/ggi.13878.
82. Zhao X, Wang L, Ge C, Zhen X, Chen Z, Wang J, et al. Smartphone application training program improves smartphone usage competency and quality of life among the elderly in an elder university in China: a randomized controlled trial. Int J Med Inform. 2020;133:104010. https://doi.org/10.1016/j.ijmedinf.2019.104010.
83. Taylor JK, Buchan IE, van der Veer SN. Assessing life-space mobility for a more holistic view on wellbeing in geriatric research and clinical practice. Aging Clin Exp Res. 2019;31:439–45. https://doi.org/10.1007/s40520-018-0999-5.
84. Carl J, Sudeck G, Geidl W, Schultz K, Pfeifer K. Competencies for a healthy physically active lifestyle-validation of an integrative model. Res Q Exerc Sport. 2020;1–15. https://doi.org/10.1080/02701367.2020.1752885.
85. Herbolsheimer F, Mosler S, Peter PR. Relationship between social isolation and indoor and outdoor physical activity in community-dwelling older adults in Germany: findings from the ActiFE study. J Aging Phys Act. 2017;25:387–94. https://doi.org/10.1123/japa.2016-0060.
86. Pejovic V, Lathia N, Mascolo C, Musolesi M. Mobile-based experience sampling for behaviour research; 2015.

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Review

Effectiveness of Social Media-Based Interventions for the Promotion of Physical Activity: Scoping Review

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Abstract: A global target of the World Health Organization (WHO) is to reduce physical inactivity among all adults and adolescents by approximately fifteen percent by 2030. Social media could have an impact in this effort because of its enormous reach, potentially addressing underserved populations in need for physical activity (PA) interventions. This scoping review provides a broad overview of social media-based interventions and systematically maps the evidence regarding their effectiveness for PA promotion and other health outcomes. Scopus and Medline were searched using the terms "physical activity" and "social media" and the names of key social media platforms. Following the PRISMA guidelines for scoping reviews, abstracts and full texts were screened for eligibility. In total, 12,321 publications were identified and 53 met the inclusion criteria. The use of Facebook was most prevalent in PA interventions, followed by study-specific platforms. More than one third of the studies revealed positive effects regarding the promotion of PA. Additionally, social media-based interventions positively affected other physical dimensions of health (e.g., weight or blood pressure). Results pertaining to feasibility were heterogeneous. Social media seems to be a promising tool for increasing PA at the population level. Future studies should take the abundance of platforms into account and select social media platforms consciously.

Keywords: social media; intervention; physical activity; scoping review; behavior change

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1. Introduction

1.1. Background

Physical inactivity is a leading risk factor for mortality worldwide and contributes to the etiology and progression of non-communicable diseases (NCDs), such as cardiovascular disease, type 2 diabetes, various types of cancer, and chronic respiratory diseases. Seventy-one percent of all global deaths in 2016 were attributed to NCDs [1,2]. In order to prevent and minimize the burden of NCDs, the World Health Organization (WHO) developed the Global Action Plan 2013–2020 with nine global targets to be accomplished by the year 2025. One of the targets is to reduce physical inactivity worldwide by ten percent [3].

A status update of the WHO from 2020 suggests that, while some progress has been made to reduce the burden of NCDs (e.g., to decrease NCD-related premature deaths), further effort is required to reduce physical inactivity because of an insufficient success in equally addressing all NCD risk factors, as indicated by a rising prevalence of obesity [2]. Particularly in low- and middle-income countries, challenging barriers to the implementation of effective interventions are frequently encountered. However, even in economically developed countries, levels of physical inactivity have increased in the past decades as a result of urbanization, digitalization, and varying options of transportation. According to the 2030 Sustainable Development Goals set by the United Nations in 2015, the WHO refined the Global Action Plan and incorporated a system-based approach to ensure that all people, no matter which age, gender, socioeconomic status, disability status, or geographical origin, have accessible opportunities for being physically active in their daily lives. The new global target is to reduce physical inactivity in all adults and adolescents by approximately fifteen percent by the year 2030 [4].

Social media holds great potential for the accessible promotion of physical activity (PA). Based on the synthesis of definitions of social media appearing from 2007 onwards, Mróz-Gorgoń and colleagues (2016) defined social media as "network community communication channels" (p. 38), which allow the exchange of information, interaction and integration on a private and commercial domain [5]. Due to the rapid development of social media, a multitude nowadays exists, for example, discussion forums, wikis, audio platforms (e.g., Clubhouse, Spotify), live streams (e.g., Twitch), blogs (e.g.,Tumblr), social networking sites (e.g., Facebook), and media sharing networks (e.g., Instagram, YouTube) which are not listed under the 2016 definition. All of these platforms have participatory features in common that facilitate the exchange with existing friends, like-minded people, communities with similar characteristics (e.g., patient communities), or brands. Results of several systematic reviews revealed that this interpersonal engagement with other users fostered via typical features of social media, such as bulletin boards and chats, effectively promotes knowledge regarding health topics [6]. Another advantage is that via these built-in social elements, supportive, encouraging, or even competitive interactions can take place easily. Both social support and social comparison can motivate individuals to engage in more PA. A study by Cavallo and colleagues, 2014, found that social support via Facebook stemming from existing friendships was more likely to change PA behavior than communication about PA in a dedicated Facebook group [7]. Results from Zhang et al., 2016, indicated that adding a competitive element to these supportive networks could have an even more pronounced positive effect on exercise levels [8].

Beyond that, social media has an enormous reach; it is estimated that the number of active social media users worldwide reached more than 3.6 billion users in 2020, and this trend is continuing to rise [9]. Due to the global technological progress and gains in internet inclusion in nine of the fifteen low-income countries, the access is no longer reserved for privileged people from high-income countries [10]. Taking into account recent user data, social media appears to have the potential to address underserved populations known to have restricted access to health care, due to physical, geographical, financial, or educational barriers [11]. Instagram mainly attracts young people, and Facebook and YouTube reach between 64 and 70% of people with lower levels of education. Additionally these two platforms have, with nearly 50%, the most users who are above the age of 65 years, as well as a large proportion of residents from rural areas (i.e., 67–74%) [12].

Although previous evidence indicates that social media-based interventions for the promotion of PA achieve high levels of engagement and retention [13], results regarding their overall effectiveness for increasing PA remain inconclusive. In the WALK 2.0 trial, Kolt and colleagues, 2017, detected a short-term increase in moderate to vigorous physical activity (MVPA) in an intervention group offered PA promotion via an interactive Web 2.0 site compared to a less interactive Web 1.0 group [14]. In contrast, Edney and colleagues, 2020, found no significant effect of their gamified, social networking intervention 'Active Team' on MVPA [15]. The application of popular online-social networks, such as Facebook, also yielded contradictory results in past studies. While one study did not find any significant changes in PA in a group including female undergraduate students that used Facebook compared to a control group receiving general educational material after twelve weeks [16], another study observed a significant increase in steps walked per day in a Facebook social support group compared to a standard walking group after eight weeks [17]. Considering that social media is quickly evolving and may hold potential for PA promotion, the overall aim of this scoping review is to provide a broad overview of existing social media-based interventions and map the evidence regarding their effectiveness for the field of PA promotion.

1.2. Objectives

This scoping review was conducted in order to:

1. Identify which social media platforms are used in interventions for the promotion of PA to date.
2. Systematically map the evidence regarding their effectiveness for PA promotion.
3. Determine which dimensions of health are captured as secondary outcomes in the studies included in the scoping review.
4. Summarize the evidence regarding the impact of social media-based PA interventions on these secondary health outcomes.
5. Summarize the evidence regarding acceptability, use, and usability of social media-based PA interventions.

2. Methods

2.1. Protocol and Registration

According to the PRISMA guidelines for scoping reviews (PRISMA-ScR) [18], a protocol was developed a priori and is accessible on Open Science Framework [19].

2.2. Eligibility Criteria

Due to the relatively broad nature of a scoping review and the explorative review questions, all published literature on social media based-interventions promoting PA was included.

Social media based-interventions encompass all interventions delivered via any type of social media or at least incorporate one social media component of either existing, popular platforms or stand-alone platforms (e.g., Facebook group, discussion forums, message boards) to promote PA.

All studies that compared the social media-based condition to either (A) a non-social media-based intervention (e.g., a face-to-face intervention, programs delivered via websites or mobile apps, mass media campaigns, video tutorials), (B) a control group not exposed to any intervention, or (C) a no-comparator condition were included. Additionally, articles needed to address PA (or conversely physical inactivity, including sedentary behavior) as a primary outcome to be included, regardless of whether PA was assessed using objective or subjective methods of measurement. PA outcomes were considered as measures of PA volume reported in various units (e.g., steps, min/day, number of repetitions).

All types of studies carried out on the research topic, so far, were eligible for inclusion (e.g., experimental and quasi-experimental designs, pilot and observational studies, reviews and meta-analysis). Furthermore, inclusion was restricted neither to any specific population, as long as study participants were human beings, nor to contexts in which studies were conducted. Conference proceedings, abstracts without full texts, and study protocols without results were excluded from this review. In addition, systematic reviews that did not provide complementary information, because they contained only a few studies on social media-based interventions, which were already included in the data extraction for this scoping review, were excluded.

2.3. Information Sources

To identify relevant literature, the electronic databases Scopus and Medline via PubMed were searched on 4 May and 12 May 2020 by the two authors LG and SS. The search was comprehensive and limited by neither publication date nor publication type or any other filters. Reference lists of the included full texts were scanned for potentially relevant other articles.

2.4. Search

The search strategy was peer-reviewed and refined by an information scientist from the Cochrane Metabolic and Endocrine Disorders Group before implementation. We searched the concepts "physical activity" and "social media" as MeSH terms or index terms and key words, as well as their appropriate synonyms. In addition, we searched key social media platforms from 2014–2020 by name [9]. The search terms were combined by using the Boolean operators AND and OR. Detailed information on the search strategy for both databases is provided in Supplementary 1.

2.5. Selection of Sources of Evidence

The selection of sources of evidence was executed in two steps after all identified records had been exported to EndNote X9.1 and Rayyan. First, two authors (LG, SS) screened titles and abstracts of all identified records independently, using the web app Rayyan. Disagreements concerning inclusion/exclusion for full text screening were discussed with a third author (CRP) until they were resolved. Second, full texts of all records that were deemed relevant after screening phase one, were obtained. Whenever a full text was not accessible, the corresponding author was contacted for retrieval. Then, the two authors LG and SS independently screened all full texts for eligibility. Any discrepancies were resolved via discussion with the third reviewer (CRP).

2.6. Data Charting Process

For the extraction of all relevant information from the included sources, a data charting sheet was developed similar to the one provided by Elm and colleagues, 2019 [20], and pilot-tested in advance, by two authors (LG, SS). Each of them extracted data from five randomly chosen articles of the pool of included articles. In a discussion, the process of data charting with this abstraction tool was evaluated and the tool was adapted, where necessary. Then, the two authors LG and SS independently charted data from each eligible full-text by using the revised data charting sheet, formatted in Microsoft Word (Supplementary 2). After completion of the data charting process, ten articles were randomly selected and the two reviewers compared their corresponding data charts and verified the accuracy of their extraction based on the a priori protocol and the original full text. In cases of differences in the extracted data between the two authors, all data charted were compared again, and the third author (CRP) was consulted to resolve inconsistencies.

2.7. Data Items

Data on the general information of the reference (e.g., title, authors, country, publication type), evidence source characteristics (e.g., participants, sample size, withdrawals), the intervention (e.g., clusters, content, duration), outcomes (type, definition, unit, measurement tools), and results (e.g., comparison, statistical results) were captured. Additional information, such as the key conclusion of the study, notes or correspondence with the lead or senior authors, was provided at the end of the charting form.

2.8. Synthesis of Results

First, the included references were grouped by study type (randomized controlled trials, pilot studies, quasi-experimental and observational studies, and systematic reviews). Additionally, articles were grouped by type of social media to obtain an overview of studies using social media platforms as stand-alone interventions, specifically designed for the purpose of the study, versus those which incorporated well-known social media applications into interventions but also included other components. Along with the main objective of this scoping review, data on how PA was quantified were charted, and studies were summarized according to their effectiveness for improving PA (dependent on reported p values for in-between group differences or withingroup differences from baseline to follow-up). Secondary health outcomes were grouped into various dimensions of health examined and by effectiveness. Additionally, the evidence on feasibility was summarized, (e.g., descriptive results on use, acceptability, and usability of interventions).

3. Results

3.1. Selection of Sources of Evidence

The initial database search generated 12,321 hits. Another 319 records were found via search alerts in the two databases before the screening process ended and were added to the final results. A total of 2064 duplicates were detected by Endnote and deleted before uploading the remaining records in Rayyan. Via a manual search, another 513 duplicates were identified by the two authors LG and SS during the screening process and subsequently deleted. This resulted in 10,063 total records, which were screened by title and abstract. After the first screening phase, 9945 records were excluded, and the full texts of the remaining 118 publications were screened for eligibility. Throughout this second screening phase, another 65 articles were excluded, with the most common reasons for exclusion being: PA was not a primary outcome (n = 21), no social-media based intervention was examined (n = 14), and the publication type was wrong (e.g., study protocols, conference proceedings, n = 16). After completion of the screening process, 53 articles referring to 43 studies/trials were included in this scoping review. For detailed information about the selection process, see Figure 1 (flow chart).

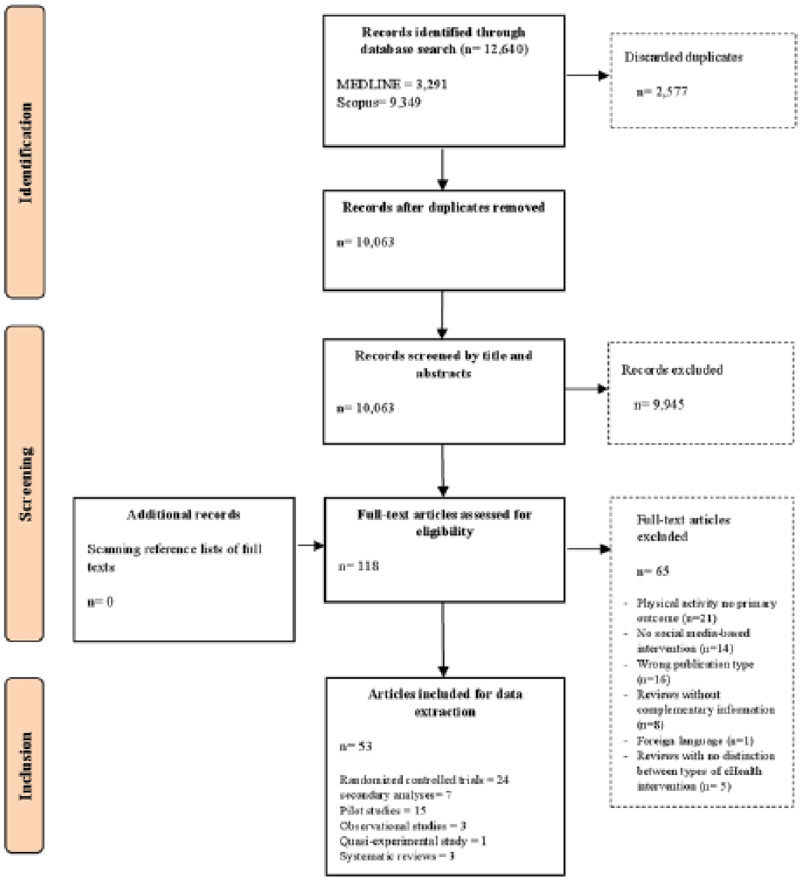

Figure 1. Flow chart of the selection process.

3.2. Characteristics of Sources of Evidence

The search delivered 24 randomized controlled trials (RCTs) [8,14–17,21–39], 15 pilot studies [40–54], 3 observational studies [55–57], and 1 quasi-experimental study that compared two groups but did not randomize its participants [58], and 3 systematic reviews [13,59,60]. The seven remaining publications presented results of secondary data analyses based on the included RCTs [61–67]. Detailed information on the study characteristics is presented in Supplementary 3.

Overall, the 43 studies included 11,469 participants, ranging from a minimum of 10 to a maximum of 5010 individuals [48,56]. Participants were between the ages of 11 and 65 years [29,37], predominantly Caucasian (except for Joseph et al., 2015, including only African American women [25]), and either predominantly or exclusively female, except for two studies that only included men [27,47].

Maher et al., 2014, included a total sample of 113,988 participants across ten studies in their systematic review [59]. The other two reviews provided data on neither sample size nor sample characteristics [13,60].

In 28 studies, a pre-existing social-media platform was used for intervention delivery [16,17,21,25,28,30–36,38,40,41,43,45,46,48–51,53–58], whereas in eleven studies, a study-specific platform was developed exclusively for the purpose of the study [8,14,22–24,27,37,39,42,47,52]. Lastly, four studies incorporated a combination of a specifically designed app with the well-known social-media platform Facebook [15,26,29,44]. Forty studies implemented a social networking site or social networking feature, with Facebook being the most commonly used by itself (n = 18) [16,17,21,25,28,31,33,35,36,38,43,45,48–51,53,54]. Other well-known social networking platforms were the Ning network (n = 1) in combination with Facebook [32], Meetup (n = 1) [34], and the Wanbu network (n = 1) [56]. The social networking feature of the Fitbit App was utilized in two studies [30,40]. Of the eleven studies that solely used their tool developed for the study, five had designed an app [24,27,37,47,52] and four had implemented a website, all of them including social networking features [8,14,22,39]. Two studies used social networking features, which remained unspecified in the respective articles [23,42]. The microblogging platform Twitter was used in two studies [41,46], one of them combined it with Facebook [41]. Another study used YouTube in combination with the online social network Instagram [58], and two investigated the virtual game Pokémon Go [55,57]. In the three systematic reviews, a wide variety of social media platforms was applied across the several studies, whereas Petersen et al., 2019 [13], summarized studies that incorporated Facebook only, Maher et al., 2014, and Williams et al., 2014, included trials examining the role of interventions using the popular platforms Facebook and Twitter, as well as study-specific online health social networks or discussion boards [59,60].

The RCTs conducted were either two-armed (n = 14) [16,17,21–23,25,27–31,34–36], three-armed (n = 7) [14,15,26,32,33,37,39] or even four-armed (n = 3) [8,24,38] interventional studies with comparator conditions or a waitlisted control group. The pilot studies either analyzed a single group (n = 8) [40,41,43,44,48,51–53] or had a two-arm study-design (n = 7) [42,45–47,49,50,54]. Intervention content varied substantially among the included RCTs and pilot studies. Most often, social media was used as a tool for the distribution of information and recommendations regarding PA. Secondly, social media enabled the sharing of PA data on an individual or team basis and reinforced interactions between intervention/study participants or with researchers via discussion boards or groups. Most studies argued that the interaction feature was a means of either providing a source of social support, motivation, comparison or accountability for PA, or a combination of all of these features. Other common features were goal setting and feedback on individual or team progress. The huge majority of the studies combined the use of this digital component with a measurement device (e.g., accelerometer, pedometer) to track PA and other intervention add-ons, such as e-mails, in-person meetings, or exercise classes. In the control groups of the studies, participants usually received comparator interventions, such as educational classes, an almost identical intervention without the social media component, or they were waitlisted.

Two observational studies tracked data of users and non-users of Pokémon Go [55,57], an augmented reality game that rewards PA in a gamified context, and one study analyzed the use of the Wanbu network, a platform onto which step data can be uploaded and discussed with friends [56].

In the one and only quasi-experimental study, a YouTube exercise video was delivered to both the intervention and control group. The intervention group obtained additionally motivation via Instagram [58].

Of the three systematic reviews, two summarized evidence on the effectiveness of interventions delivered via a social media platform for changing PA and other health outcomes, such as diet and weight [59,60], and quality of life [59]. The third review focused on PA and psychosocial constructs related to PA and compared the effectiveness of mobile apps with and without social networking features [13].

In all of the included articles, PA was the primary outcome, but it was captured in numerous ways. Most of the studies (n = 23) reported the minutes of PA executed at a certain level of intensity, better known as time spent with moderate to vigorous PA (MVPA) or sedentary time; time spent on either light, moderate, or vigorous PA; and total weekly PA [14,15,23,25–29,31–33,36,40,44–50,53–55]. Further, eighteen studies quantified PA in steps per hour, day, or week [14,17,21,25,31,34,37,40,42,44,46–48,51–53,56,57]. Another five studies reported energy expenditure and metabolic equivalents (METs) [30,31,35,38,48]. Less frequently used measures of PA were active travel (n = 1) [41], number of attended exercise classes (n = 3) [8,39,58], physical fitness (n = 1) [43], and exercise frequency (n = 2) [16,22]. Some studies captured the time spent performing a specific type of PA, such as walking (n = 5) [23,26,29,44,55], or the time spent in plank position (n = 1) [24]. In most studies, at least two measurements were performed to quantify PA.

Across the three systematic reviews, only Peterson et al., 2019, reported the PA outcomes of interest in this scoping review in detail (e.g., light, moderate, vigorous PA, daily steps, and sedentary behavior) [13], whereas Maher et al., 2014, and Williams et al., 2014, referred to PA in general [59,60].

Secondary health outcomes were measured in 30 studies investigating between one and eleven outcomes. The majority of studies captured aspects of physical health via anthropometric measures, such as height and weight in order to determine body-mass index (n = 10) [14,21,22,25,26,32,33,47,53,55] or only weight (n = 11) [17,21,23,27,31,36,47–50,53]. Others assessed fat mass or the percentage of body fat (n = 8) [21,22,27,31,46,48–50], hip/waist circumference (n = 6) [17,21,27,32,47,53], blood pressure (n = 4) [21,46,47,53], and serum lipids (e.g., total cholesterol and triglycerides, n = 2) [21,23]. Physical fitness was also a commonly included outcome with five studies measuring cardiorespiratory fitness [28,31,48–50], two studies investigating aerobic fitness [27,32] and one focusing on grip strength [27]. Another three studies captured health behaviors, such as eating habits, nutrition, and alcohol consumption [47,49,53]. Psychosocial outcomes related to PA that were tracked in the included studies were motivation, enjoyment, perceived barriers, social support, self-efficacy, group cohesion and outcome expectancies or combinations of these outcomes were reported in fourteen studies [24,25,28,31,34,36–38,45,48–50,53,58]. Eleven studies measured mental health outcomes, such as quality of life, mood, depressive symptoms or signs of anxiety or stress, psychological well-being, vitality, and sleep [14,15,26,29,31,36,38,45,47,48,51]. Singular and more specific outcome measures were dog's PA (n = 1) [34], attention deficit hyperactivity disorder (ADHD) symptoms (n = 1) [51], and premenstrual syndrome (PMS) symptoms (n = 1) [30].

Overall, 29 studies examined the use, acceptability, and usability of the interventions [15–17,24–29,31,32,34,36,37,40–45,48–50,52–54,56,58,61]. Twenty-four studies reported results on use pertaining to the social media components (e.g., number of posts, number of logins, step entries) [16,17,25–29,31,32,34,36,37,40–42,44,45,48,50,52–54,56,61]. Acceptability was assessed either regarding the entire program (n = 11) [24–26,32,34,36,40,43,53,54,58] or the digital component only (n = 10) [25,27–29,31,36,48–50,53]. Usability (n = 8) was commonly determined via rating scales or evaluation forms mainly focused on tracking how easy the intervention (component) was to use [15,31,42,44,49,50,52,61]. In two of the included systematic reviews, results on use and engagement with the intervention materials across the included studies were synthesized [13,59].

3.3. Results of Individual Sources of Evidence

Individual results on PA and the dimensions of health captured as secondary outcomes in the included studies are displayed in Supplementary 3.

3.4. Synthesis of Results

In total, 24 studies demonstrated positive effects concerning PA [8,15,17,21,23,25,26,28–30,35,36,39,41,43,44,46,47,51,53,55–58]. Sixteen studies found significant between-group differences in favor of the intervention group that was exposed to a social media condition [8,15,17,21,23,25,28–30,35,36,39,46,47,55,58]. Another eight studies reported significant improvements in PA over time within groups (from baseline to follow-up) [26,41,43,44,51,53,56,57].

Conversely, in the WALK 2.0 study [67], PA increased by 92.8 min/ week more in the intervention group that used standard Web 1.0 features compared to the group that used Web 2.0 features. At the three-month follow-up, 77% of the Web 1.0 participants were sufficiently active compared to 71.5% of the Web 2.0 participants. In the study conducted by van Woudenberg et al., 2020, the waitlisted control group showed even greater improvement in total PA than the group which was exposed to vlogs [37].

Considering the evidence reported in the three systematic reviews included in this scoping review, Petersen et al., 2019, showed in their systematic review that combined social networking apps were less effective in increasing PA (n = 3) than conventional standalone apps (n = 7) [13]. In the review by Williams et al., 2014 [60], only one of five studies found that PA was positively affected by a social media-based intervention, whereas Maher et al., 2014, found in their review that of four studies, three had a sufficient, two a moderate, and one a high effect size [59].

Physical aspects of health, such as weight [23], BMI [47,67], body fat [46], waist circumference, eating behavior [46,47], blood pressure [47], and triglycerides [47] were improved effectively in favor of the intervention groups employing social media in four studies. Another two studies reported improvements within groups from pre- to post-measurement in waist circumference [17], as well as fruit and vegetable intake [53]. Chee et al., 2014, provided evidence that increasing PA was beneficial for improving components of the metabolic syndrome (e.g., HDL cholesterol, blood pressure, triglycerides, waist circumference, fasting glucose) [21]. Regarding psychosocial aspects of health, the results were contradictory. Five studies found that enjoyment [38], group cohesion [24], motivation [45], social norms [37], self-regulation, and social support from family members [25] were positively affected in the groups that participated in a social media based- intervention compared to controls. In contrast, two studies found that social support and self-efficacy were lower among participants of the intervention groups and perceived barriers to higher PA [31,66]. Schoenfelder et al., 2017, reported improvements in ADHD symptoms from baseline to 4-week follow-up of a Fitbit intervention supported by a Facebook group [51].

Only one study found significant effects of an exercise program that was supplemented by a social network on health-related quality of life [47]. A second study found that individuals who were more physically active scored higher on the scale for health-related quality of life [64]. Furthermore, Nam et al., 2020, provided evidence that a range of PMS symptoms (e.g., fatigue, anxiety) that contribute to all dimensions of health decreased in a social media-based support group compared to a control group [30].

Summarized evidence on secondary health outcomes analyzed in the three included systematic reviews was marginal. Whereas Williams et al., 2014, found that dietary fat consumption decreased significantly in social media-supported study conditions [60], Maher et al., 2014, found an effect on weight change across three studies with a varying effect size from negligible to large [59]. In the third review, only one included study revealed improvements in the assessed psychosocial outcomes (e.g., self-efficacy and exercise motivation) over time [13].

Two-third of the included studies and two of the systematic reviews reported results pertaining to feasibility. Due to the great heterogeneity in the assessment of acceptability, use, and usability across the different references, pooling of the data was difficult. Nevertheless, it was noticeable that across six studies the use of Facebook as a motivator for PA was rated positively by study participants [25,28,31,49,50,53,62], whereas the usability of three study-specific networks was rated poorly [15,27,52].

Descriptively reported results regarding the primary or secondary outcomes are shown in Supplementary 3.

4. Discussion

4.1. Summary of Evidence

This scoping review identified 53 publications with findings from 43 studies and three systematic reviews on the promotion of PA via social media-based interventions. Social networking sites were used most frequently for the promotion of PA. In the twenty-eight studies and the three systematic reviews evaluating the role of pre-existing social networking sites, the use of Facebook was most prevalent. Secondly, the incorporation of a developed standalone, health-focused online social network was very common. Four studies combined the use of a study-specific social networking site with Facebook. Regarding the other types of social media, only pre-existing applications were utilized, in particular, Twitter, Pokémon Go, and YouTube.

Most studies included in this scoping review were RCTs followed by pilot studies, of which 34 were at least two-armed and compared their intervention content ranging from simple recommendations for PA to fostering social interactions facilitating PA or making PA enjoyable and measurable, to another condition or a waitlisted control group. Comparator conditions usually consisted of identical intervention content without the social media (social interaction) component. Additionally, three systematic reviews were included in this scoping review. In sum, more than three quarter of the studies employed study designs allowing for an estimation of intervention effects.

More than one third of the studies revealed positive effects on PA. Most frequently, PA was improved due to a social media-based intervention when compared to an alternative intervention in eleven cases, and five studies showed increases in PA in comparison to a waitlisted control group. Evidence from the systematic review was, in part, inconclusive. Here, only seven studies were identified in which PA was effectively increased through social media, whereas seven studies found effects in favor of conventional apps.

Nearly two-thirds of the articles included covered other dimensions of health as secondary outcomes. These addressed, in addition to the physical dimension, psychosocial and mental aspects of health. Here, social media-based interventions had the most positive impact on physical parameters of health related to weight/body composition or cardiovascular parameters, as they were predominantly captured. Psychosocial parameters of health were less frequently measured, and results were contradictory. Only a handful of studies could demonstrate that social media-based interventions had beneficial effects on PA by fostering motivation, social support, and self-efficacy. A positive effect on psychological and health-related quality of life, the most recorded mental health outcome, was evident in only one study that incorporated social media.

A range of results concerning acceptability, use, and usability of social media-based PA interventions were uncovered in this scoping review and it is impossible to draw any generic conclusion regarding the feasibility of such interventions. The results should be interpreted study by study and with caution taking their different ways of assessing feasibility into account.

One of the main findings, of this work is that the most commonly incorporated platform in PA interventions is Facebook. Given the rapid development of a variety of social media platforms during the last decade, it can be argued that a broad spectrum of innovative social media have not yet been incorporated and scientifically tested. Future intervention studies should take advantage of this abundance of platforms and select them consciously, according to the requirements, needs, and preferences of the individual target populations. This is supported by a scoping review of Lee and colleagues, 2019, concluding that mobile apps that focus on health behavior change have to be appropriate for their target sample [68]. In line with this argument, a specifically modified app and social network for overweight hockey fans demonstrated a high retention and significant improvements in PA when compared to a waitlisted control group [47].

It is important to emphasize that there is no fundamental need for the development of new platforms, but relying on pre-existing applications and using them purposefully will be sufficient for future health behavior change interventions. Emerging evidence provides some indication that social media can be effective for improving PA and other physical parameters of health. However, there is limited research about the efficacy of social media concerning other secondary health outcomes necessitating additional research.

Despite those positive findings, the utilization of social media in health care and prevention should be very carefully considered and always critically questioned. Although the availability of the internet has increased widely worldwide, mostly via technological improvements (e.g., broadband quality) [10], social inequalities continue to exist. The so-called digital divide has shifted from a lack of material resources over a shortcoming of skills to use them to an absence of personal capacities transferring consumed information of the World Wide Web into favorable behavior, better known as third-level digital divide [69]. Recent study findings from Finland suggest that especially disadvantaged populations which should be the target of eHealth intervention approaches and services, such as older people and those with a low socioeconomic status, poor health, or socially isolated persons are at the highest risk for digital exclusion because ICT-based health care seems less beneficial for them [70]. Furthermore, the use of social media can affect health negatively, as was lately shown in a cross-sectional survey analysis by Henzel et al. 2021, [71], who found out that addictive social media use is prevalent in the young generation and is related to mental distress and other addictive behaviors such as gaming. Another harmful effect of social media that has become a challenging public health issue is the occurrence of fake news that causes fear, uncertainty, and social division, as seen in the current COVID-19 pandemic. Misleading information spread via social media has the potential to influence health and wellbeing negatively at a global level [72].

4.2. Limitations

A key limitation of the scoping review is the heterogeneity of the included literature concerning methodology and outcome measures used in the studies. This resulted in difficulties in pooling quantitative data and evaluating them appropriately as envisaged to understand the effects of social media-based interventions on PA and health, and, in particular, interpreting their feasibility. Furthermore, it could be argued that restricting the search to two literature databases is another limitation, because relevant studies may have been missed. Because a scoping review does not assess the risk of bias, conclusions about the quality of the included sources of evidence cannot be drawn, and the generalizability of the described findings remains unclear. Another limitation is that the included studies were conducted prior to the emergence of the COVID-19 pandemic. The role of social media for PA promotion may have somewhat changed under pandemic conditions, possibly even becoming increasingly important, as gyms and sports facilities were temporarily closed during lockdowns. However, this aspect will have to be analyzed in future scoping reviews, including studies conducted and published after the spring of 2020.

5. Conclusions

To our knowledge, this is the first scoping review which provides a broad overview of the incorporation of the latest social media technologies in research on PA promotion. Taking into account key social media platforms from 2014–2020, this work is up-to-date concerning recent Web 2.0 approaches to prevent and minimize the burden of physical inactivity and NCDs, but continuous updates will be essential considering the fact that social media is a quickly evolving field. Future effort in this line of research is required to attain an increased standardization of these indicators and measures and an overarching public health framework that can be used to appraise the feasibility of future social media interventions in health promotion and care.

Supplementary Materials: The search strategy, the data charting sheet, and information on the study characteristics are available online at https://www.mdpi.com/article/10.3390/ijerph182413018/s1, Supplementary 1: Search strategy, Supplementary 2: Data charting sheet, Supplementary 3: Study characteristics.

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Abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
BMI	body mass index
MeSH	medical subject headings
METs	metabolic equivalents
MVPA	moderate to vigorous physical activity
NCDs	non-communicable diseases
PA	physical activity
PMS	premenstrual syndrome
RCTs	randomized controlled trials
WHO	World Health Organization

References

1. WHO. Guidelines on Physical Activity and Sedentary Behaviour. Available online: https://apps.who.int/iris/bitstream/handle/10665/336656/9789240015128-eng.pdf?sequence=1&isAllowed=y (accessed on 6 December 2021).
2. World Health Statistics 2020: Monitoring Health for the SDGS, Sustainable Development Goals. Available online: https://apps.who.int/iris/bitstream/handle/10665/332070/9789240005105-eng.pdf?sequence=1&isAllowed=y (accessed on 9 September 2021).
3. Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2020. Available online: http://apps.who.int/iris/bitstream/handle/10665/94384/9789241506236_eng.pdf;jsessionid=4CA84C00F7C0DAA6409D6F633750A5FD?sequence=1 (accessed on 9 September 2021).
4. Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World. Available online: https://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf?ua=1 (accessed on 9 September 2021).
5. Mróz-Gorgoń, B.; Peszko, K. Marketing analysis of social media—Definition considerations. *Eur. J. Serv. Manag.* **2016**, *20*, 33–40. [CrossRef]
6. Welch, V.; Petkovic, J.; Pardo, J.P.; Rader, T.; Tugwell, P. Interactive social media interventions to promote health equity: An overview of reviews. *Health Promot. Chronic Dis. Prev. Can.* **2016**, *36*, 63–75. [CrossRef] [PubMed]
7. Cavallo, D.N.; Tate, D.F.; Ward, D.S.; DeVellis, R.F.; Thayer, L.M.; Ammerman, A.S. Social support for physical activity—role of Facebook with and without structured intervention. *Transl. Behav. Med.* **2014**, *4*, 346–354. [CrossRef]

8. Zhang, J.; Brackbill, D.; Yang, S.; Becker, J.; Herbert, N.; Centola, D. Support or competition? How online social networks increase physical activity: A randomized controlled trial. *Prev. Med. Rep.* **2016**, *4*, 453–458. [CrossRef]
9. Number of Social Network Users Worldwide from 2017 to 2025. Available online: https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/#statisticContainer (accessed on 6 December 2021).
10. The Inclusive Internet Index 2021. Executive Summary. Available online: https://theinclusiveinternet.eiu.com/assets/external/downloads/3i-executive-summary.pdf (accessed on 6 December 2021).
11. Vandelanotte, C.; Müller, A.M.; Short, C.; Hingle, M.; Nathan, N.; Williams, S.L.; Lopez, M.L.; Parekh, S.; Maher, C. Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. *J. Nutr. Educ. Behav.* **2016**, *48*, 219–228.e1. [CrossRef]
12. Use of Online Platforms, Apps Varies- Sometimes Widely- by Demographic Group. Available online: https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2021/04/PI_2021.04.07_social-media_0-03.png?w=640 (accessed on 6 December 2021).
13. Petersen, J.M.; Prichard, I.; Kemps, E. A Comparison of Physical Activity Mobile Apps With and Without Existing Web-Based Social Networking Platforms: Systematic Review. *J. Med. Internet Res.* **2019**, *21*, e12687. [CrossRef]
14. Kolt, G.S.; Rosenkranz, R.; Vandelanotte, C.; Caperchione, C.M.; Maeder, A.; Tague, R.; Savage, T.; Van, I.A.; Mummery, W.K.; Oldmeadow, C.; et al. Using Web 2.0 applications to promote health-related physical activity: Findings from the WALK 2.0 randomised controlled trial. *Br. J. Sports Med.* **2017**, *51*, 1433–1440. [CrossRef] [PubMed]
15. Edney, S.M.; Olds, T.; Ryan, J.C.; Vandelanotte, C.; Plotnikoff, R.C.; Curtis, R.; Maher, C.A. A Social Networking and Gamified App to Increase Physical Activity: Cluster RCT. *Am. J. Prev. Med.* **2020**, *58*, e51–e62. [CrossRef] [PubMed]
16. Cavallo, D.N.; Tate, D.F.; Ries, A.V.; Brown, J.D.; DeVellis, R.F.; Ammerman, A.S. A Social Media–Based Physical Activity Intervention. *Am. J. Prev. Med.* **2012**, *43*, 527–532. [CrossRef]
17. Rote, A.E.; Klos, L.A.; Brondino, M.J.; Harley, A.E.; Swartz, A.M. The Efficacy of a Walking Intervention Using Social Media to Increase Physical Activity: A Randomized Trial. *J. Phys. Act. Health* **2015**, *12*, S18–S25. [CrossRef]
18. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.J.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]
19. A Scoping Review Protocol to Map the Evidence Regarding the Effectiveness of Social Media-Based Interventions for the Promotion of Physical Activity. Available online: https://osf.io/v9dxj/ (accessed on 9 September 2021).
20. von Elm, E.; Schreiber, G.; Haupt, C.C. Methodische Anleitung für Scoping Reviews (JBI-Methodologie). *Z. Evidenz Fortbild. Qual. Gesundh.* **2019**, *143*, 1–7. [CrossRef]
21. Chee, H.P.; Hazizi, A.S.; Barakatun, M.Y.; Mohd, M.T. A Randomised Controlled Trial of a Facebook-Based Physical Activity Intervention for Government Employees with Metabolic Syndrome. *Malays. J. Nutr.* **2014**, *20*, 165–181.
22. Gotsis, M.; Wang, H.; Spruijt-Metz, D.; Jordan-Marsh, M.; Valente, T.W. Wellness Partners: Design and Evaluation of a Web-Based Physical Activity Diary with Social Gaming Features for Adults. *JMIR Res. Protoc.* **2013**, *2*, e10. [CrossRef] [PubMed]
23. Greene, J.; Sacks, R.; Piniewski, B.; Kil, D.; Hahn, J.S. The Impact of an Online Social Network with Wireless Monitoring Devices on Physical Activity and Weight Loss. *J. Prim. Care Community Health* **2013**, *4*, 189–194. [CrossRef] [PubMed]
24. Irwin, B.; Kurz, D.; Chalin, P.; Thompson, N.; Feltz, D.; Shaw, R.; Blair, S. Testing the Efficacy of OurSpace, a Brief, Group Dynamics-Based Physical Activity Intervention: A Randomized Controlled Trial. *J. Med. Internet Res.* **2016**, *18*, e87. [CrossRef]
25. Joseph, R.P.; Keller, C.; Adams, M.A.; Ainsworth, B.E. Print versus a culturally-relevant Facebook and text message delivered intervention to promote physical activity in African American women: A randomized pilot trial. *BMC Women's Health* **2015**, *15*, 30. [CrossRef]
26. Kernot, J.; Lewis, L.; Olds, T.; Maher, C. Effectiveness of a Facebook-Delivered Physical Activity Intervention for Postpartum Women: A Randomized Controlled Trial. *J. Phys. Act. Health* **2019**, *16*, 125–133. [CrossRef] [PubMed]
27. Leinonen, A.-M.; Pyky, R.; Ahola, R.; Kangas, M.; Siirtola, P.; Luoto, T.; Enwald, H.; Ikäheimo, T.M.; Röning, J.; Keinänen-Kiukaanniemi, S.; et al. Feasibility of Gamified Mobile Service Aimed at Physical Activation in Young Men: Population-Based Randomized Controlled Study (MOPO). *JMIR mHealth uHealth* **2017**, *5*, e146. [CrossRef]
28. Looyestyn, J.; Kernot, J.; Boshoff, K.; Maher, C. A Web-Based, Social Networking Beginners' Running Intervention for Adults Aged 18 to 50 Years Delivered via a Facebook Group: Randomized Controlled Trial. *J. Med. Internet Res.* **2018**, *20*, e67. [CrossRef]
29. Maher, C.; Ferguson, M.; Vandelanotte, C.; Plotnikoff, R.; De Bourdeaudhuij, I.; Thomas, S.; Nelson-Field, K.; Olds, T. A Web-Based, Social Networking Physical Activity Intervention for Insufficiently Active Adults Delivered via Facebook App: Randomized Controlled Trial. *J. Med. Internet Res.* **2015**, *17*, e174. [CrossRef] [PubMed]
30. Nam, S.J.; Cha, C. Effects of a social-media-based support on premenstrual syndrome and physical activity among female university students in South Korea. *J. Psychosom. Obstet. Gynecol.* **2020**, *41*, 47–53. [CrossRef]
31. Pope, Z.C.; Zeng, N.; Zhang, R.; Lee, H.Y.; Gao, Z. Effectiveness of Combined Smartwatch and Social Media Intervention on Breast Cancer Survivor Health Outcomes: A 10-Week Pilot Randomized Trial. *J. Clin. Med.* **2018**, *7*, 140. [CrossRef] [PubMed]
32. Rovniak, L.S.; Kong, L.; Hovell, M.F.; Ding, D.; Sallis, J.F.; Ray, C.; Kraschnewski, J.L.; Matthews, S.; Kiser, E.; Chinchilli, V.M.; et al. Engineering Online and In-Person Social Networks for Physical Activity: A Randomized Trial. *Ann. Behav. Med.* **2016**, *50*, 885–897. [CrossRef]

33. Ruotsalainen, H.; Kyngäs, H.; Tammelin, T.; Heikkinen, H.; Kääriäinen, M. Effectiveness of Facebook-Delivered Lifestyle Counselling and Physical Activity Self-Monitoring on Physical Activity and Body Mass Index in Overweight and Obese Adolescents: A Randomized Controlled Trial. *Nurs. Res. Pract.* **2015**, *2015*, 159205. [CrossRef]
34. Schneider, K.L.; Murphy, D.; Ferrara, C.; Oleski, J.; Panza, E.; Savage, C.; Gada, K.; Bozzella, B.; Olendzki, E.; Kern, D.; et al. An Online Social Network to Increase Walking in Dog Owners. *Med. Sci. Sports Exerc.* **2015**, *47*, 631–639. [CrossRef]
35. Todorovic, J.; Terzic-Supic, Z.; Djikanovic, B.; Nesic, D.; Piperac, P.; Stamenkovic, Z. Can social media intervention improve physical activity of medical students? *Public Health* **2019**, *174*, 69–73. [CrossRef] [PubMed]
36. Valle, C.G.; Tate, D.F.; Mayer, D.K.; Allicock, M.; Cai, J. A randomized trial of a Facebook-based physical activity intervention for young adult cancer survivors. *J. Cancer Surviv.* **2013**, *7*, 355–368. [CrossRef]
37. Van Woudenberg, T.J.; Bevelander, K.E.; Burk, W.J.; Smit, C.R.; Buijs, L.; Buijzen, M. Testing a Social Network Intervention Using Vlogs to Promote Physical Activity Among Adolescents: A Randomized Controlled Trial. *Front. Psychol.* **2020**, *10*, 2913. [CrossRef]
38. Wang, C.K.J.; Leng, H.K.; Kee, Y.H. Use of Facebook in physical activity intervention programme. A test of self-determination theory. *Int. J. Sport Psychol.* **2015**, *46*, 210–224.
39. Zhang, J.; Brackbill, D.; Yang, S.; Centola, D. Efficacy and causal mechanism of an online social media intervention to increase physical activity: Results of a randomized controlled trial. *Prev. Med. Rep.* **2015**, *2*, 651–657. [CrossRef]
40. Arigo, D.; Schumacher, L.; Pinkasavage, E.; Butryn, M.L. Addressing barriers to physical activity among women: A feasibility study using social networking-enabled technology. *Digit. Health* **2015**, *1*, 2055207615583564. [CrossRef] [PubMed]
41. Bopp, M.; Sims, D.; Matthews, S.A.; Rovniak, L.S.; Poole, E.; Colgan, J. Development, Implementation, and Evaluation of Active Lions: A Campaign to Promote Active Travel to a University Campus. *Am. J. Health Promot.* **2018**, *32*, 536–545. [CrossRef]
42. Elloumi, L.; van Beijnum, B.-J.; Hermens, H. Exploratory study of a virtual community for physical activity. *Health Technol.* **2018**, *8*, 81–95. [CrossRef]
43. Forrest, C.K.; Bruner, M.W. Evaluating social media as a platform for delivering a team-building exercise intervention: A pilot study. *Int. J. Sport Exerc. Psychol.* **2017**, *15*, 190–206. [CrossRef]
44. Kernot, J.; Olds, T.; Lewis, L.K.; Maher, C. Usability Testing and Piloting of the Mums Step It Up Program—A Team-Based Social Networking Physical Activity Intervention for Women with Young Children. *PLoS ONE* **2014**, *9*, e108842. [CrossRef]
45. Mendoza, J.A.; Baker, K.S.; Moreno, M.A.; Whitlock, K.; Abbey-Lambertz, M.; Waite, A.; Colburn, T.; Chow, E.J. A Fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: A pilot study. *Pediatr. Blood Cancer* **2017**, *64*, e26660. [CrossRef]
46. Nishiwaki, M.; Nakashima, N.; Ikegami, Y.; Kawakami, R.; Kurobe, K.; Matsumoto, N. A pilot lifestyle intervention study: Effects of an intervention using an activity monitor and Twitter on physical activity and body composition. *J. Sports Med. Phys. Fit.* **2017**, *57*, 402–410. [CrossRef]
47. Petrella, R.J.; Gill, D.P.; Zou, G.; De Cruz, A.; Riggin, B.; Bartol, C.; Danylchuk, K.; Hunt, K.; Wyke, S.; Gray, C.M.; et al. Hockey Fans in Training. *Med. Sci. Sports Exerc.* **2017**, *49*, 2506–2516. [CrossRef] [PubMed]
48. Pope, Z.; Lee, J.E.; Zeng, N.; Lee, H.Y.; Gao, Z. Feasibility of smartphone application and social media intervention on breast cancer survivors' health outcomes. *Transl. Behav. Med.* **2018**, *9*, 11–22. [CrossRef]
49. Pope, Z.C.; Barr-Anderson, D.J.; Lewis, B.A.; Pereira, M.A.; Gao, Z. Use of Wearable Technology and Social Media to Improve Physical Activity and Dietary Behaviors among College Students: A 12-Week Randomized Pilot Study. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3579. [CrossRef] [PubMed]
50. Pope, Z.C.; Gao, Z. Feasibility of smartphone application- and social media-based intervention on college students' health outcomes: A pilot randomized trial. *J. Am. Coll. Health* **2020**, 1–10. [CrossRef] [PubMed]
51. Schoenfelder, E.; Moreno, M.; Wilner, M.; Whitlock, K.B.; Mendoza, J.A. Piloting a mobile health intervention to increase physical activity for adolescents with ADHD. *Prev. Med. Rep.* **2017**, *6*, 210–213. [CrossRef]
52. Tong, H.L.; Coiera, E.; Tong, W.; Wang, Y.; Quiroz, J.C.; Martin, P.; Laranjo, L. Efficacy of a Mobile Social Networking Intervention in Promoting Physical Activity: Quasi-Experimental Study. *JMIR mHealth uHealth* **2019**, *7*, e12181. [CrossRef] [PubMed]
53. Torquati, L.; Kolbe-Alexander, T.; Pavey, T.; Leveritt, M. Changing Diet and Physical Activity in Nurses: A Pilot Study and Process Evaluation Highlighting Challenges in Workplace Health Promotion. *J. Nutr. Educ. Behav.* **2018**, *50*, 1015–1025. [CrossRef]
54. Wójcicki, T.R.; Grigsby-Toussaint, D.; Hillman, C.H.; Huhman, M.; McAuley, E. Promoting Physical Activity in Low-Active Adolescents via Facebook: A Pilot Randomized Controlled Trial to Test Feasibility. *JMIR Res. Protoc.* **2014**, *3*, e56. [CrossRef] [PubMed]
55. Broom, D.R.; Flint, S.W. Gotta Catch 'Em All: Impact of Pokémon Go on Physical Activity, Sitting Time, and Perceptions of Physical Activity and Health at Baseline and Three-Month Follow-Up. *Games Health J.* **2018**, *7*, 401–408. [CrossRef]
56. Wang, L.; Guo, X.; Wu, T.; Lv, L.; Zhang, Z. Short-term effects of social encouragement on exercise behavior: Insights from China's Wanbu network. *Public Health* **2017**, *148*, 25–29. [CrossRef]
57. Xian, Y.; Xu, H.; Xu, H.; Liang, L.; Hernandez, A.F.; Wang, T.Y.; Peterson, E.D. An Initial Evaluation of the Impact of Pokémon GO on Physical Activity. *J. Am. Heart Assoc.* **2017**, *6*, e005341. [CrossRef]
58. Al-Eisa, E.; Al-Rushud, A.; Alghadir, A.; Anwer, S.; Al-Harbi, B.; Al-Sughaier, N.; Al-Yoseef, N.; Al-Otaibi, R.; Al-Muhaysin, H.A. Effect of Motivation by "Instagram" on Adherence to Physical Activity among Female College Students. *BioMed. Res. Int.* **2016**, *2016*, 1546013. [CrossRef]

59. Maher, C.A.; Lewis, L.K.; Ferrar, K.; Marshall, S.; De Bourdeaudhuij, I.; Vandelanotte, C. Are Health Behavior Change Interventions That Use Online Social Networks Effective? A Systematic Review. *J. Med. Internet Res.* **2014**, *16*, e40. [CrossRef] [PubMed]
60. Williams, G.; Hamm, M.P.; Shulhan-Kilroy, J.; VanderMeer, B.; Hartling, L. Social media interventions for diet and exercise behaviours: A systematic review and meta-analysis of randomised controlled trials. *BMJ Open* **2014**, *4*, e003926. [CrossRef]
61. Alley, S.J.; Kolt, G.S.; Duncan, M.J.; Caperchione, C.M.; Savage, T.N.; Maeder, A.J.; Rosenkranz, R.R.; Tague, R.; Van Itallie, A.K.; Mummery, W.K.; et al. The effectiveness of a web 2.0 physical activity intervention in older adults—A randomised controlled trial. *Int. J. Behav. Nutr. Phys. Act.* **2018**, *15*, 4. [CrossRef] [PubMed]
62. Edney, S.; Looyestyn, J.; Ryan, J.; Kernot, J.; Maher, C. Posts, pics, or polls? Which post type generates the greatest engagement in a Facebook physical activity intervention? *Transl. Behav. Med.* **2018**, *8*, 953–957. [CrossRef]
63. Kolt, G.S.; Duncan, M.J.; Vandelanotte, C.; Rosenkranz, R.R.; Maeder, A.J.; Savage, T.N.; Tague, R.; Van Itallie, A.; Mummery, W.K.; Caperchione, C.M. Successes and Challenges of an IT-Based Health Behaviour Change Program to Increase Physical Activity. *Stud. Health Technol. Inform.* **2020**, *268*, 31–43.
64. Kolt, G.S.; George, E.S.; Rebar, A.L.; Duncan, M.J.; Vandelanotte, C.; Caperchione, C.M.; Maeder, A.J.; Tague, R.; Savage, T.N.; Van Itallie, A.; et al. Associations between quality of life and duration and frequency of physical activity and sedentary behaviour: Baseline findings from the WALK 2.0 randomised controlled trial. *PLoS ONE* **2017**, *12*, e0180072. [CrossRef] [PubMed]
65. Valle, C.G.; Tate, D.F. Engagement of young adult cancer survivors within a Facebook-based physical activity intervention. *Transl. Behav. Med.* **2017**, *7*, 667–679. [CrossRef] [PubMed]
66. Valle, C.G.; Tate, D.F.; Mayer, D.K.; Allicock, M.; Cai, J. Exploring Mediators of Physical Activity in Young Adult Cancer Survivors: Evidence from a Randomized Trial of a Facebook-Based Physical Activity Intervention. *J. Adolesc. Young Adult Oncol.* **2015**, *4*, 26–33. [CrossRef] [PubMed]
67. Vandelanotte, C.; Kolt, G.S.; Caperchione, C.M.; Savage, T.N.; Rosenkranz, R.R.; Maeder, A.J.; Van Itallie, A.; Tague, R.; Oldmeadow, C.; Mummery, W.K.; et al. Effectiveness of a Web 2.0 Intervention to Increase Physical Activity in Real-World Settings: Randomized Ecological Trial. *J. Med. Internet Res.* **2017**, *19*, e390. [CrossRef]
68. Lee, A.M.; Chavez, S.; Bian, J.; Thompson, L.A.; Gurka, M.J.; Williamson, V.G.; Modave, F. Efficacy and Effectiveness of Mobile Health Technologies for Facilitating Physical Activity in Adolescents: Scoping Review. *JMIR mHealth uHealth* **2019**, *7*, e11847. [CrossRef]
69. Scheerder, A.; van Deursen, A.; van Dijk, J. Determinants of Internet skills, uses and outcomes. A systematic review of the second- and third-level digital divide. *Telemat. Inform.* **2017**, *34*, 1607–1624. [CrossRef]
70. Heponiemi, T.; Jormanainen, V.; Leemann, L.; Manderbacka, K.; Aalto, A.-M.; Hyppönen, H. Digital Divide in Perceived Benefits of Online Health Care and Social Welfare Services: National Cross-Sectional Survey Study. *J. Med. Internet Res.* **2020**, *22*, e17616. [CrossRef]
71. Henzel, V.; Håkansson, A. Hooked on virtual social life. Problematic social media use and associations with mental distress and addictive disorders. *PLoS ONE* **2021**, *16*, e0248406. [CrossRef] [PubMed]
72. McKee, M.; Van Schalkwyk, M.C.I.; Stuckler, D. The second information revolution: Digitalization brings opportunities and concerns for public health. *Eur. J. Public Health* **2019**, *29*, 3–6. [CrossRef] [PubMed]

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Feasibility of a Social Network-Based Physical Activity Intervention Targeting Vocational School Students: A Pilot Study

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Abstract: Globally, four out of five adolescents do not meet the recommendations for physical activity (PA). Moving large segments of young adults from inactivity to activity is essential to reach the global target of a 15% relative reduction in inactivity by 2030 worldwide. This study aimed to examine the feasibility of a social network-based PA intervention (WALK2gether) in vocational school students. Fourteen students from one vocational school in the city of Duesseldorf were instructed to walk ten thousand steps per day over six weeks. Applied behavior change techniques were self-monitoring of steps and social comparison via a pedometer app and a Facebook group. Indicators of feasibility were documented. The intervention was minimally resource intensive, with a total of 92 h spent by the research staff. The recruitment rate was 19.2% and loss-to-follow up 28.6%. Our data revealed no significant change in the target behavior PA from baseline to follow-up. The target population did not interact in the Facebook group, while a moderate use of the pedometer app was noted. Although the results ought to be interpreted with caution due to the small sample size, the findings suggest that the WALK2gether intervention was partially feasible, but not appropriate for the target group.

Keywords: physical activity; social media; vocational students; pilot study; Facebook

check for updates

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1. Introduction

1.1. Background

It is well known that regular physical activity (PA) during childhood and adolescence is beneficial for cardiorespiratory fitness, weight status, muscular strength, and bone health and that these preventive effects of regular PA are likely to accumulate until adulthood [1]. Unfortunately, four out of five adolescents aged 11–17 years did not meet the World Health Organization (WHO) recommendation of at least 60 min of moderate to vigorous physical activity (MVPA) per day and muscle strengthening exercises three days per week in 2016 [2]. Should public health strategies not be successful in moving large segments of adolescents from inactivity to activity, it is unlikely that the global target of a 15% relative reduction in inactivity by 2030 will still be met [3]. There are multiple settings for PA promotion that young adults can be targeted in Germany, one of them is the school setting. In Germany, three units (one unit = a 45 min lesson) of physical education are mandatory [4], but recently published survey data revealed that participation in physical education is the lowest among adolescents aged 14–17 years, with an average of 2.03 units spent in physical education and 23% in extracurricular sports activities [5]. Social media is defined as "network community communication channels" [6] (p. 38) and seems to be a promising tool for PA promotion in adolescents [7]. From 2012 to 2018, the daily use of social media doubled among 13–17-year old teenagers (from 34% to 70%) [8]. Characterized by participatory features, social media is used for social interaction and processes of social influence may encourage behavioral changes, as shown in a systematic review by Hosseinpour and Terlutter [9]. They found that competition and social sharing of PA performances with familiar users are the third most effective techniques for promoting PA. Zhang et al. (2016) discovered that social comparison in online social networks had an even more pronounced effect on PA-levels than social support [10]. Although it is known that students at vocational schools are at high risk for insufficient PA [11], they continue to be underrepresented in PA intervention studies. Given the relevance of social media in this age group, a Web 2.0-based PA program for PA promotion seems promising in this population. However, before conducting a full-fledged resource-intensive controlled intervention study, it is advisable to examine the feasibility of the intervention and the implementation processes involved [12].

According to the framework of Thabane et al. [12], the following characteristics of feasibility ought to be covered in a feasibility study piloting an intervention:

- Processes for successful implementation of the intervention, which are documented and rated,
- Resources necessary for the implementation of the intervention, which are tracked and quantified,
- Challenges during the development and implementation of the intervention, which are noted,
- Resources and challenges faced during data processing, which are recorded,
- Use and acceptability of the employed intervention (in our case the Web 2.0 platforms), as well as reasons for non-use, which are assessed.

1.2. Objectives

Hence, the overall aim of this pilot study was to examine the feasibility of a social network-based PA intervention that targets young adults in vocational schools based on the indicators outlined in the framework by Thabane et al. [12] (see above). Secondly, the magnitude of potential effects was determined, including an estimation of the possible magnitude of intervention effects on the primary outcome PA and an estimation of the possible magnitude of intervention effects on the secondary outcomes body mass index (BMI), subjective health status, quality of life (QOL), and exercise motives.

2. Materials and Methods

2.1. Participants and Setting

Participants were students of a vocational school in the city of Duesseldorf between 16 and 27 years old. They were eligible for study enrolment, if they met the following inclusion criteria: (a) had an internet-enabled smartphone, (b) had an active Facebook account or were willing to set up one for the intervention, (c) were willing to set up an account for the pedometer app, Pacer, (d) had no medical conditions or absolute contraindications prohibiting PA or exercise and (e) were German speaking.

In order to reach vocational school students, eight out of twelve vocational schools in the city of Dusseldorf were selected and a community-based-sampling strategy was applied. First, the school administration of each school was contacted via email to inform them about the study and to initiate the cooperation. Teachers from schools that were willing to participate offered access to pre-selected classes for the study staff to provide information and for recruitment.

Interested participants were handed a written informed consent and asked to return it to their vocational school teacher before baseline assessment. After screening these participants for eligibility with a paper-pencil questionnaire that was completed immediately before baseline measurement (T0), participants were formally enrolled in the study and asked to set up their Facebook and Pacer accounts and join the private Facebook group created by the study staff. Then, participants of each class were prompted to form equal teams consisting of 3–8 individuals and to choose one team captain. This formation process was intended to encourage students to walk in self-selected teams of close friends or classmates. Team captains had organizational tasks, e.g., to set up their group in the pedometer app Pacer and invite their teammates. After the team building process was completed, the study staff offered time for questions and troubleshooting regarding the use of Facebook and Pacer. Additionally, a tutorial on how to use the most relevant features in Pacer and Facebook was provided in the joint Facebook group. Figure 1 illustrates the five different stages of the community-based sampling of vocational school students.

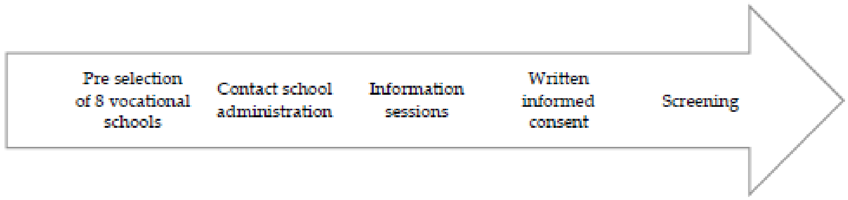


Figure 1. Five stages of the community-based sampling.

2.2. *Intervention*

The intervention WALK2gether is adapted based on the Active Team intervention by Maher et al. [13] and designed as a resource-friendly standalone digital intervention aimed at increasing PA. Self-monitoring and social comparison were the behavior change techniques (BCTs) that were used to motivate the students to walk 10,000 steps per day over a period of 6 weeks [14]. In the design process, we deliberately chose to use an online social network used by the general public and did not develop an app for the study because we wanted to pilot the use of already existing platforms.

A private group administered by the study coordinator in Facebook helped organize the study-related issues (e.g., termination of measurements, reminder to return accelerometers) and communicate with participants. Over the six-week period, the study coordinator provided information four times to reinforce the steps goal (e.g., a YouTube clip with tips for daily walking routines, also see Table 1).

Table 1. Digital intervention materials.

What	Content	Intervention Week
Tutorials app usage	Screen recording on how to use *Facebook* and *Pacer*	1
Post team ranking	Screenshot of team leader board of each group	2
Spotify podcast	"Quarks Daily" episode with scientific background information about the PA recommendation of 10,000 steps	3
YouTube clip	Video with tips on how to implement steady walking routines in everyday life	5

In addition, the pedometer app Pacer was utilized to assist participants in monitoring their daily steps. Pacer has a built-in group feature to reinforce sharing individual PA and to foster social comparisons. Individually logged steps were automatically displayed at the leader board and ranked from high to low. This kind of friendly rivalry between classmates was intended to encourage participants in achieving 10,000 steps every day. WALK2gether took place between November 2021 and January 2022.

2.3. *Outcomes*

The main outcome of this study was feasibility which was evaluated following the framework of Thabane et al. [12]. Processes involved during the development and implementation of the intervention and study, resources required, and the management of challenges were documented. Quantitatively assessed parameters were captured at the baseline (T0) and at follow-up (T1) after completion of the six-week intervention to estimate the magnitude of the potential intervention effects. Data on PA, health outcomes, and participant feedback were collected in person by trained study staff at the Heinrich-Heine-University Duesseldorf (see Table 2).

Table 2. Overview of feasibility outcomes and assessments.

	Parameter	Measurement Tool	Measurement Time
Process	Recruitment rate Withdrawal Drop outs/completion rate Attendance on Facebook Adequacy eligibility criteria Adequacy assessments	Documentation	Implementation Implementation Implementation Implementation Implementation Implementation
Ressources	Study staff Time expenditure Material Costs	Documentation	Entire study Entire study Entire study Entire study
Management	Challenges Solution strategies	Documentation	Entire study Entire study
Preliminary effects	Objective PA Subjective PA BMI Subjective health Quality of Life Exercise motives	Accelerometer, activity diary IPAQ-SF Stadiometer + Scale Questionnaire WHOQOL-BREF EMI-2	T0, T1 T0, T1 T0, T1 T0, T1 T0, T1 T0, T1
Feedback	Usage and acceptability Facebook and Pacer Quality Pacer	Questionnaire MARS-G	T1 T1

Habitual PA was tracked with an accelerometer (wGT3X-BT, ActiGraph, Pensacola, FL, USA). Participants were instructed to wear the device on their non-dominant wrist during the day for one week and acceleration was recorded along three axes with a sample rate of 30 Hz. Valid wear-times were filtered with the algorithm of Choi et al. [15] and comprised at least four days with a minimum of ten hours (600 min) wear-time. By using the cut-off points for MVPA, according to Freedson et al. [16], the data were analyzed within a 10-s epoch, using the ActiLife 6.13.4 software. Participants were asked to simultaneously keep an activity diary to account for non-wear time. In addition, the German version of the IPAQ-SF was used to subjectively assess PA [17]. MVPA, walking, and sedentary time were calculated, using the cut-off points recommended by the IPAQ Research Committee [18]. The IPAQ has a good test-retest reliability (r = 0.80) [19], but a low criterion validity (r = 0.30) [19]. Weight (kg) and height (cm) were assessed by the study staff at the baseline and follow-up to calculate the BMI (kg/m^2), using a scale (Seca 899) and a stadiometer (Seca213). Participants had to rate their subjective general health on a scale ranging from one (very bad) to five (very good) [20]. The WHOQOL-BREF is a 26-item questionnaire that was used to investigate QOL, in general, and the four dimensions physiological health, psychological health, social relationships, and environment [21,22]. The degree of internal consistency for the subscales has been previously shown to vary between $\alpha = 0.57$ and $\alpha = 0.88$ [23]. Fourteen motives for exercise participation were assessed with the German version of the Exercise Motivations Inventory (EMI-2) [24].

Structured feedback regarding the Web 2.0 platforms was gathered via a self-generated questionnaire. Additionally, a German version of the MARS scale (MARS-G) was employed to examine the quality of Pacer regarding objective dimensions, such as engagement, functionality, esthetics and information quality, as well as subjective app quality and perceived impact. The MARS-G has good internal consistency for all subscales ($\omega = 0.82$, 95% CI 0.76–0.86) and good validity in all dimensions compared to the original version ($r = 0.93$ to 0.98) [25].

All questionnaires were converted to online surveys, using the program Lime Survey 5.2.8+220103, and could be accessed via a URL at both assessment points on two iPads.

2.4. Statistical Methods

As there is no need for a formal sample size calculation in a pilot study for a phase III trial according to Thabane et al. [12], sample size was not calculated. Sociodemographic sample characteristics were analyzed descriptively. The magnitude of the potential treatment effects was estimated with a *t*-test (IBM SPSS 25), performing intra-group comparisons regarding PA and secondary health outcomes. Results are shown as means ± standard deviations or percentages. Potential effects are displayed in standardized mean differences, including confidence intervals.

2.5. Feasibility Criteria

The study is considered feasible if at least 20 participants are deemed eligible for inclusion and decide to participate. Furthermore, a loss to follow-up rate of 10% was considered as likely. Assessments were not supposed to take more than 70 min per person at T0 and 85 min at T1. We expected many questions during the screening for medical contraindications for PA and missing data for questions about social status. The total time expense for the study ought to be manageable by one full-time employee. As the intervention was digital, and therefore time- and location-independent, we expected an attendance rate of 100% regarding the Facebook viewings. Furthermore, we considered the intervention as feasible if the estimation of potential intervention effects revealed a trend towards an improvement in all outcome parameters (i.e., PA, BMI, subjective health status, QOL and exercise motives) or at least maintenance at a high level. We assumed that Pacer would, on average, be used daily and Facebook to a lesser extent.

2.6. Ethical Aspects

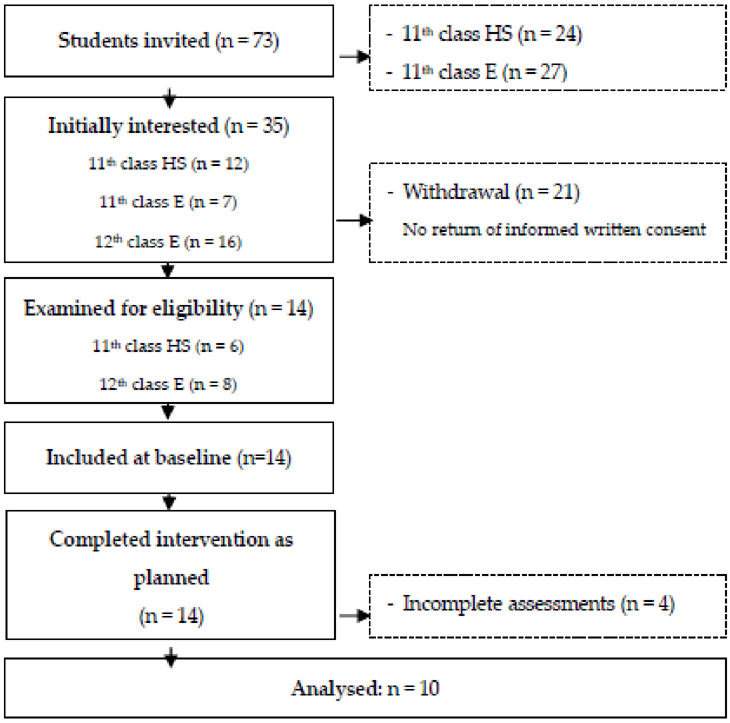
This study was approved by the Ethics Committee of the Medical Faculty of the Heinrich-Heine-University Duesseldorf, Germany, on 4 June 2020 (Study-No.: 2020-860) and was conducted in accordance with the ethical principles of the World Medical Association's Declaration of Helsinki [26]. Participants 18 years or older gave their own consent and for participants under the age of 18 years, at least one of their parents provided informed written consent.

3. Results

3.1. Recruitment

The first attempt to initiate a cooperation with eight vocational schools in Duesseldorf took place in June 2020. Due to the start of the COVID-19 pandemic, which led to recurring school closures, no school was at first willing to participate in the study. A second attempt was made in April 2021, still under COVID-19 restrictions, which finally resulted in a cooperation with one of the eight local vocational schools. In order to achieve certain representativeness, students of two different educational tracks at this school were invited to participate in the study. While two classes were pursuing an educational track focused on economics in the 11th and 12th grade, a third class was enrolled in an educational track that focused on health and social affairs in the 11th grade. All three classes were striving for an entrance qualification for enrolment at universities of applied sciences.

Recruitment took place at the end of October until the beginning of November 2021, baseline assessments were carried out subsequently, and follow-up assessment started mid-January 2022, immediately after the completion of the six-week intervention. Detailed information on recruitment rates and participant flow throughout the study is provided in Figure 2.



HS = Health and social affairs; E = economics

Figure 2. Recruitment rate and participant flow.

3.2. *Participants*

Fourteen vocational school students from two classes participated in the study, seven were female and eleven had a migration background. All participants had an intermediate graduation and rated their subjective social status (SSS) as moderate (5–6) on the MacArthur scale for adolescents (range including minimum of one and maximum of ten [27]) (see Table 3).

Table 3. Sociodemographic characteristics of the sample at baseline.

	Total (n = 14)	Male (n = 7)	Female (n = 7)
Age, years	17.4 ± 1.2	18 ± 1.5	17.1 ± 0.7
Body mass index, kg/m²	23.5 ± 4.8	21.3 ± 5.4	25.4 ± 2.3
Subjective social status	5.7 ± 1.7	5.3 ± 2.4	6 ± 0.8
Migration background	78.6	28.6	50
Graduation (O-levels)	100	50	50
MVPA/day < 60 min	71.4	21.4	50

Data are shown as mean ± standard deviation or percentage, MVPA = moderate to vigorous physical activity derived from IPAQ-SF.

3.3. *Feasibility*

In total, 35 (48.0%) of the invited vocational school students were interested in participating in the study and 21 (28.8%) withdrew from participation by not returning completed consent forms to their teachers. Of the 14 (19.2%) vocational school students who were willing to participate, all met the eligibility criteria. Due to illness, four of them dropped out at the follow-up assessments. Facebook posts were, on average, watched by six participants, with no likes and just one comment was provided. During T0 and T1, no questions from the participants regarding the assessments were raised. However, during data analysis, frequently missing responses were found in the screening questionnaire with regard to items on household income. Nine participants did not give an estimate and seven participants did not assign household income to any given category.

Overall, study staff invested 92 h in the WALK2gether study and EUR 1535 costs emerged for the required measurement equipment (two iPads, two stadiometers, and two scales). Participants, on average, needed 34 min to carry out the baseline assessments and 28 min for the follow-up assessments, plus another 10 min per participant for the set-up of Pacer and to enter the Facebook group. The reception of all intervention materials provided by study staff took approximately 22 min per participant (see Table 4).

Table 4. Expended time and staff resources.

What		Time (h)	Study Staff (n)
Recruitment		14.5	1–2
Assessments	Organization	33	3
	Implementation	15	2–3
Intervention	Design	14	1–2
	Implementation	1	1
Data management		15	1

Most challenges were faced during recruitment and assessment. Due to the ongoing COVID-19 pandemic, we had to adjust to the constantly changing hygiene rules, recurring school closures, cancellations of lessons and illness (i.e., COVID-19 infections of students and/or teachers). This resulted in a shortened intervention period from eight to six weeks, as well as limited access to the target group via community-based sampling. In total, only three classes from one school could be recruited to the study. Furthermore, the assessments had to be relocated from the study site to vocational schools, so that two or more researchers could assess all participants of one class simultaneously during class or free time between classes in the gym or a recreation room. Due to the scarcity of time, paper-and pencil versions of the questionnaires were used instead of the online surveys.

Furthermore, participants were neither familiar with Facebook nor with Pacer and during the installation and we found that, depending on the latest software update, versions and functionalities of the two platforms differed. We, therefore, provided two tutorials that demonstrated the use of the most important app functions. Pacer seemed to have a technical bug with several participants reporting their steps not being transferred, resulting in zero steps being displayed in the individual and team statistics.

Overall, communication with participants during the intervention period via Facebook was difficult and teachers, therefore, often served as mediators. Vocational school students seemed to be less compliant when they were approached outside the school setting as reflected in the low response, as well as long return periods or non-use of study materials (e.g., accelerometers).

3.4. Estimation of Potential Effects

The results regarding PA at T0 and T1 were only reported for subjective PA (based on the questionnaire data derived from the IPAQ-SF), because analysis of the accelerometer data revealed that five participants wore the accelerometer at T0 and T1, but none of them reached the minimum of four valid wear time days. These results are discrepant with the PA diaries, which were completed by eight participants, indicating that at least four participants should have had valid accelerometer data for a minimum of four days. Subjectively rated PA (MVPA and walking time) and time spent in the sedentary state slightly increased from T0 to T1. BMI and subjective health status (predominantly rated as "good") remained constant over the intervention period. Regarding QOL, different trends were observed for the different domains. In the physical health domain, QOL decreased from baseline to follow-up, whereas in the other domains, QOL increased and was most pronounced for the domain environment. Challenge, enjoyment and ill-health-avoidance were predominantly listed as exercise motives at T1 and all other motives were mentioned less or almost equally often after the six weeks of intervention. None of these results reached statistical significance (see Table 5).

Table 5. Estimation of treatment effects.

	T0	T1	SMD (95%CI)	*p*
Subjective PA				
MVPA (min/day)	42.1 ± 55.6	59.7 ± 52.9	−17.6 (−67.1, 31.8)	0.440
MVPA walking (min/day)	112.6 ± 113.4	125.1 ± 92.6	−12.5 (−122.4, 97.4)	0.803
Sedentary time (min/day) *	360 ± 49	381.4 ± 94.4	−21.4 (−117.2, 74.3)	0.604
Subjective health	2.1 ± 0.9	2.2 ± 1.1	0.1 (−0.5, 0.7)	0.726
BMI	23.5 ± 4.8	23.5 ± 4.5	0 (−0.4, 0.5)	0.887
QOL (4–20)				
General	14.4 ± 3.1	14.4 ± 3	0 (−1.8, 1.8)	1.0
Physical health	15.7 ± 2.8	15.3 ± 2.2	0.4 (−1.5, 2.2)	0.663
Psychological health	13.7 ± 3.7	14 ± 3.5	−0.2 (−3, 2.5)	0.846
Social relations	14.7 ± 2.2	14.9 ± 2.9	−0.3 (−2.8, 2.2)	0.814
Environment	14.7 ± 3.5	15.9 ± 2.8	−1.2 (−4.5, 2.1)	0.427
Exercise motives (0–5)				
Affiliation	2.2 ± 0.9	1.9 ± 1.5	0.3 (−1, 1.6)	0.582
Appearance	3.6 ± 1	3.3 ± 1	0.3 (−0.4, 0.9)	0.401
Challenge	3.3 ± 1.1	3.7 ± 1.1	−0.4 (−1.4, 0.6)	0.395
Competition	2.2 ± 1.5	2.2 ± 1.5	−0.1 (−1.5, 1.4)	0.940
Enjoyment	3 ± 1.3	3.4 ± 0.8	−0.4 (−1.4, 0.6)	0.404
Ill-health-avoidance	3.5 ± 1.2	4.2 ± 0.5	−0.7 (−1.7, 0.2)	0.109
Nimbleness	3.3 ± 1.1	3.4 ± 0.8	−0.1 (−0.9, 0.7)	0.787
Positive health	4.3 ± 0.8	4.2 ± 0.5	0.1 (−0.6, 0.8)	0.714
Revitalization	3.6 ± 1.1	3.8 ± 0.8	−0.2 (−1, 0.6)	0.604
Social pressure	0.7 ± 1.0	0.5 ± 0.8	0.1 (−0.6, 0.9)	0.701
Social recognition	1.4 ± 1.2	1.4 ± 1.0	−0.1 (−1, 0.8)	0.856
Strength and endurance	3.9 ± 1.5	3.6 ± 1	0.3 (−1, 1.6)	0.608
Stress nanagement	2.7 ± 1.2	2.8 ± 1.3	−0.1 (−0.7, 0.6)	0.806
Weight nanagement	2.2 ± 1.7	2.4 ± 1.7	−0.2 (−1.3, 1)	0.727

Data are based on n = 10 and are shown as mean ± standard deviation or percentage, SMD = standardized mean differences, CI = confidence intervals, PA = physical activity, MVPA = moderate to vigorous physical activity, BMI = body mass index, QOL = quality of life. * Data based on n = 7, n = 3 answered "I do not know".

3.5. Participants' Feedback

Four participants reported that they used Pacer at least several times per week and some of them even daily (n = 4), mostly to monitor their individual step statistics (n = 8) and also to view the team ranking (n = 4). Six students stated that they would continue to use Pacer after the completion of the study. The overall quality of Pacer was rated as fair (3.3 ± 0.5). Its functionality was rated best (3.6 ± 0.7), followed by esthetics (3.2 ± 0.7). Lowest ratings were noted for the subscale information (3.1 ± 0.6) and engagement (3.1 ± 0.6). Subjective app quality was evaluated as moderate (2.8 ± 0.6).

Feedback pertaining to the utilization of Facebook was rather critical. Half of the respondents stated that they used Facebook less than once per week and three said they never used it. Reasons were lack of time and meaning (n = 2) and forgetting about it (n = 1). Only three participants reported that they used the private Facebook group for organizational matters. Furthermore, use of Facebook was declined by eight participants and seven participants stated that they would have liked to use another social media channel, with Instagram being the most popular choice (n = 5), followed by WhatsApp (n = 3).

4. Discussion

In the present study, we found that a social network-based PA intervention that targeted young vocational school students was partially feasible. We were not able to recruit the intended sample of 20 vocational school students and our loss to follow-up was nearly three times higher as expected. Both can certainly be explained by the fact that the study was carried out during the fourth wave of the COVID-19 pandemic in Germany. At that time, in-person contacts were restricted to a minimum; therefore, visits of the vocational schools for recruitment and assessment were severely restricted. Additionally, the incidence rates had reached a peak and schools, in particular, were affected by the illness of students, resulting in their absence at the follow-up assessment. The study turned out to be as resource friendly as intended. Both the amount of work, as well as the study material and associated costs, were manageable. Most assessments seemed to be appropriate for the target population. They took, on average, less than half of the scheduled time and, apart from the incomplete questionnaire data regarding household income, no questionnaire data were missing. However, irrespective of the pandemic, WALK2gether did not have the desired effect, because neither an improvement in PA nor a positive change in the other health outcomes from T0 to T1 could be observed. Nevertheless, subjective health status, BMI, and general QOL were maintained at relatively high initial levels. Participants' feedback revealed a poor acceptance of Facebook, while Pacer was moderately used by the target group.

The aim of WALK2gether was to promote PA in a sample of vocational school students with an intervention strategy that was minimally supportive and related to Web 2.0 use behavior of adolescents. However, our results suggest that this was not appropriate for the target population. Students of both classes showed limited engagement with the intervention and study, whenever they were not supervised by either their teacher or study staff. This became evident by the high non-use rates of the study materials, such as accelerometers, activity diaries, and Facebook and led to the assumption that the target group needs a very structured regimen in a supportive environment to adopt behavioral changes in PA. A pilot study from Finland indicated higher engagement and acceptability of an environmental approach to promote PA in the school setting, but, similar to our results, reported that their optional website was barely used by the target group [28]. However, this is contrasted by the findings of Kuipers and colleagues [29], who reported that autonomous motivation is associated with increased MVPA in vocational school students and sustainability in behavior changes. They call for interventions that foster competence paired with autonomy, conducive to self-beliefs in individual success and confirm that peer relations are supportive for autonomous motivation.

The selection of adequate social media platforms for the target population is controversial. In a focus group study, vocational school students rated Facebook and text messaging as feasible methods for PA interventions [30]. These findings can neither be confirmed by our results, nor by the study of Saez et al. [31], who found that a Facebook challenge group was barely used by overweight, socially disadvantaged adolescents in a nutritional program.

The harmful consequences of social media use should always be carefully weighed against the benefits. Social media can cause stress, anxiety and depressive symptoms among adolescents due to envy and comparison and these effects are more pronounced in a mentally challenging crisis, such as the COVID-19 pandemic [32].

One limitation of this pilot study is the very small sample size that does not allow for preliminary estimations of the intervention effects and restricts the generalizability of the described findings. Another key limitation is the selection bias. Due to the COVID-19 pandemic, recruitment was performed at only one school and in three pre-selected classes. Furthermore, migration background and prevailing cultural and social norms regarding PA, which may influence the behavior, were not assessed in this small pilot study, but will be assessed in the full trial that will be conducted in the future [33]. One strength was the use of the framework of Thabane et al. [12] and the feasibility criteria specified a-priori.

5. Conclusions

Despite several limitations, this small pilot study provided important information regarding the needs and behavior of the target group of vocational school students and implementation processes involved when delivering a social media-based intervention. The results will inform the development and implementation of future social media-based PA interventions on a larger scale. Based on our results, we conclude that an optimization of WALK2gether is necessary and the following key points should be considered during the adaptation process:

- Creating a supportive environment, including integration of the program in the daily setting of the target group, e.g., school increasing autonomous motivation via peer relations and social support.
- Providing a social media add-on, including incorporation of an existing social media platform that is frequently and easily used by the target population during their leisure time.
- Addition of BCTs, including complementing the intervention with other effective BCTs, such as feedback and goal setting.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the Medical Faculty of the Heinrich-Heine-University Duesseldorf, Germany, on 4 June 2020 (Study No.: 2020-860).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study. Participants 18 years or older gave their own consent and for participants under the age of 18 years, at least one of their parents provided informed written consent.

Data Availability Statement: The raw and statistical data of this study are available upon request from the corresponding author. The data are not publicly available due to reasons of privacy.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

BCT	behaviour change technique
BMI	body mass index
MVPA	moderate to vigorous physical activity
PA	physical activity
QOL	quality of life
SSS	subjective social status
WHO	World Health Organization

References

1. 2018 Physical Activity Guidelines Advisory Committee Scientific Report. Available online: https://health.gov/sites/default/files/2019-09/PAG_Advisory_Committee_Report.pdf (accessed on 7 April 2022).
2. World Health Organization. World Health Statistics 2020: Monitoring Health for the Sdgs, Sustainable Development Goals. Available online: https://apps.who.int/iris/bitstream/handle/10665/332070/9789240005105-eng.pdf?sequence=1&isAllowed=y (accessed on 28 May 2022).
3. Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global Trends in Insufficient Physical Activity among Adolescents: A Pooled Analysis of 298 Population-Based Surveys with 1.6 Million Participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [CrossRef]
4. World Health Organization. Germany Physical Activity Factsheet. 2018. Available online: https://www.euro.who.int/__data/assets/pdf_file/0020/382511/germany-eng.pdf (accessed on 31 May 2022).
5. Adimon-Themenblatt: Sportliche Aktivität in der Schule. Available online: https://www.rki.de/adimon (accessed on 31 May 2022).
6. Mróz-Gorgoń, B.; Peszko, K. Marketing Analysis of Social Media—Definition Considerations. *Eur. J. Serv. Manag.* **2016**, *20*, 33–40. [CrossRef]
7. Günther, L.; Schleberger, S.; Pischke, C.R. Effectiveness of Social Media-Based Interventions for the Promotion of Physical Activity: Scoping Review. *Int. J. Environ. Res. Public Health* **2021**, *18*, 13018. [CrossRef] [PubMed]
8. Teens' Social Media Usage Is Drastically Increasing. Available online: https://www.statista.com/chart/15720/frequency-of-teenagers-social-media-use/ (accessed on 31 May 2022).
9. Hosseinpour, M.; Terlutter, R. Your Personal Motivator Is with You: A Systematic Review of Mobile Phone Applications Aiming at Increasing Physical Activity. *Sports Med.* **2019**, *49*, 1425–1447. [CrossRef]
10. Zhang, J.; Brackbill, D.; Yang, S.; Becker, J.; Herbert, N.; Centola, D. Support or Competition? How Online Social Networks Increase Physical Activity: A Randomized Controlled Trial. *Prev. Med. Rep.* **2016**, *4*, 453–458. [CrossRef]
11. Reik, R.; Woll, A.; Gröben, F.; Berndt, E.D. Betriebliche Gesundheitsförderung in der Ausbildung. Wie verändert Sich der Lebensstil der Jugendlichen über einen zweijährigen Ausbildungszeitraum und welchen Beitrag kann ein Azubi-Fit Programm leisten? *Arbeitsmed. Sozialmed. Umweltmed.* **2010**, *45*, 640–646.
12. Thabane, L.; Ma, J.; Chu, R.; Cheng, J.; Ismaila, A.; Rios, L.P.; Robson, R.; Thabane, M.; Giangregorio, L.; Goldsmith, C.H. A Tutorial on Pilot Studies: The What, Why and How. *BMC Med. Res. Methodol.* **2010**, *10*, 1. [CrossRef]
13. Maher, C.; Ferguson, M.; Vandelanotte, C.; Plotnikoff, R.; De Bourdeaudhuij, I.; Thomas, S.; Nelson-Field, K.; Olds, T. A Web-Based, Social Networking Physical Activity Intervention for Insufficiently Active Adults Delivered Via Facebook App: Randomized Controlled Trial. *J. Med. Internet Res.* **2015**, *17*, e174. [CrossRef]
14. Michie, S.; Richardson, M.; Johnston, M.; Abraham, C.; Francis, J.; Hardeman, W.; Eccles, M.P.; Cane, J.; Wood, C.E. The Behavior Change Technique Taxonomy (V1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. *Ann. Behav. Med.* **2013**, *46*, 81–95. [CrossRef]
15. Choi, L.; Liu, Z.; Matthews, C.E.; Buchowski, M.S. Validation of Accelerometer Wear and Nonwear Time Classification Algorithm. *Med. Sci. Sports Exerc.* **2011**, *43*, 357–364. [CrossRef]
16. Freedson, P.S.; Melanson, E.; Sirard, J. Calibration of the Computer Science and Applications, Inc. Accelerometer. *Med. Sci. Sports Exerc.* **1998**, *30*, 777–781. [CrossRef]
17. International Physical Activity Questionnaire. Downloadable Questionnaires. Available online: https://sites.google.com/site/theipaq/questionnaire_links (accessed on 7 May 2022).
18. International Physical Activity Questionnaire. Ipaq Scoring Protocol. Available online: https://sites.google.com/site/theipaq/scoring-protocol (accessed on 7 May 2022).
19. 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.; et al. International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Med. Sci. Sports Exerc.* **2003**, *35*, 1381–1395. [CrossRef] [PubMed]
20. World Health Organization. Health Interview Surveys: Towards International Harmonization of Methods and Instruments. Available online: https://apps.who.int/iris/bitstream/handle/10665/107328/E72841.pdf?sequence=1&isAllowed=y (accessed on 7 May 2022).

21. WHOQOL Group. Development of the World Health Organization Whoqol-Bref Quality of Life Assessment. *Psychol. Med.* **1998**, *28*, 551–558. [CrossRef] [PubMed]
22. World Health Organization. Whoqol: Measuring Quality of Life. Available online: https://www.who.int/tools/whoqol/whoqol-bref/docs/default-source/publishing-policies/whoqol-bref/german-whoqol-bref (accessed on 7 May 2022).
23. Angermeyer, M.C.; Kilian, R.; Matschinger, H. *Handbuch für die deutschsprachigen Versionen der WHO Instrumente zur Erfassung von Lebensqualität*, 1st ed.; Hogrefe: Göttingen, Germany, 2000.
24. Emi-2 in German. Available online: http://exercise-motivation.bangor.ac.uk/emi/german.php (accessed on 7 May 2022).
25. Messner, E.M.; Terhorst, Y.; Barke, A.; Baumeister, H.; Stoyanov, S.; Hides, L.; Kavanagh, D.; Pryss, R.; Sander, L.; Probst, T. The German Version of the Mobile App Rating Scale (Mars-G): Development and Validation Study. *JMIR Mhealth Uhealth* **2020**, *8*, e14479. [CrossRef]
26. World Medical Association. Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Available online: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/ (accessed on 31 May 2022).
27. Lampert, T.; Hoebel, J.; Kuntz, B.; Müters, S.; Kroll, L.E. Messung Des sozioökonomischen Status und des subjektiven sozialen Status in KIGGS Welle. *J. Health Monit.* **2018**, *3*, 114–133. [CrossRef]
28. Hankonen, N.; Heino, M.T.; Hynynen, S.T.; Laine, H.; Araújo-Soares, V.; Sniehotta, F.F.; Vasankari, T.; Sund, R.; Haukkala, A. Randomised Controlled Feasibility Study of a School-Based Multi-Level Intervention to Increase Physical Activity and Decrease Sedentary Behaviour among Vocational School Students. *Int. J. Behav. Nutr. Phys. Act.* **2017**, *14*, 37. [CrossRef] [PubMed]
29. Kuipers, A.; Kloek, G.C.; de Vries, S.I. Understanding Vocational Students' Motivation for Dietary and Physical Activity Behaviors. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1381. [CrossRef]
30. Van Dyck, D.; D'Haese, S.; Plaete, J.; De Bourdeaudhuij, I.; Deforche, B.; Cardon, G. Opinions Towards Physical Activity Interventions Using Facebook or Text Messaging: Focus Group Interviews with Vocational School-Aged Adolescents. *Health Soc. Care Communit.* **2019**, *27*, 654–664. [CrossRef] [PubMed]
31. Saez, L.; Langlois, J.; Legrand, K.; Quinet, M.; Lecomte, E.; Omorou, A.; Briançon, S. PRALIMAP-INÈS Trial Group Reach and Acceptability of a Mobile Reminder Strategy and Facebook Group Intervention for Weight Management in Less Advantaged Adolescents: Insights From the PRALIMAP-INÈS Trial. *JMIR Mhealth Uhealth* **2018**, *6*, e110. [CrossRef] [PubMed]
32. Ellis, W.E.; Dumas, T.M.; Forbes, L.M. Physically isolated but socially connected: Psychological adjustment and stress among adolescents during the initial COVID-19 crisis. *Can. J. Behav. Sci. /Rev. Can. Des Sci. Du Comport.* **2020**, *52*, 177–187. [CrossRef]
33. Fernandes, S.; Caperchione, C.M.; Thornton, L.E.; Timperio, A. A qualitative exploration of perspectives of physical activity and sedentary behaviour among Indian migrants in Melbourne, Australia: How are they defined and what can we learn? *BMC Public Health* **2021**, *21*, 2085. [CrossRef] [PubMed]

4 Discussion

The use of new technologies has the potential to promote healthy lifestyles in a scalable, cost-efficient, user-oriented and targeted manner. However, so far, digitalization has contributed to the widening of existing health inequalities leading to the so-called digital divide for the areas of health and PA promotion. A limited amount of research previously addressed populations that are socially disadvantaged. The three original articles included in this dissertation contribute to closing this research gap by investigating the feasibility and effectiveness of eHealth interventions for PA promotion sensitive to the needs of these populations. The following chapter will answer the three underlying research questions based on the results from each associated exploratory research presented in section 3 and discuss the findings in the context of the existing literature. Then strengths and limitations pertaining to various aspects of the study and intervention design are discussed and, lastly, implications for future research are provided.

4.1 Summary of main findings

4.1.1 Pilot study I

The first pilot study intended to evaluate the feasibility of a complex intervention combining smartphone app-supported training of physical and cognitive functions, and activities embedded in the neighborhood of older individuals. The recruitment was sufficient and resulted in an n=39 (initially intended n=40) community-dwelling adults aged 73.1±6.8. years. Their high initial levels of PA, physical and cognitive fitness at baseline were maintained after the intervention period. The only significant improvements recorded from baseline to follow-up, were in balance and in the cognitive parameters inhibition, executive functioning, word fluency, and short-term memory. This is a common phenomenon in PA studies, as they intend to include inactive individuals, but often spark the interest of those who are already sufficiently active (El-Kotob & Giangregorio, 2018).

Nonetheless, the *Quartier Agil* intervention appeared to be generally safe and feasible for older adults. The average attendance rate was high with 76 ± 15% of sessions attended and, in total, only six dropouts appeared over the intervention period of one year. Most participants were satisfied with the program and more than two-third reported increased social participation through the program. The question remains open which component of the intervention strengthened social participation, because ultimately *Quartier Agil* was a hybrid intervention. Traditional group PA programs foster social participation by meeting three psychosocial needs of older individuals: social interaction, sense of belonging, and regular engagement (Zimmer et al., 2021). Some previous research suggests that the social component even facilitates the uptake of group PA trainings among elderly (Devereux-Fitzgerald et al., 2016; Stodle et al., 2019) and may reduce feelings of loneliness, operationalized by feeling subjectively younger (Lippke et al.,2022). A pilot study found that the social presence of avatars in a virtual gym significantly increased engagement in exercise sessions (Far et al., 2015) in older individuals. Based on the current evidence, it seems that older individuals per se prefer being physically active with others, either virtually or in person.

The development and implementation of the intervention resulted in an average time expenditure of nine person-hours per week from the tutors. They considered this to be feasible, but noted that the group size was at its maximum with twenty people participating, and that, due to the heterogeneity of the group, it was difficult to provide safety and tailored supervision. The use of the study-specific smartphone app turned out to be not feasible. The app had technical bugs and could not be developed as planned due to time constraints, resulting in widely varying satisfaction and usage among participants. In addition, familiarization of the participants with the app was very time-consuming for the tutors. Soon, the use of the study-specific app was trimmed down to the most relevant features and replaced with intuitive, conventional applications, such as *WhatsApp*. This was welcomed by the study participants and, lastly, led to an enjoyable use of the smartphone.

The implementation of a standalone study-specific smartphone app seems to be somewhat outdated, considering that the use of online social networks with a multi-layered architecture to promote different lifestyle factors, such as sleep and PA in elderly, continues to evolve (Choi & Lee, 2021). The abundance of social media platforms e.g., messenger (e.g. Snapchat, WhatsApp), live streams (e.g., Twitch) audio platforms (e.g., *Clubhouse, Spotify*), blogs (e.g., *Tumblr, Twitter*), social networking sites (e.g., *Facebook*), and media sharing networks (e.g., *Instagram, Tik Tok)* rather complicates the purposeful selection than warranting the need for developing new platforms.

The time required for the assessment (i.e., two hours per person) was perceived as extensive by the participants and a large number of incomplete data sets at follow-up were documented (n=13). Mainly, clinical and functional data (e.g. strength, aerobic capacity or concentration) were collected which might not have reflected the scope of the intervention (dual-task training, neighborhood connectedness) nor social participation in all its dimensions adequately.

In sum, a smartphone app-supported, combined PA and cognitive program in the neighborhood seems feasible and appropriate for older individuals. However, the selection of the Web 2.0 platform and the selection of outcome parameters sensitive to the objectives and study sample should be carefully considered in the future. In addition, generous time should be allocated for technological support of the target group.

4.1.2 Scoping Review

The scoping review aimed to comprehensively map the nature of social media used in PA interventions and the range of evidence of effects on PA behavior and secondary health outcomes. Among 53 identified publications referring to 43 trials, social networking sites were most often used to promote PA. The incorporation of *Facebook* was prevailing followed by study-specific, standalone online social networks. In the studies summarized, online social networks were primarily used as a source to provide information on PA and secondarily for social sharing to reinforce social interaction. Both is in line with the findings from a recent review on individuals with chronic conditions (McKeon et al., 2022) and can be explained by the fact that *Facebook* with currently 2,91 billion active users worldwide (Statista Research Department, 2022) among diverse populations reaches most people.

We found that the use of social networking sites positively influenced PA behavior, compared to either control conditions or from pre to post-testing. This is not surprising, because, beyond the access to information and services, individuals need the support of key stakeholders in their living environment, such as family and friends for health behavior change (Putland et al., 2013). As technology has advanced, interpersonal interactions more often take place online, making social networking sites with their interactive system-architecture the platform for social support and, thus, for behavior change interventions in the narrower sense (Moorhead et al., 2013; Vitak & Ellison, 2013).

Secondary health outcomes that were predominantly examined in the included literature were related to other physical dimensions of health. Improvements in weight, body mass index (BMI), body fat, waist circumference, blood pressure, eating behavior and indicators of the metabolic syndrome were found as a result of participation in social media-based interventions. A frequently studied target outcome in eHealth literature next to PA is dietary behavior. This outcome is studied for good reason, because poor dietary habits, such as high sodium intake and low fruit or vegetable consumption, are the second largest risk factor for NCDs and account for 22% of all adult deaths (GBD 2017 Diet Collaborators, 2019). This might explain why their physical indicators, such as weight, blood, and body composition, are well addressed in Web 2.0 interventions. Moreover, they appear to be modifiable, which is consistent with the findings in this scoping review. Other reviews confirmed that Web 2.0 interventions positively influence nutrition-related outcomes in adolescents and adults (Goodyear et al., 2021; Rose et al., 2017). Conversely, more recent evidence on individuals already suffering from NCDs suggests that only their exercise behavior could be improved through the use of social media, but not their dietary habits (McKeon et al., 2022). Psychosocial and mental health parameters (e.g., group cohesion, enjoyment, and QoL) were barely addressed in the included studies and, therefore, the impact of social media-based interventions remains unclear.

In contrast, feasibility was assessed in more than two-thirds of the literature, but due to a great heterogeneity in the assessment of the construct feasibility, pooling of data was difficult. *Facebook* was generally rated as motivational for enhancing PA and evidence from another systematic review emerged that its use also led to sustained intervention engagement (Petersen et al., 2019). Because the value of a feasibility assessment before a costly efficacy assessment has been increasingly emphasized, the number of conducted studies rose. However, there are differing guidelines (Eldridge et al., 2016; Pearson et al., 2020) and no consensus on how these studies should be named, what their objectives and content should be, and how they should be reported (Moore et al., 2018). This ultimately results in a diversity of findings pertaining to feasibility in the scoping review and elsewhere.

To conclude, the use of social media interventions has been shown to positively impact PA behavior and other physical health outcomes in studies which recorded them in a standardized manner.

4.1.3 Pilot study II

Pilot study II attempted to adapt the original *Active Team* intervention for adolescents enrolled in a vocational school in the city of Duesseldorf and to evaluate the program's feasibility, as well as to determine the magnitude of potential intervention effects on PA behavior and secondary health outcomes. At the process level, the *WALK2gether* study was shown not to be feasible. First, only n=14 participants could be recruited instead of the targeted twenty, and the loss-to-follow-up was three times as high, resulting in only ten processed data sets. The assessments seemed partly feasible qua time spent and completeness, but the main outcome PA behavior could not be evaluated based on objective data, as the sample did not wear the accelerometers sufficiently. This is in line with an observational study in Irish children from socially disadvantaged areas, in which only 52% of 408 participants had valid accelerometer wear times for inclusion, which was explained by the rigorous algorithm cut-offs (Belton et al., 2019). Additionally, participant compliance may play an essential role as shown in a trial, where early morning reminders sent via SMS improved wear time and device removal after school was associated with longer non-wear periods among second-level school students (Belton et al., 2013).

During the intervention period, the interaction with *Facebook* was low as posts were not even viewed by half of the study participants, on average, and participants were rather critical of its use, while *Pacer* was moderately used and rated, but had technical bugs. Contrary to these results, vocational school students rated text messaging and *Facebook* as appropriate tools for PA promotion in a focus group study (Van Dyck et al., 2019) and the pedometer app *Pacer* had the best app store user ratings compared to five other conventional PA apps outlined in a previous content analysis (Kebede et al., 2018).

The study proved to be resource friendly, considering the time invested by the study staff with a total of 92 hours and the costs of 1,535 € for initial acquisition of measuring devices (two iPads, two stadiometers, two scales).

This minimally supportive intervention strategy could have been one of the reasons why the *WALK2gether* study did neither achieve an improvement in PA behavior in a predominantly inactive sample at baseline nor was associated with changes in BMI, subjective health status, QoL, and exercise motives after the six-week intervention period. We conclude from the limited participation of the sample in the intervention and high non-usage of study materials that the target population seemed less compliant whenever the teacher or study staff did not supervise them. They presumably need a more structured regimen to adopt behavioral changes in PA, but evidence from other studies in this respect is inconsistent, too. An approach at the individual and environmental levels targeting vocational school students and their teachers indicated high engagement and acceptability in the intervention condition (Hankonen et al., 2017), whereas an internet-based intervention providing skills for teachers to improve PA among their secondary school students during physical education led to only modest increases in MVPA, exclusively during lessons (Lonsdale et al., 2019). Kuipers and colleagues (2021) reported that autonomous motivation, i.e. doing something for the individual's sake is associated with increases of MVPA among students from vocational schools and the best driver for sustainability in behavior change. In the *PLAN-A* intervention improvements in PA among teenaged girls were attributed to the peer-led training by classmates in school (Sebire et al., 2019).

Further, the *WALK2gether* intervention was not appropriate for promoting PA behavior and other health outcomes in our sample of vocational school students. Nevertheless, these findings attribute to the development and implementation of future social media-based PA programs for young adolescents enrolled in vocational schools.

4.2 Strengths and limitations

4.2.1 Use of exploratory study designs

The three studies conducted in the context of this dissertation were all exploratory in nature. Such exploratory approaches are a necessary pre-requisite for informing future research as they investigate emerging, yet heterogeneous research areas and identify key mechanisms, uncertainties, and gaps (Peters et al., 2015; Skivington et al., 2021; Thabane et al., 2016). Another strength is that the three published articles fit within the updated MRC guideline framework and encompass two of the four phases of complex intervention research, i.e., intervention identification/development and feasibility testing (see figure 5). In doing so, all of the aforementioned core elements were considered except for two: pilot study I failed to document the total costs and to weigh them against the benefits and, in pilot study II, the time was too scarce to refine the intervention.

These exploratory designs also have their disadvantages. One major limitation is their restricted quality of evidence, consequently not allowing for any generalizability of the findings described above.

Both, pilot study I and pilot study II, were not conceptualized to have high internal and external validity, resulting in a small, selective sample and a non-controlled study design. Although the sample size in pilot study I allowed for intragroup comparisons using inferential statistics, positive treatment effects, especially on physical outcomes, were absent due to a selection bias of an initially active sample. This occurred through partial recruitment by word-of-mouth recommendations, which attracted a majority of members from the local sports club in which the weekly training sessions were held. The very small sample in pilot study II does neither allow for preliminary estimates of intervention effects nor for general conclusions based on the descriptive results. Unfortunately, it was a consequence of the study being implemented under COVID-19 conditions that also led to a selection bias. Recruitment could only be carried out in three pre-selected classes at one vocational school with students who already possessed an intermediate educational qualification and were striving to qualify for a university of applied science. Thus, we recruited a middle class sample rather than young vocational school students with a low SES as originally intended. This was reflected in the moderate values for subjective social status reported by participating students. Therefore, included participants were not representative of the actual target group in both pilot studies.

The scoping review provides an accumulation of knowledge without considering and critical appraising the quality of the included sources. Finally, it is not possible to determine whether the positive results on PA behavior and physical health outcomes are universal and accurate, as risk of bias assessments and summary measures are not by nature applicable in a scoping review (Tricco et al., 2018). This is accompanied by the methodological weakness that the search was restricted to two literature databases, possibly overlooking relevant studies.

4.2.2 Methodological approaches

A methodological strength in all three studies is the systematic acquisition of information and the reporting, based on existing frameworks. In pilot study I and II, the framework of Thabane and colleagues (2010) was applied to schematically capture feasibility and evaluate it based on a-priori specified criteria. In pilot study I, we followed the *TIDieR* checklist for reporting (Hoffmann et al., 2014). In the scoping review, we closely adhered to the *PRISMA* guidelines for scoping reviews (Tricco et al., 2018) while conducting the study and during the reporting of study findings. This systematic approach is needed because it leads to a better replicability of studies (Hoffmann et al., 2014).

Methodological limitations arose from the broad inclusion criteria. While, on the one the hand, wide eligibility criteria were an advantage of the scoping review, because they provided a vast amount of literature, neither the search nor the charting of evidence were specified regarding socially disadvantaged populations. In both pilot studies, the broad inclusion criteria and the lack of screening of the corresponding baseline characteristics (PA level and SES) might have contributed to the selection biases.

Additionally, the assessments utilized in both pilot studies have to be critically scrutinized. Even though the *Berg Balance Scale (BBS)* is a reliable tool for assessing a low fall risk in community-dwelling adults (Park, 2018), a well-known ceiling effect appeared in pilot study I. Similarly, the *six-minute walk test* revealed good psychometric properties when addressing lower-functioning older individuals (Du et al., 2009; Southard et al., 2005). Further, accelerometry is a widely used and reliable method to assess habitual PA in research under free-living conditions (Ekelund et al., 2011) and was supplemented by an activity diary to monitor non-wear times.

In the *WALK2gether* study, these measurement tools, however, did not provide useful data sets, because vocational school students did not wear them as instructed. Thus, this measurement approach does not seem to be appropriate to objectively capture the main outcome PA behavior in this population.

4.2.3 Design of the two eHealth interventions

An absolute strength of both interventions was that they were resource efficient as intended qua time. However, the selection of new technologies should be reconsidered because one major limitation of both interventions was that the samples did not sufficiently interact with the selected platforms for various reasons. In pilot study I, recurring technical issues and limited functions of the smartphone app resulted in refusal to interact with the app. In pilot study II, all participants installed *Facebook* for the first time meaning that they were not familiar with this online social network. They mentioned that they would have preferred another platform, such as *WhatsApp* or *Instagram*.

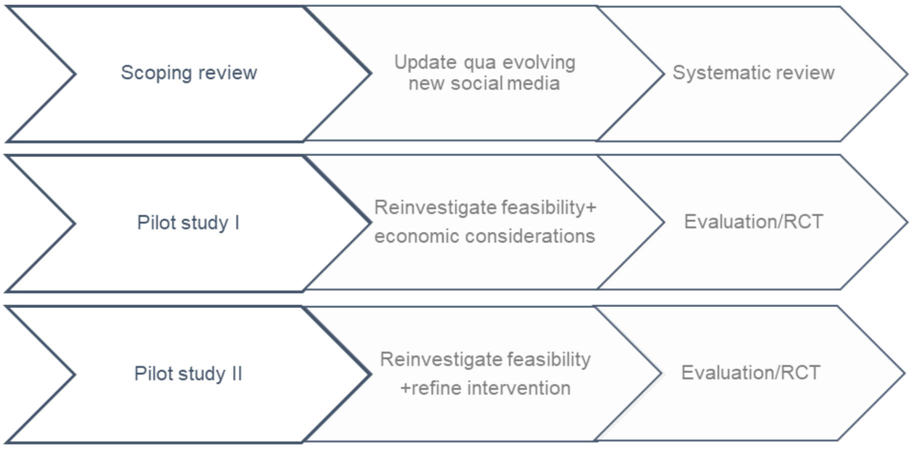
Furthermore, the underlying program theory in the *WALK2gether* intervention to motivate students to walk 10,000 steps per day, i.e., reinforcing social comparison with the pedometer app *Pacer*, has to be questioned. Behavior and social science theories emphasize the role of social support, but not competition to be associated with healthy behavior, such as PA (U.S. Department of Health and Human Services, 1996). Social support can either be instrumental, informational, emotional or appraising (Israel & Schurmann, 1990). In the *Quartier Agil* intervention, the number of six overlapping intervention components, supposed to gain substantial interest among participants giving them the opportunity to choose a variety of options, made it difficult to detect the mechanism of change and underlying mediators.

4.3 Implications for future research

The three original articles in the dissertation provide a comprehensive overview of the effects of new technologies in PA interventions, taking a closer look at the feasibility of two different eHealth approaches in two socially disadvantaged populations. Thus, this dissertation can serve as a basis for researchers to further develop and implement eHealth interventions promoting an active lifestyle in these populations. Subsequent studies could be developed based on the three studies included in the dissertation. They first should strive to update the current evidence and complete feasibility testing. Secondly the quality of evidence has to be improved with more robust study designs as outlined in figure 6.

Figure 6

Implications for continuation based on the framework for developing and evaluating complex interventions



Note. RCT = randomized controlled trial

Some methodological considerations must be taken into account to avoid the previous pitfalls. In order to avoid the recurrence of a selection bias in future studies, the recruitment strategy should be modified. Community-based sampling is known to be beneficial in order to reach socially disadvantaged individuals (Bonevski et al., 2014), but should ideally be done in cooperation with higher-level institutions (e.g. the department for school or health affairs) to reach several facilities at the organizational level. Another option is to combine sampling strategies, as was done in the previous *Active Team* study (Maher et al., 2015). Maher and colleagues complemented a media campaign with respondent driven sampling, guiding initially interested participants to invite their eligible *Facebook* friends and reached the required sample size.

Measurement tools should be reconsidered and carefully chosen specific to the target group and sensitive to changes in the outcome parameters. For example, regarding social participation, surveys that assess instrumental activities of daily life (IADLs) measure dual-tasking abilities required for complex actions, such as public transportation or grocery shopping, and appear to be better indicators of participation than measures of physical functions, such as strength or aerobic capacity (Camino & Mioshi, 2017; Tomioka et al., 2017). Some other instruments capture different facets of participation linked to the *International Classification of Functioning, Disability and Health (ICF)* domains and reveal good psychometric properties (Hashidate et al., 2021), such as the *Participation Objective, Participation Subjective* (*POPS*; Brown et al., 2004) or the *Rating of Perceived Participation* (*ROPP;* Sandström & Lundin-Olsson, 2007).

To assess PA behavior objectively, dual-accelerometer systems attached to the skin are promising to supply valid movement data of children and adolescents (Duncan et al., 2018). Alternatively, researchers may consider multiple imputation strategies, as they are appropriate to deal with missing data sets and improve sample size power (Peeters et al., 2015).

The question remains how digital PA interventions for socially disadvantaged populations have to be designed in the future in order to initially change behavior and promote sustainability of long-term behavior change. Technological innovations on the market always spark substantial interest and attention and cause short-term increases in PA. A good example is *Pokémon GO*. After its release, daily steps significantly increased in users, but this effect could not be sustained after six weeks (Howe et al., 2016). A recent trend is the Web 3.0 app *STEPN*. Based on the move to earn concept, users buy a virtual sneaker and are incentivized to walk or run during their daily lives by earning crypto currency. They can either cash out their earnings or continue using it in the game (https://whitepaper.stepn.com/).

But is external motivation the key? Researchers argue that interventions for PA promotion have to be theory-based and acknowledge psychological explanations of motivation, such as the self-determination theory (SDT). Broken down to PA, part of this theory states that a person whose three basic psychological needs -autonomy, competence, and relatedness- are met by a PA program is more likely to continue doing so autonomously through intrinsic motivation (Wang et al., 2009).

Based on the lessons-learned from the three studies conducted as part of this dissertation, I assume that future interventions have to be participant driven. Why not ask target populations themselves what they need to become physically active, which platform they would like to use, and which barriers they have to overcome using new technologies for a healthier lifestyle? This participatory approach is better known as co-creation and, according to the earlier outlined SEM model (see figure 2), it should not be restricted to the individual level, but engage multiple levels in design and implementation of interventions (Stokols, 1996), i.e. stakeholders actively involved in the development of PA-friendly environments in different settings.

Physical inactivity is a pandemic and has to be addressed at a population level to improve health globally. As demanded by the WHO we have to involve stakeholders of these systems where scaled-up public health interventions can be implemented and delivered to improve PA population-wide. In Canada, a PA-initiative for older adults was implemented in collaboration with community-based partner organizations. McKay and colleagues (2018) successfully enrolled the target population with their partner-based delivery strategy at a broad community level and improved PA, mobility, and social connectedness among older individuals in British Columbia. A study in the vocational education setting targeting the nursing care and automotive mechatronics sector concluded that co-creation approaches for long-term implementation of PA interventions at the institutional level have to elaborated in more detail considering relevant contextual factors. Gruene and colleagues (2022) found a sustained implementation of intervention components in the nursing care, but not in the automotive mechatronics sector. Effects at the individual level were absent.

4.4 Conclusions

The overarching aim of this dissertation was to investigate the feasibility and effectiveness of eHealth interventions for the promotion of PA behavior in socially disadvantaged populations. Findings of this dissertation suggest that research on eHealth interventions for PA promotion in socially disadvantaged populations is still in its infancy. Given the abundance of new technologies and social media, there is no necessity for the development of new platforms. A purposeful consideration and adoption of existing platforms should be the task of future intervention research. In our digitalized world which has gained momentum with the outbreak of COVID-19 the harmful effects of, for example, social media use should always be critically questioned and weighed against the benefits before adopting new technologies in PA and health promoting programs. Likewise, the tertiary digital divide should be taken into account, which excludes individuals with low eHealth literacy levels and unfortunately those most in need for PA promotion. That is why participatory efforts in this area of research are needed to develop tailored interventions and to obtain more study data from socially disadvantaged populations.

The results also highlight that the present evidence on eHealth interventions to promote PA among socially disadvantaged populations is scarce and of low quality. Increased standardization of indicators, measurements, and reporting are recommended. Considerably more effort will be necessary to generate robust evidence on the feasibility and effectiveness of intervention approaches disseminated at a larger scale (e.g. at the community level) which will ultimately inform political decision makers on how to create PA-promoting programs for socially disadvantaged populations that incorporate the social and built environment.

5 References

2018 Physical Activity Guidelines Advisory Committee. (2018). *2018 Physical Activity Guidelines Advisory Committee Scientific Report*. https://health.gov/sites/default/files/2019-09/PAG_Advisory_Committee_Report.pdf

ARD/ZDF-Forschungskommission. (2021). *ARD/ZDF-Onlinestudie 2021.* https://www.ard-zdf-onlinestudie.de/files/2021/ARD_ZDF_Onlinestudie_2021_Publikationscharts_final.pdf

Atorkey, P., Paul, C., Bonevski, B., Wiggers, J., Mitchell, A., Byrnes, E., Lecathelinais, C., & Tzelepis, F. (2021). Uptake of proactively offered online and telephone support services targeting multiple health risk behaviors among vocational education students: Process evaluation of a cluster randomized controlled trial. *Journal of Medical Internet Research*, *23*(1), Article e19737. https://doi.org/10.2196/19737

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice Hall.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior*, *31*(2), 143-164. https://doi.org/10.1177/1090198104263660

Bantham, A., Taverno Ross, S. E., Sebastiao, E., & Hall, G. (2021). Overcoming barriers to physical activity in underserved populations. *Progress in Cardiovascular Diseases*, *64*, 64-71. https://doi.org/10.1016/j.pcad.2020.11.002

Barha, C. K., Davis, J. C., Falck, R. S., Nagamatsu, L. S., & Liu-Ambrose, T. (2017). Sex differences in exercise efficacy to improve cognition: A systematic review and meta-analysis of randomized controlled trials in older humans. *Frontiers in Neuroendocrinology*, *46*, 71-85. https://doi.org/10.1016/j.yfrne.2017.04.002

Belton, S., Breslin, G., Shannon, S., O'Brien, W., Fitzpatrick, B., Haughey, T., Chambers, F., Powell, D., McCullagh, D., & Brennan, D. (2019). Every minute counts: Patterns and times of physical activity participation in children from socially disadvantaged areas in Ireland. *Journal of Physical Activity and Health*, *16*(5), 333-339. https://doi.org/10.1123/jpah.2018-0368

Belton, S., O'Brien, W., Wickel, E. E., & Issartel, J. (2013). Patterns of noncompliance in adolescent field-based accelerometer research. *Journal of Physical Activity and Health*, *10*(8), 1181-1185. https://doi.org/10.1123/jpah.10.8.1181

Belvederi Murri, M., Ekkekakis, P., Magagnoli, M., Zampogna, D., Cattedra, S., Capobianco, L., Serafini, G., Calcagno, P., Zanetidou, S., & Amore, M. (2019). Physical Exercise in Major

Depression: Reducing the Mortality Gap While Improving Clinical Outcomes. *Frontiers in Psychiatry*, *9*, Article 762. https://doi.org/10.3389/fpsyt.2018.00762

Bennett, G. G., & Glasgow, R. E. (2009). The delivery of public health interventions via the internet: Actualizing their potential. *Annual Review of Public Health*, *30*, 273-292. https://doi.org/10.1146/annurev.publhealth.031308.100235

Blondell, S. J., Hammersley-Mather, R., & Veerman, J. L. (2014). Does physical activity prevent cognitive decline and dementia?: A systematic review and meta-analysis of longitudinal studies. *BioMed Central Public Health*, *14*, Article 510. https://doi.org/https://doi.org/10.1186/1471-2458-14-510

Bokolo, A. J. (2021). Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic. *Health and Technology*, *11*(2), 359-366. https://doi.org/10.1007/s12553-020-00516-4

Bonevski, B., Randell, M., Paul, C., Chapman, K., Twyman, L., Bryant, J., Brozek, I., & Hughes, C. (2014). Reaching the hard-to-reach: A systematic review of strategies for improving health and medical research with socially disadvantaged groups. *BioMed Central Medical Research Methodology*, *14*, Article 42. https://doi.org/10.1186/1471-2288-14-42

Boogerd, E. A., Arts, T., Engelen, L. J., & van de Belt, T. H. (2015). "What Is eHealth": Time for an update? *Journal of Medical Internet Research Research Protocols*, *4*(1), Article e29. https://doi.org/10.2196/resprot.4065

Brown, M., Dijkers, M. P., Gordon, W. A., Ashman, T., Charatz, H., & Cheng, Z. (2004). Participation objective, participation subjective: a measure of participation combining outsider and insider perspectives. *The Journal of Head Trauma Rehabilitation*, *19*(6), 459-481. https://doi.org/10.1097/00001199-200411000-00004

Camino, J., & Mioshi, E. (2017). Assessment of functional abilities in older adults (BADLs, IADLs). In N. A. Pachana (Ed.), *Encyclopedia of Geropsychology*. Springer. https://doi.org/https://doi.org/10.1007/978-981-287-082-7_266

Ceci, L. (2021 November, 12). *Mobile app usage in Europe - Statistics & Facts*. Statista. https://www.statista.com/topics/8693/mobile-app-usage-in-europe/#dossierContents__outerWrapper

Chekroud, S. R., Gueorguieva, R., Zheutlin, A. B., Paulus, M., Krumholz, H. M., Krystal, J. H., & Chekroud, A. M. (2018). Association between physical exercise and mental health in 1.2 million individuals in the USA between 2011 and 2015: A cross-sectional study. *Lancet Psychiatry*, *5*(9), 739-746. https://doi.org/10.1016/S2215-0366(18)30227-X

Choi, H. K., & Lee, S. H. (2021). Trends and effectiveness of ICT interventions for the elderly to reduce loneliness: A systematic review. *Healthcare*, *9*(3), Article 293. https://doi.org/10.3390/healthcare9030293

Condello, G., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Simon, C., Ciarapica, D., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P., Jaeschke, L., . . . Boccia, S. (2017). Behavioral determinants of physical activity across the life course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) umbrella systematic literature review. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), Article 58. https://doi.org/10.1186/s12966-017-0510-2

Cornejo Mueller, A., Wachtler, B., & Lampert, T. (2020). Digital Divide – Soziale Unterschiede in der Nutzung digitaler Gesundheitsangebote. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz*, *63*(2), 185-191. https://doi.org/10.1007/s00103-019-03081-y

Cotie, L. M., Prince, S. A., Elliott, C. G., Ziss, M. C., McDonnell, L. A., Mullen, K. A., Hiremath, S., Pipe, A. L., Reid, R. D., & Reed, J. L. (2018). The effectiveness of eHealth interventions on physical activity and measures of obesity among working-age women: A systematic review and meta-analysis. *Obesity Reviews*, *19*(10), 1340-1358. https://doi.org/10.1111/obr.12700

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2013). Developing and evaluating complex interventions: the new Medical Research Council guidance. *International Journal of Nursing Studies*, *50*(5), 587-592. https://doi.org/10.1016/j.ijnurstu.2012.09.010

Davies, C. A., Spence, J. C., Vandelanotte, C., Caperchione, C. M., & Mummery, W. K. (2012). Meta-analysis of internet-delivered interventions to increase physical activity levels. *International Journal of Behavioral Nutrition and Physical Activity*, *9*, Article 52. https://doi.org/10.1186/1479-5868-9-52

De Cocker, K., De Bourdeaudhuij, I., Brown, W., & Cardon, G. (2009). Moderators and mediators of pedometer use and step count increase in the "10,000 Steps Ghent" intervention. *The International Journal of Behavioral Nutrition and Physical Activity*, *6*, Article 3. https://doi.org/10.1186/1479-5868-6-3

Degenhard, J. (2021 August, 23). *Forecast of the smartphone penetration in Europe from 2010 to 2025*. Statista. https://www.statista.com/forecasts/1147144/smartphone-penetration-forecast-in-europe

Devereux-Fitzgerald, A., Powell, R., Dewhurst, A., & French, D. P. (2016). The acceptability of physical activity interventions to older adults: A systematic review and meta-synthesis. *Social Science & Medicine*, *158*, 14-23. https://doi.org/10.1016/j.socscimed.2016.04.006

Di Lorito, C., van der Wardt, V., O'Brien, R., Gladman, J., Masud, T., & Harwood, R. H. (2022). Impact of COVID-19 lockdown on physical exercise among participants receiving the Promoting Activity, Independence and Stability in Early Dementia (PrAISED) intervention: A repeated measure study. *BioMed Central Geriatrics*, *22*(1), Article 605. https://doi.org/10.1186/s12877-022-03239-5

Du, H., Newton, P. J., Salamonson, Y., Carrieri-Kohlman, V. L., & Davidson, P. M. (2009). A review of the six-minute walk test: its implication as a self-administered assessment tool. *European Journal of Cardiovascular Nursing*, *8*(1), 2-8. https://doi.org/10.1016/j.ejcnurse.2008.07.001

Duan, Y., Shang, B., Liang, W., Du, G., Yang, M., & Rhodes, R. E. (2021). Effects of eHealth-based multiple health behavior change interventions on physical activity, healthy diet, and weight in people with non-communicable diseases: Systematic review and meta-analysis. *Journal of Medical Internet Research*, *23*(2), Article e23786. https://doi.org/10.2196/23786

Duncan, S., Stewart, T., Mackay, L., Neville, J., Narayanan, A., Walker, C., Berry, S., & Morton, S. (2018). Wear-time compliance with a dual-accelerometer system for capturing 24-h behavioural profiles in children and adults. *International Journal of Environmental Research and Public Health*, *15*(7), Article 1296. https://doi.org/10.3390/ijerph15071296

Ekelund, U., Tomkinson, G., & Armstrong, N. (2011). What proportion of youth are physically active? Measurement issues, levels and recent time trends. *British Journal of Sports Medicine 45*(11), 859-865. https://doi.org/10.1136/bjsports-2011-090190

Eldridge, S. M., Lancaster, G. A., Campbell, M. J., Thabane, L., Hopewell, S., Coleman, C. L., & Bond, C. M. (2016). Defining feasibility and pilot studies in preparation for randomised controlled trials: Development of a conceptual framework. *PloS One*, *11*(3), Article e0150205. https://doi.org/10.1371/journal.pone.0150205

Elgar, F. J., Pfortner, T. K., Moor, I., De Clercq, B., Stevens, G. W., & Currie, C. (2015). Socioeconomic inequalities in adolescent health 2002-2010: A time-series analysis of 34 countries participating in the health behaviour in school-aged children study. *Lancet*, *385*(9982), 2088-2095. https://doi.org/10.1016/S0140-6736(14)61460-4

El-Kotob, R., & Giangregorio, L. M. (2018). Pilot and feasibility studies in exercise, physical activity, or rehabilitation research. *Pilot and Feasibility Studies*, *4*, Article 137. https://doi.org/10.1186/s40814-018-0326-0

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), Article e20. https://doi.org/10.2196/jmir.3.2.e20

Far, I. K., Ferron, M., Ibarra, F., Baez, M., Tranquillini, S., Casati, F., & Doppio, N. (2015). The interplay of physical and social wellbeing in older adults: Investigating the relationship between physical training and social interactions with virtual social environments. *PeerJ Computer Science*, *1*(7), Article e30. https://doi.org/ 10.7717/peerj-cs.30

Franceschi, R., Fornari, E., Ghezzi, M., Buzzi, E., Toschi, M., Longhi, S., Maimone, R., Forti, S., Carneri, S., Pirous, F. M., Agostini, B., Iori, T., Gibin, M., Porchia, S., Soffiati, M., & Maffeis, C. (2021). Educational intervention of healthy life promotion for children with a migrant background or at socioeconomic disadvantage in the north of Italy: Efficacy of telematic tools in improving nutritional and physical activity knowledge. *Nutrients*, *13*(10), Article 3634. https://doi.org/10.3390/nu13103634

Franco, M. R., Tong, A., Howard, K., Sherrington, C., Ferreira, P. H., Pinto, R. Z., & Ferreira, M. L. (2015). Older people's perspectives on participation in physical activity: A systematic review and thematic synthesis of qualitative literature. *British Journal of Sports Medicine*, *49*(19), 1268-1276. https://doi.org/10.1136/bjsports-2014-094015

GBD 2017 Diet Collaborators. (2019). Health effects of dietary risks in 195 countries, 1990–2017: A systematic analysis for the global burden of disease study 2017. *The Lancet*, *393*(10184), 1958-1972. https://doi.org/10.1016/S0140-6736(19)30041-8

Geyer, S. (2008). Einzelindikator oder Index? Maße sozialer Differenzierung im Vergleich. *Das Gesundheitswesen*, *70*(5), 281-288. https://doi.org/10.1055/s-2008-1078722

Geyer, S. (2021, November 16). *Soziale Ungleichheit und Gesundheit/Krankheit*. Bundeszentrale für gesundheitliche Aufklärung. https://leitbegriffe.bzga.de/alphabetisches-verzeichnis/soziale-ungleichheit-und-gesundheitkrankheit/

Geyer, S., Eberhard, S., Schmidt, B. M. W., Epping, J., & Tetzlaff, J. (2018). Morbidity compression in myocardial infarction 2006 to 2015 in terms of changing rates and age at occurrence: A longitudinal study using claims data from Germany. *PLoS One*, *13*(8), Article e0202631. https://doi.org/10.1371/journal.pone.0202631

Gomes, M., Figueiredo, D., Teixeira, L., Poveda, V., Paúl, C., Santos-Silva, A., & Costa, E. (2017). Physical inactivity among older adults across Europe based on the SHARE database. *Age and Ageing*, *46*(1), 71-77. https://doi.org/10.1093/ageing/afw165

Goodyear, V. A., Wood, G., Skinner, B., & Thompson, J. L. (2021). The effect of social media interventions on physical activity and dietary behaviours in young people and adults: A systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), Article 72. https://doi.org/10.1186/s12966-021-01138-3

Gruene, E., Popp, J., Carl, J., Semrau, J., & Pfeifer, K. (2022). Examining the sustainability and effectiveness of co-created physical activity interventions in vocational education and training: a multimethod evaluation. *BioMed Central Public Health*, *22*(1), Article 765. https://doi.org/10.1186/s12889-022-13133-9

Guenther, L., Osterhoff, A., Sommer, S., Thiel, C., & Grueneberg, C. (2022). Quartier agil - aktiv vor Ort: Praxishandbuch zur Durchführung eines kombinierten, quartiersbezogenen Trainingsprogrammes für ältere Menschen [Supplement]. *Zenodo*. https://doi.org/10.5281/zenodo.6998000

Guenther, L., & Pischke, C. R. (2021). A scoping review protocol to map the evidence regarding the effectiveness of social media-based interventions for the promotion of physical activity [Supplement]. https://osf.io/v9dxj

Guenther, L., & Pischke, C. R. (2021, 12th-14th October). A social media-based physical activity intervention targeting socially disadvantaged young adults: Pilot study [conference poster]. 8th International Society for Physical Activity and Health (ISPAH) Congress, Vancouver, Canada.

Guenther, L., Schleberger, S., & Pischke, C. R. (2021a). Effectiveness of Social Media-Based Interventions for the Promotion of Physical Activity: Scoping Review. *International Journal of Environmental Research and Public Health*, *18*(24), Article 13018. https://doi.org/10.3390/ijerph182413018

Guenther, L., Schleberger, S., & Pischke, C. R. (2021b). Effectiveness of social media-based interventions for the promotion of physical activity: Scoping review [Supplement]. *International Journal of Environmental Research and Public Health*, *18*(24), Article 13018. https://www.mdpi.com/article/10.3390/ijerph182413018/s1

Guenther, L., Schleberger, S., & Pischke, C. R. (2022, 31st August-2nd September). Effectiveness of social media-based interventions for the promotion of physical activity: Scoping review [conference poster]. 7th annual meeting and 11th conference of HEPA Europe, Nice, France.

Guenther, L., Schleberger, S., & Pischke, C. R. (2022). Feasibility of a social network-based physical activity intervention targeting vocational school students: A pilot study. *International Journal of Environmental Research and Public Health*, *19*(15), Article 9474. https://doi.org/10.3390/ijerph19159474

Guenther, L., Schleberger, S., & Pischke, C. R. (2022, 9th-12th November). Feasibility of a social network-based physical activity intervention targeting vocational students [conference poster]. 15th European Public Health Conference, Berlin, Germany.

Guthold, R., Stevens, G. A., Riley, L.M., & Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: A pooled analysis of 358 population-based surveys with 1,9 million participants. *The Lancet Global Health, 6*(10), Article e1077–86. https://doi.org/10.1016/S2214-109X(18)30357-7

Guthold, R., Stevens, G.A., Riley, L.M., & Bull, F. C. (2020) Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1,6 million participants. *The Lancet Child & Adolescent Health, 4*(1) 23-35. https://doi.org/10.1016/S2352-4642(19)30323-2

Hankonen, N., Heino, M. T., Hynynen, S. T., Laine, H., Araujo-Soares, V., Sniehotta, F. F., Vasankari, T., Sund, R., & Haukkala, A. (2017). Randomised controlled feasibility study of a school-based multi-level intervention to increase physical activity and decrease sedentary behaviour among vocational school students. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*, Article 37. https://doi.org/10.1186/s12966-017-0484-0

Harvey, J. A., Chastin, S. F. M., & Skelton, D. A. (2015). How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging and Physical Activity*, *23*(3), 471-487. https://doi.org/10.1123/japa.2014-0164

Hashidate, H., Shimada, H., Fujisawa, Y., & Yatsunami, M. (2021). An overview of social participation in older adults: Concepts and sssessments. *Physical Therapy Research*, *24*(2), 85-97. https://doi.org/10.1298/ptr.R0013

Heponiemi, T., Jormanainen, V., Leemann, L., Manderbacka, K., Aalto, A.-M., & Hyppönen, H. (2020). Digital divide in perceived benefits of online health care and social welfare services: National cross-sectional survey study. *Journal of Medical Internet Research*, *22*(7), Article e17616. https://doi.org/10.2196/17616

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S. E., Dixon-Woods, M., McCulloch, P., Wyatt, J. C., Chan, A. W., & Michie, S. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal*, *348*, Article g1687. https://doi.org/10.1136/bmj.g1687

Hosseinpour, M., & Terlutter, R. (2019). Your personal motivator is with you: A systematic review of mobile phone applications aiming at increasing physical activity. *Sports Medicine*, *49*(9), 1425-1447. https://doi.org/10.1007/s40279-019-01128-3

Howe, K. B., Suharlim, C., Ueda, P., Howe, D., Kawachi, I., & Rimm, E. B. (2016). Gotta catch'em all! Pokémon GO and physical activity among young adults: difference in differences study. *British Medical Journal*, *355*, Article i6270. https://doi.org/10.1136/bmj.i6270

Institute for Health Metrics and Evaluation. (n.d.). *Results from the 2019 Global Burden of Disease (GBD) study*. Retrieved June 06, 2022, from https://vizhub.healthdata.org/gbd-results/

Israel, B. A., & Schurman, S. J. (1990). Social support, control, and the stress process. In K. Glanz, F. M. Lewis, & B. K. Rimer (Eds.), *Health behavior and health education: theory, research, and practice* (pp. 187–215). Jossey-Bass Publishers.

Jaeschke, L., Steinbrecher, A., Luzak, A., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Chantal, S., Ciarapica, D., Condello, G., Coppinger, T., Cortis, C., De Craemer, M., D'Haese, S., Di Blasio, A., Hansen, S., Iacoviello, L., . . . Pischon, T. (2017). Socio-cultural determinants of physical activity across the life course: A 'Determinants of Diet and Physical Activity' (DEDIPAC) umbrella systematic literature review. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), Article 173. https://doi.org/10.1186/s12966-017-0627-3

Kaba-Schönstein, L., & Kilian, H. (2018, June 15). *Gesundheitsförderung und soziale Benachteiligung/ Gesundheitsförderung und gesundheitliche Chancengleichheit*. Bundeszentrale für gesundheitliche Aufklärung. https://leitbegriffe.bzga.de/alphabetisches-verzeichnis/gesundheitsfoerderung-und-soziale-benachteiligung-gesundheitsfoerderung-und-gesundheitliche-chanceng/

Kaihlanen, A. M., Virtanen, L., Buchert, U., Safarov, N., Valkonen, P., Hietapakka, L., Horhammer, I., Kujala, S., Kouvonen, A., & Heponiemi, T. (2022). Towards digital health equity - a qualitative study of the challenges experienced by vulnerable groups in using digital health services in the COVID-19 era. *BioMed Central Health Services Research*, *22*(1), Article 188. https://doi.org/10.1186/s12913-022-07584-4

Kandola, A., Vancampfort, D., Herring, M., Rebar, A., Hallgren, M., Firth, J., & Stubbs, B. Moving to beat anxiety: Epidemiology and therapeutic issues with physical activity for anxiety. (2018). *Current Psychiatry Reports, 20*(8), Article 63. https://doi.org/10.1007/s11920-018-0923-x

Kebede, M., Steenbock, B., Helmer, S. M., Sill, J., Mollers, T., & Pischke, C. R. (2018). Identifying evidence-informed physical activity apps: Content analysis. *Journal of Medical Internet Research mHealth and uHealth*, *6*(12), Article e10314. https://doi.org/10.2196/10314

Kontos, E., Blake, K. D., Chou, W. Y., & Prestin, A. (2014). Predictors of eHealth usage: insights on the digital divide from the Health Information National Trends Survey 2012. *Journal of Medical Internet Research*, *16*(7), e172. https://doi.org/10.2196/jmir.3117

Krebs, P., Prochaska, J. O., & Rossi, J. S. (2010). Defining what works in tailoring: A meta-analysis of computer-tailored interventions for health behavior change. *Preventive Medicine 51*(3-4), 214-221. https://doi.org/10.1016/j.ypmed.2010.06.004

Kuipers, A., Kloek, G. C., & de Vries, S. I. (2021). Understanding vocational students' motivation for dietary and physical activity behaviors. *International Journal of Environmental Research and Public Health*, *18*(4), Article 1381. https://doi.org/10.3390/ijerph18041381

Kwan, R. Y., Lee, D., Lee, P. H., Tse, M., Cheung, D. S., Thiamwong, L., & Choi, K. S. (2020). Effects of an mHealth brisk walking intervention on increasing physical activity in older people with cognitive frailty: Pilot randomized controlled trial. *Journal of Medical Internet Research mHealth and uHealth*, *8*(7), Article e16596. https://doi.org/10.2196/16596

Kwan, R. Y. C., Salihu, D., Lee, P. H., Tse, M., Cheung, D. S. K., Roopsawang, I., & Choi, K. S. (2020). The effect of e-health interventions promoting physical activity in older people: a systematic review and meta-analysis. *European Review of Aging and Physical Activity*, *17*, Article 7. https://doi.org/10.1186/s11556-020-00239-5

Lambert, J. D., Greaves, C. J., Farrand, P., Price, L., Haase, A. M., & Taylor, A. H. (2018). Web-based intervention using behavioral activation and physical activity for adults with depression (The eMotion study): Pilot randomized controlled trial. *Journal of Medical Internet Research*, *20*(7), Article e10112. https://doi.org/10.2196/10112

Latulippe, K., Hamel, C., & Giroux, D. (2017). Social health inequalities and eHealth: A literature review with qualitative synthesis of theoretical and empirical studies. *Journal of Medical Internet Research*, *19*(4), Article e136. https://doi.org/10.2196/jmir.6731

Lawler, M., Heary, C., & Nixon, E. (2020). Peer support and role modelling predict physical activity change among adolescents over twelve months. *Journal of Youth and Adolescence*, *49*(7), 1503-1516. https://doi.org/10.1007/s10964-019-01187-9

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working Group. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*, *380*(9838), 219-229. https://doi.org/10.1016/S0140-6736(12)61031-9

Lippke, S., Ratz, T., Keller, F. M., Juljugin, D., Peters, M., Pischke, C., & Voelcker-Rehage, C. (2022). Mitigating feelings of loneliness and depression by means of web-based or print-based physical activity interventions: Pooled analysis of 2 community-based intervention trials. *Journal of Medical Internet Research Aging*, *5*(3), e36515. https://doi.org/10.2196/36515

Lonsdale, C., Lester, A., Owen, K. B., White, R. L., Peralta, L., Kirwan, M., Diallo, T. M. O., Maeder, A. J., Bennie, A., MacMillan, F., Kolt, G. S., Ntoumanis, N., Gore, J. M., Cerin, E., Cliff, D. P., & Lubans, D. R. (2019). An internet-supported school physical activity intervention in low socioeconomic status communities: results from the Activity and Motivation in Physical Education (AMPED) cluster randomised controlled trial. *British Journal of Sports Medicine*, *53*(6), 341-347. https://doi.org/10.1136/bjsports-2017-097904

Maher, C., Ferguson, M., Vandelanotte, C., Plotnikoff, R., De Bourdeaudhuij, I., Thomas, S., Nelson-Field, K., & Olds, T. (2015). A web-based, social networking physical activity intervention for insufficiently active adults delivered via Facebook app: Randomized controlled trial. *Journal of Medical Internet Research*, *17*(7), Article e174. https://doi.org/10.2196/jmir.4086

Matos Fialho, P. M., Guenther, L., Schmitz, E., Truemmler, J., Willemsen, S., Vomhof, M., Icks, A., Lang, A., Kuss, O., Weyers, S., & Pischke, C. R. (2022). Effects of the population-based "10,000 Steps Duesseldorf" intervention for promoting physical activity in community-dwelling adults: Protocol for a nonrandomized controlled trial. *Journal of Medical Internet Research Research Protocols*, *11*(9), e39175. https://doi.org/10.2196/39175

McDermott, A., Haberlin, C., & Moran, J. (2021). The use of eHealth to promote physical activity in people living with Parkinson's disease: A systematic review. *Physiotherapy Practice and Research*, *42*(8), 79-92. https://doi.org/http://dx.doi.org/10.3233/PPR-200474

McGarrigle, L., & Todd, C. (2020). Promotion of physical activity in older people using mHealth and eHealth technologies: Rapid review of reviews. *Journal of Medical Internet Research*, *22*(12), Article e22201. https://doi.org/10.2196/22201

McKay, H., Nettlefold, L., Bauman, A., Hoy, C., Gray, S. M., Lau, E., & Sims-Gould, J. (2018). Implementation of a co-designed physical activity program for older adults: positive impact when delivered at scale. *BioMed Central Public Health*, *18*(1), Article 1289. https://doi.org/10.1186/s12889-018-6210-2

McKeon, G., Papadopoulos, E., Firth, J., Joshi, R., Teasdale, S., Newby, J., & Rosenbaum, S. (2022). Social media interventions targeting exercise and diet behaviours in people with non-communicable diseases (NCDs): A systematic review. *Internet Interventions*, *27*, Article 100497. https://doi.org/10.1016/j.invent.2022.100497

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly*, *15*(4), 351-377. https://doi.org/10.1177/109019818801500401

Mendoza-Vasconez, A. S., Linke, S., Munoz, M., Pekmezi, D., Ainsworth, C., Cano, M., Williams, V., Marcus, B. H., & Larsen, B. A. (2016). Promoting physical activity among underserved populations. *Current Sports Medicine Report*, *15*(4), 290-297. https://doi.org/10.1249/JSR.0000000000000276

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: A Publication of the Society of Behavioral Medicine*, *46*(1), 81-95. https://doi.org/10.1007/s12160-013-9486-6

Millett, E. R. C., Peters, S. A. E., & Woodward, M. (2018). Sex differences in risk factors for myocardial infarction: cohort study of UK Biobank participants. *British Medical Journal*, *363*, Article k4247. https://doi.org/10.1136/bmj.k4247

Moller, A. C., Merchant, G., Conroy, D. E., West, R., Hekler, E., Kugler, K. C., & Michie, S. (2017). Applying and advancing behavior change theories and techniques in the context of a digital health revolution: proposals for more effectively realizing untapped potential. *Journal of Behavioral Medicine*, *40*(1), 85-98. https://doi.org/10.1007/s10865-016-9818-7

Montague, J., & Haith-Cooper, M. (2021). A study to assess the feasibility of using a novel digital animation to increase physical activity levels in asylum seeking communities. *Health & Social Care in the Community*, *30*(5), 1960-1968. https://doi.org/10.1111/hsc.13575

Moore, L., Hallingberg, B., Wight, D., Turley, R., Segrott, J., Craig, P., Robling, M., Murphy, S., Simpson, S. A., & Moore, G. (2018). Exploratory studies to inform full-scale evaluations of complex public health interventions: the need for guidance. *Journal of Epidemiology and Community Health*, *72*(10), 865-866. https://doi.org/10.1136/jech-2017-210414

Moorhead, S. A., Hazlett, D. E., Harrison, L., Carroll, J. K., Irwin, A., & Hoving, C. (2013). A new dimension of health care: systematic review of the uses, benefits, and limitations of social media for health communication. *Journal of Medical Internet Research*, *15*(4), Article e85. https://doi.org/10.2196/jmir.1933

Mueller, A. M., Maher, C. A., Vandelanotte, C., Hingle, M., Middelweerd, A., Lopez, M. L., DeSmet, A., Short, C. E., Nathan, N., Hutchesson, M. J., Poppe, L., Woods, C. B., Williams, S. L., & Wark, P. A. (2018). Physical activity, sedentary behavior, and diet-related eHealth and mHealth research: Bibliometric analysis. *Journal of Medical Internet Research*, *20*(4), Article e122. https://doi.org/10.2196/jmir.8954

Nahum-Shani, I., Hekler, E. B., & Spruijt-Metz, D. (2015). Building health behavior models to guide the development of just-in-time adaptive interventions: A pragmatic framework. *Health Psychology*, *34*(0), 1209-1219. https://doi.org/10.1037/hea0000306

Norman, C. D., & Skinner, H. A. (2006). eHealth Literacy: Essential skills for consumer health in a networked world. *Journal of Medical Internet Research*, *8*(2), Article e9. https://doi.org/10.2196/jmir.8.2.e9

Nyman, S. R., Adamczewska, N., & Howlett, N. (2018). Systematic review of behaviour change techniques to promote participation in physical activity among people with dementia. *British Journal of Health Psychology*, *23*(1), 148-170. https://doi.org/10.1111/bjhp.12279

Oh, H., Rizo, C., Enkin, M., & Jadad, A. (2005). What is eHealth (3): A systematic review of published definitions. *Journal of Medical Internet Research*, *7*(1), Article e1. https://doi.org/10.2196/jmir.7.1.e1

Olander, E. K., Fletcher, H., Williams, S., Atkinson, L., Turner, A., & French, D. P. (2013). What are the most effective techniques in changing obese individuals' physical activity self-efficacy and behaviour: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *10*, Article 29. https://doi.org/10.1186/1479-5868-10-29

Park, S. H. (2018). Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. *Aging Clinical and Experimental Research*, *30*(1), 1-16. https://doi.org/10.1007/s40520-017-0749-0

Pearson, N., Naylor, P. J., Ashe, M. C., Fernandez, M., Yoong, S. L., & Wolfenden, L. (2020). Guidance for conducting feasibility and pilot studies for implementation trials. *Pilot and Feasibility Studies*, *6*(1), Article 167. https://doi.org/10.1186/s40814-020-00634-w

Peeters, M., Zondervan-Zwijnenburg, M., Vink, G., & van de Schoot, R. (2015). How to handle missing data: A comparison of different approaches. *European Journal of Developmental Psychology*, *12*(4), 377-394. https://doi.org/https://doi.org/10.1080/17405629.2015.1049526

Peters, M. D., Godfrey, C. M., Khalil, H., McInerney, P., Parker, D., & Soares, C. B. (2015). Guidance for conducting systematic scoping reviews. *International journal of evidence-based healthcare*, *13*(3), 141-146. https://doi.org/10.1097/XEB.0000000000000050

Petersen, J. M., Prichard, I., & Kemps, E. (2019). A Comparison of physical activity mobile apps with and without existing web-based social networking platforms: Systematic review. *Journal of Medical Internet Research*, *21*(8), Article e12687. https://doi.org/10.2196/12687

Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., Carlin, A., Chantal, S., Ciarapica, D., Condello, G., Coppinger, T., Cortis, C., D'Haese, S., De Craemer, M., Di Blasio, A., Hansen, S., Iacoviello, L., Issartel, J., Izzicupo, P., Jaeschke, L., . . . Boccia, S. (2017). Policy determinants of physical activity across the life course: a 'DEDIPAC' umbrella systematic literature review. *European Journal of Public Health*, *28*(1), 105-118. https://doi.org/10.1093/eurpub/ckx174

Putland, C., Baum, F., Ziersch, A., Arthurson, K., & Pomagalska, D. (2013). Enabling pathways to health equity: developing a framework for implementing social capital in practice. *BioMed Central Public Health*, *13*, Article 517. https://doi.org/10.1186/1471-2458-13-517

Reik, R., Woll, A., Gröben, F., & Berndt, E. D. (2010). Betriebliche Gesundheitsförderung in der Ausbildung. Wie verändert sich der Lebensstil der Jugendlichen über einen zweijährigen Ausbildungszeitraum und welchen Beitrag kann ein Azubi-Fit Programm leisten? *Arbeitsmedizin, Sozialmedizin, Umweltmedizin*, *45*, 640-646.

Rimmer, J. H., Wilroy, J., Galea, P., Jeter, A., & Lai, B. W. (2022). Retrospective evaluation of a pilot eHealth/ mHealth telewellness program for people with disabilities: Mindfulness, exercise, and nutrition to optimize resilience (MENTOR). *mHealth*, *8*, Article 15. https://doi.org/10.21037/mhealth-21-34

Robert Koch-Institut. (2008, October 30). *Gesundheitliche Folgen von Gewalt unter besonderer Berücksichtigung von häuslicher Gewalt gegen Frauen*. https://www.gbe-bund.de/pdf/gewalt.pdf

Robinson, L., Cotten, S. R., Ono, H., Quan-Haase, A., Mesch, G., Chen, W. H., Schulz, J., Hale, T. M., & Stern, M. J. (2015). Digital inequalities and why they matter. *Information Communication & Society*, *18*(5), 569-582. https://doi.org/10.1080/1369118x.2015.1012532

Rogers, W. A. (2004). Evidence based medicine and justice: a framework for looking at the impact of EBM upon vulnerable or disadvantaged groups. *Journal of Medical Ethics*, *30*(2), 141-145. https://doi.org/10.1136/jme.2003.007062

Rose, T., Barker, M., Maria Jacob, C., Morrison, L., Lawrence, W., Strommer, S., Vogel, C., Woods-Townsend, K., Farrell, D., Inskip, H., & Baird, J. (2017). A systematic review of digital interventions for improving the diet and physical activity behaviors of adolescents. *The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine*, *61*(6), 669-677. https://doi.org/10.1016/j.jadohealth.2017.05.024

Rosenbaum, S., Tiedemann, A., Sherrington, C., Curtis, J., & Ward, P. B. (2014). Physical activity interventions for people with mental illness: a systematic review and meta-analysis. *The Journal of Clinical Psychiatry*, *75*(9), 964-974. https://doi.org/10.4088/JCP.13r08765

Saez, L., Langlois, J., Legrand, K., Quinet, M. H., Lecomte, E., Omorou, A. Y., Briancon, S., & Group, P.-I. T. (2018). Reach and acceptability of a mobile reminder strategy and Facebook group intervention for weight management in less advantaged adolescents: Insights from the PRALIMAP-INES trial. *Journal of Medical Internet Research mHealth and uHealth*, *6*(5), Article e110. https://doi.org/10.2196/mhealth.7657

Salas-Gomez, D., Fernandez-Gorgojo, M., Pozueta, A., Diaz-Ceballos, I., Lamarain, M., Perez, C., Kazimierczak, M., & Sanchez-Juan, P. (2020). Physical activity is associated with better executive function in university students. *Frontiers in Human Neuroscience*, *14*, Article 11. https://doi.org/10.3389/fnhum.2020.00011

Salk, R. H., Hyde, J. S., & Abramson, L. Y. (2017). Gender differences in depression in representative national samples: Meta-analyses of diagnoses and symptoms. *Psychological Bulletin*, *143*(8), 783-822. https://doi.org/10.1037/bul0000102

Sampasa-Kanyinga, H., Colman, I., Goldfield, G. S., Janssen, I., Wang, J., Podinic, I., Tremblay, M. S., Saunders, T. J., Sampson, M., & Chaput, J. P. (2020). Combinations of physical activity, sedentary time, and sleep duration and their associations with depressive symptoms and other mental health problems in children and adolescents: a systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), Article 72. https://doi.org/10.1186/s12966-020-00976-x

Sandström, M., & Lundin-Olsson, L. (2007). Development and evaluation of a new questionnaire for rating perceived participation. *Clinical Rehabilitation*, *21*(9), 833-845. https://doi.org/10.1177/0269215507077278

Sawyer, A., Lewthwaite, H., Gucciardi, D. F., Hill, K., Jenkins, S., & Cavalheri, V. (2019). Behaviour change techniques to optimise participation in physical activity or exercise in adolescents and young adults with chronic cardiorespiratory conditions: A systematic review. *Internal Medicine Journal*, *49*(10), 1209-1220. https://doi.org/10.1111/imj.14141

Sebire, S. J., Banfield, K., Jago, R., Edwards, M. J., Campbell, R., Kipping, R., Blair, P. S., Kadir, B., Garfield, K., Matthews, J., Lyons, R. A., & Hollingworth, W. (2019). A process evaluation of the PLAN-A intervention (peer-led physical activity intervention for adolescent girls). *BioMed Central Public Health*, *19*(1), Article 1203. https://doi.org/10.1186/s12889-019-7545-z

Shaw, T., McGregor, D., Brunner, M., Keep, M., Janssen, A., & Barnet, S. (2017). What is eHealth (6)? Development of a conceptual model for eHealth: Qualitative study with key informants. *Journal of Medical Internet Research*, *19*(10), Article e324. https://doi.org/10.2196/jmir.8106

Short, C. E., James, E. L., Plotnikoff, R. C., & Girgis, A. (2011). Efficacy of tailored-print interventions to promote physical activity: A systematic review of randomised trials. *International Journal of Behavioral Nutrition and Physical Activity*, *8*, Article 113. https://doi.org/10.1186/1479-5868-8-113

Siegrist, J. (2021). *Gesundheit für alle? Die Herausforderung sozialer Ungleichheit*. Wbg Academic.

Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M., & Moore, L. (2021). A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *British Medical Journal*, *374*, Article n2061. https://doi.org/10.1136/bmj.n2061

Southard, V., Dave, M., Davis, M. G., Blanco, J., & Hofferber, A. (2005). The multiple tasks test as a predictor of falls in older adults. *Gait & Posture*, *22*(4), 351-355. https://doi.org/10.1016/j.gaitpost.2004.11.013

Statista Research Department. (2022). *Number of internet users in EU countries as of December 2020 (in millions)*. Statista. https://www.statista.com/statistics/252753/number-of-internet-users-eu-countries/#:~:text=Internet%20ac-cess%20in%20the%20EU%20Over%20the%20past,per-cent%20of%20all%20EU%20households%20had%20internet%20access

Statista Research Department. (2022). *Social Networks mit den meisten Nutzern weltweit 2022*. Statista. https://de.statista.com/statistik/daten/studie/181086/umfrage/die-weltweit-groessten-social-networks-nach-anzahl-der-user/

STEPN. (n.d). Retrieved September 07, 2022, from https://whitepaper.stepn.com/

Stodle, I. V., Debesay, J., Pajalic, Z., Lid, I. M., & Bergland, A. (2019). The experience of motivation and adherence to group-based exercise of Norwegians aged 80 and more: A qualitative study. *Archives of Public Health*, *77*(1), 26-37. https://doi.org/10.1186/s13690-019-0354-0

Stokols, D. (1996). Bridging the theoretical and applied facets of environmental psychology. *American Psychologist*, *51*(11), 1188-1189. https://doi.org/10.1037/0003-066X.51.11.1188

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., Salum, G. A., & Schuch, F. B. (2017). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Research*, *249*, 102-108. https://doi.org/10.1016/j.psychres.2016.12.020

Stubbs, B., Vancampfort, D., Smith, L., Rosenbaum, S., Schuch, F., & Firth, J. (2018). Physical activity and mental health. *Lancet Psychiatry*, *5*(11), 873. https://doi.org/10.1016/S2215-0366(18)30343-2

Thabane, L., Hopewell, S., Lancaster, G. A., Bond, C. M., Coleman, C. L., Campbell, M. J., & Eldridge, S. M. (2016). Methods and processes for development of a CONSORT extension for reporting pilot randomized controlled trials. *Pilot and Feasibility Studies*, *2*, Article 25. https://doi.org/10.1186/s40814-016-0065-z

Thabane, L., Ma, J., Chu, R., Cheng, J., Ismaila, A., Rios, L. P., Robson, R., Thabane, M., Giangregorio, L., & Goldsmith, C. H. (2010). A tutorial on pilot studies: the what, why and how. *Central Medical Research Methodology*, *10*, Article 1. https://doi.org/10.1186/1471-2288-10-1

Thiel, C., Günther, L., Osterhoff, A., Sommer, S., & Grüneberg, C. (2022). Feasibility of smartphone-supported, combined physical and cognitive activities in the neighbourhood for stimulating social participation of the elderly. *BioMed Central Geriatrics*, *22*(1), Article 629. https://doi.org/10.1186/s12877-022-03303-0

Tomioka, K., Kurumatani, N., & Hosoi, H. (2017). Association between social participation and 3-year change in instrumental activities of daily living in community-dwelling elderly adults. *Journal of the American Geriatrics Society*, *65*(1), 107-113. https://doi.org/10.1111/jgs.14447

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., Levac, D., Ng, C., Sharpe, J. P., Wilson, K., Kenny, M., Warren, R., Wilson, C., Stelfox, H. T., & Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BioMed Central Medical Research Methodology*, *16*, Article 15. https://doi.org/10.1186/s12874-016-0116-4

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., . . . Straus, S. E. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, *169*(7), 467-473. https://doi.org/10.7326/m18-0850

Trompette, J., Kivits, J., Minary, L., & Alla, F. (2020). Dimensions of the complexity of health interventions: What are we talking about? A review. *International Journal of Environmental Research and Public Health*, *17*(9), Article 3069. https://doi.org/10.3390/ijerph17093069

Tu, R. T., Hsieh, P., & Feng, W. T. (2018). Walking for fun or for "likes"? The impacts of different gamification orientations of fitness apps on consumers' physical activities. *Sport Management Review*, *22*(5), 682-693. https://doi.org/10.1016/j.smr.2018.10.005

U.S. Department of Health and Human Services. (1996). *Physical activity and health: A report of the surgeon general*. https://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf

Van Acker, R., De Bourdeaudhuij, I., De Cocker, K., Klesges, L. M., & Cardon, G. (2011). The impact of disseminating the whole-community project '10,000 Steps': A RE-AIM analysis. *BioMed Central Public Health*, *11*, Article 3. https://doi.org/10.1186/1471-2458-11-3

Vandenberghe, D., & Albrecht, J. (2020). The financial burden of non-communicable diseases in the European Union: A systematic review. European Journal of Public Health, 30(4), 833-839. https://doi.org/10.1093/eurpub/ckz073

Van Deursen, A. J. A. M., & Helsper, E. J. (2015). The third-level digital divide: who benefits most from being online? In L. Robinson, S. R. Cotten, J. Schulz, T. M. Hale, & A. Williams (Eds.), Communication and information technologies annual (Studies in media and communications; Vol. 10). Emerald Group Publishing Limited. https://doi.org/10.1108/S2050-206020150000010002

Van Deursen, A. J. A. M., Van Dijk, J.A.G.M. (2014). The digital divide shifts to differences in usage. *New Media & Society*, *16*(3), 507-526. https://doi.org/http://dx.doi.org/10.1177/1461444813487959

Van Dyck, D., D'Haese, S., Plaete, J., De Bourdeaudhuij, I., Deforche, B., & Cardon, G. (2019). Opinions towards physical activity interventions using Facebook or text messaging: Focus group interviews with vocational school-aged adolescents. *Health & Social Care in the Community*, *27*(3), 654-664. https://doi.org/10.1111/hsc.12679

Viswanath, K., & Kreuter, M. W. (2007). Health disparities, communication inequalities, and eHealth. *American Journal of Preventive Medicine*, *32*(5 Suppl), 131-133. https://doi.org/10.1016/j.amepre.2007.02.012

Vitak, J., & Ellison, N. B. (2013). 'There's a network out there you might as well tap': Exploring the benefits of and barriers to exchanging informational and support-based resources on Facebook. *New Media & Society* *15*(2), 243-259. https://doi.org/10.1177/1461444812451566

von Elm, E., Schreiber, G., & Haupt, C. C. (2019). Methodische Anleitung für Scoping Reviews (JBI-Methodologie). *Zeitschrift für Evidenz, Fortbildung und Qualität im Gesundheitswesen*, *143*, 1-7. https://doi.org/10.1016/j.zefq.2019.05.004

Wahid, A., Manek, N., Nichols, M., Kelly, P., Foster, C., Webster, P., Kaur, A., Friedemann Smith, C., Wilkins, E., Rayner, M., Roberts, N., & Scarborough, P. (2016). Quantifying the association between physical activity and cardiovascular disease and diabetes: A systematic review and meta-analysis. *Journal of the American Heart Association Cardiovascular and Cerebrovascular Disease*, *5*(9), Article e002495. https://doi.org/10.1161/JAHA.115.002495

Wang, C. K., Liu, W. C., Lochbaum, M. R., & Stevenson, S. J. (2009). Sport ability beliefs, 2 x 2 achievement goals, and intrinsic motivation: the moderating role of perceived competence in sport and exercise. *Research Quarterly for Exercise and Sport*, *80*(2), 303-312. https://doi.org/10.1080/02701367.2009.10599565

Wang, F. F., & Boros, S. (2021). The effect of physical activity on sleep quality: A systematic review. *European Journal of Physiotherapy*, *23*(1), 11-18. https://doi.org/10.1080/21679169.2019.1623314

Wei, K. K., Teo, H. H., Chan, H. C., & Tan, B. C. Y. (2011). Conceptualizing and testing a social cognitive model of the digital divide. *Information Systems Research* *22*(1), 170-187. https://doi.org/10.1287/isre.1090.0273

Weitz, T. A., Freund, K. M., & Wright, L. (2001). Identifying and caring for underserved populations: Experience of the national centers of excellence in women's health. *Journal of Women's Health & Gender Based Medicine*, *10*(10), 937-952. https://doi.org/https://doi.org/10.1089/152460901317193521

Western, M. J., Armstrong, M. E. G., Islam, I., Morgan, K., Jones, U. F., & Kelson, M. J. (2021). The effectiveness of digital interventions for increasing physical activity in individuals of low socioeconomic status: a systematic review and meta-analysis. *The International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), Article 148. https://doi.org/10.1186/s12966-021-01218-4

World Health Organization. (2018). *Global action plan on physical activity 2018–2030: More active people for a healthier world*. https://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf?ua=1

World Health Organization. (2019). *Risk Reduction of Cognitive Decline and Dementia: WHO Guidelines*. World Health Organization. https://www.who.int/publications/i/item/9789241550543

World Health Organization. (2020). *WHO guidelines on physical activity and sedentary behaviour*. https://apps.who.int/iris/rest/bitstreams/1315866/retrieve

World Health Organization. (2021). *Premature deaths due to noncommunicable diseases (NCD) as a proportion of all NCD deaths*. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/ncd-deaths-under-age-70-(percent-of-all-ncd-deaths)

World Medical Association. (2013, November 27). *Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects*. https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/

Zimmer, C., McDonough, M. H., Hewson, J., Toohey, A., Din, C., Crocker, P. R. E., & Bennett, E. V. (2021). Experiences with social participation in group physical activity programs for older adults. *Journal of Sport & Exercise Psychology*, *43*(4), 335-344. https://doi.org/10.1123/jsep.2020-0335

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), Article e0180902. https://doi.org/10.1371/journal.pone.018090

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"Gratitude is the memory of the heart" ~ Jean-Baptiste Massieu