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A video-based smartphone app ("VIDEA bewegt") for physical activity support in German adults, a single armed observational study

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ABSTRACT

Objectives

The primary objective of this study was to investigate the effect of the video-based smartphone app ('VIDEA bewegt') over eight program weeks on physical activity in German adults.

Design

The study used a single-arm observational design, assessing the app's effectiveness under real-life conditions. Data was collected from July 2019 to July 2020.

Setting

The app is enabling users to access video-based educational content via their smartphone. A clinical visit or in-person contact was not required.

Participants

All individuals registered in the app were invited to take part in the study.

Interventions

The app aims to increase physical activity in everyday life. It combines educative videos on life-style related benefits and instructional videos of strength and endurance exercises to do at home with motivational components like goal setting, documentation of progress, and personalized messages.

Primary and Secondary outcome measures

Primary outcomes were physical activity based one MET minutes per week (metabolic equivalent) and step numbers.

Secondary outcomes included physical self-efficacy (motivational, maintenance, recovery self-efficacy), health-related quality of life: MCS (mental health component summary score) and PCS (physical health component summary score).

Results

Of 97 people included in the data analysis, 55 successfully completed the program and all questionnaires. Significant increases over eight program weeks (between T0 and T2) were observed in physical activity based on MET-Minutes per week, health-related quality of life, and recovery self-efficacy. Time spent sitting and BMI significantly decreased for those completing the program.

Conclusions

Although significant benefits of physical activity were observed following a complete-case-analysis, results should be dealt with caution. Studies with a larger and less heterogeneous sample and robust study designs able to measure causal effects would be desirable.

Trial registration

German Clinical Trials Register (DRKS): Evaluation of an app-based activity intervention for statutory health insured people. DRKS-ID: DRKS00017392. (14 June 2019)

Strengths and limitations of this study

- The evaluation of the intervention is carried out under real-life conditions.
- Various approaches were used to describe the effects of the intervention.
- The small sample size, broad inclusion criteria for participation bias and a high dropout rate limit the internal validity.
- Due to its observational design and the absence of a control group and randomisation, this study can only provide limited data on how individual app components contributed to the overall effect of the app.
- Most data collected was based on self-assessment.

INTRODUCTION

Background

Non-communicable diseases are substantially caused by lifestyle-associated factors like insufficient physical activity [1]. In addition to non-communicable diseases, activity also influences quality of life and mental health [2]. To prevent chronic diseases like diabetes, it is recommended to promote physical activity across all age groups [3–6]. Effective strategies to increase motivation and reduce barriers for behaviour change require sustained efforts and ongoing support [7–9]. Behavioral change support by the use of smartphones in particular seems promising due to their widespread use and low barriers to participation uptake [10,11].

Smartphone app based interventions providing performance-related feedback, psychosocial networking and goal setting have been found to effectively increase physical activity [12–16]. Additionally, self-efficacy has been widely demonstrated to positively impact a range of health-promoting behavioral processes [17–19]. According to the Health Action Process Approach (HAPA), different subcomponents of self-efficacy can be distinguished [20]. Particularly decisive is the stability respectively variability of the subcomponents in the present study. Digital interventions have the unique potential to combine these effective strategies while keeping user acceptance high [21,22].

Despite these known components of successful behavior change, the generation of evidence in the field of digitally supported behavior change predominantly focused on apps developed in relation to scientific studies, rather than evaluating freely accessible apps [23,24]. As a result, despite the increasing number of health apps on the market, the minority of them is based on strong empirical and scientific evidence [10,25–28]. Scientific evaluations of available apps offer great potential for improving both present and future apps [29–31]. While studies show promising results on the effectiveness of these interventions to prevent [32] or successfully manage [6,33] chronic lifestyle-related diseases, e.g. by using videos for preventive purposes,[34] the strategies needed to achieve sustainable behavior change seem to have received little attention [12].

Reasons for the described limited evidence base of digital health apps include methodological challenges during evaluation. In order to guide evidence-based decision making, RCTs are regarded as highest level [35]. However, digital health interventions usually comprise multiple components and are mostly designed as modular interventions offering tailored as well as performance-based adaptations or feedback [36]. This may end up in circumstances where RCTs may not be feasible. As such, challenges including randomization, timing of assessment, acceptance by patients and physicians, blinding, as well as defining control groups and relevant endpoints need to be considered [37]. In addition to the described challenges during evaluation, limited guidance is available on the mid- to long term outcomes [38,39].

Therefore, the primary objective of this study was to investigate the effect of the video-based smartphone app (‘VIDEA bewegt’) over eight program weeks on physical activity (MET-minutes per Week and steps per day) in German adults. Secondary objectives were to analyse the associated changes in self-efficacy and health-related quality of life.

Hypotheses

The users of ‘VIDEA bewegt’ who participate in the study increase their average daily step count and achieve a higher number of metabolic equivalent (MET) minutes per week, a significantly higher health-related quality of life, a significantly higher motivational,

maintenance and recovery self-efficacy after the first four weeks, and after completion of the eight-week course, compared to the beginning of data collection.

MATERIALS AND METHODS

A detailed study protocol following important recommendations formulated by Eysenbach and the CONSORT-EHEALTH Group [40] was published prior to the data analysis [41].

Study design and summary of intervention

Data collection took place from July 2019 to July 2020. The evaluation of the app 'VIDEA bewegt' is designed as a single-arm observational study, assessing the app's effectiveness and usability under real-life conditions. The smartphone app 'VIDEA bewegt' is a video-based program to increase physical activity in everyday life. The app is divided into eight program weeks, each of which follows a consistent structure. The core of the app are four videos per program week. Theoretical videos explain and illustrate the importance of exercise and lifestyle, as well as ways to build up motivation. Practical videos present exercises to improve strength and endurance in a way which can be followed without the use of supplies. Additionally, motivational components such as goal setting, progress documentation, and personal messages are included. More extensive information can be found in the study protocol [41].

Setting

'VIDEA bewegt' is an app enabling users to access educational content via their smartphone anywhere and at any time. It was made available on the German market for Android and iOS in March 2019. Costs of the program are partially reimbursed by health insurance companies. Further information can be found on the German website [42].

A clinical visit or in-person contact with a physician or diabetes specialist was not required. However, it was possible to consult experts in preventative health care and sports science via an integrated chat function. Problems could also be discussed with other users and experts in a forum.

Participants

To register in the app, interested individuals had to be of legal age (≥ 18 years old) and declare that they were free of serious medical conditions such as heart failure. All registered individuals were invited to the study without further restriction.

Patient and public involvement

Potential participants were included in pretesting the questionnaires in order to assess their logic, understandability, and technical performance. A usability test with ten individuals provided insight in strengths and weaknesses of the app. Additionally, all study participants were asked to answer questions regarding their experience with the app's components. All data that made it possible to further optimize the app was forwarded to the developing company.

Procedure

App users interested in the study received an email and access to the first online questionnaire, which included the consent form and privacy policy. Individuals who completed the first questionnaire became study participants and received further questionnaires after completion of the fourth and eighth program weeks. In addition, internal app usage data including step counts were collected. For the analysis, three relevant time points were defined at which the individual outcome variables would be compared. The program start defined the time point T0, the program half the time point T1 and the program completion the time point T2. Participants received an email with a link to the online questionnaire at each time point. As such, data collection depended on participants' program usage. If a questionnaire was not completed after two days, the participants received a reminder. The study was conducted entirely digitally.

Outcomes

Primary outcomes were physical activity based one MET minutes per week (metabolic equivalent) and step numbers.

Secondary outcomes included physical self-efficacy (motivational, maintenance, recovery self-efficacy), health-related quality of life: MCS (mental health component summary score) and PCS (physical health component summary score).

To measure the outcome variables, validated measurement instruments were applied. The Global Physical Activity Questionnaire (GPAQ) was used to record MET minutes per week [43,44]. The assessment of health-related quality of life is based on the SF-8 questionnaire [45,46]. Self-efficacy was measured in the three dimensions of motivation self-efficacy, maintenance self-efficacy and recovery self-efficacy [47,48]. Step counts per day were entered into the app by the users themselves. For the comparison between T0 and T2, all persons were included who had entered their steps on at least 5 of 14 days at both start and end of the program. For the comparison between T0 and T1, all persons who had entered their steps on at least 3 of 7 days were included.

Statistical analyses

Sociodemographic data and user behaviour were analysed descriptively. The Shapiro-Wilk-Test was used to test for normal distribution. The hypotheses were tested using a one-sided Wilcoxon-Test for dependent samples at T0, T1 and T2 due to lack of normal distribution (see Table 3 – Statistical methods). A subgroup analysis was not conducted on account of the small sample size. Due to the exploratory nature of the data analysis, Bonferroni correction was omitted [49,50]. Instead, an exploratory analysis was added to separate individuals who completed the program and who showed an increase in activity.

Average values were calculated for the number of steps per day. For the comparison of T0 and T2, all persons were included who synchronized steps on at least 5 of 14 days at the beginning and end. For the comparison of T0 and T1, persons with at least three out of seven days of synchronization were included following the same method.

The analysis was conducted as a complete case analysis.

RESULTS

Description of the sample

During the data collection period, 1519 individuals registered with the app. Of those, 103 individuals (6,8%) followed the study invitation and completed the first questionnaire. Two people withdrew their participation during the survey, and four people were excluded from the analysis because of not completing the first questionnaire at the beginning of program use. Consequently, 97 people were included in the data analysis, 55 of whom successfully completed the program and all questionnaires (see Table 1).

Table 1 Characteristics of the study population

Overall n	97
Age mean (SD) in years	47.52 (13.52)
Sex	80 female (82%), 17 male (18%)
Body-Mass-Index median (IQR) in kg/m^2	26.26 (8.8)
Marital status	
Married	57
Living in stable relationship	15
Divorced, separated	10
Single	11
Widowed	3
Other	1
Level of education	
completed training	32

completed studies	35
high school	14
secondary school	13
other	4
Gainful employment	
full-time	49
half-time	16
retired	16
part-time employed	7
not employed	9
Other Sports courses[1]	
Yes	49
No	48
Other Health apps [2]	
Yes	30
No	67

Notes. 1 = Participation in sports courses, 2 = Use of other health apps in addition to the VIDEA program. SD=standard deviation, IQR=Interquartile range

The median duration of program use was 68 days (Interquartile range (IQR) 64 days). The female participants accounted for 82% of the participants.

Comparison of persons with and without program completion

A total of 42 out of 97 study participants had not completed the program, which resulted in 42 (43%) incomplete datasets. Due to the proportion of missing data exceeding 40%, imputation methods were not used [51].

Comparing the groups of persons with and without program completion, age, gender distribution and marital status did not differ substantially. In the group with program completion, the proportion of persons with a university degree was larger. The proportion of full-time employees was smaller resulting in a larger proportion of retired persons. In the group with program completion, the proportion of people who used additional health apps was smaller. BMI was also lower here, while health-related quality of life and physical activity did not differ.

Physical Activity

The hypothesis that physical activity increases significantly between program start and completion can be supported for MET minutes per week. In contrast, the hypothesis that there is a significant increase in MET minutes already within the first half of the program cannot be

confirmed (see Table 2). For the number of steps per day, neither a significant increase in the first half nor over the entire program time was detected.

Table 2 Primary outcome measures, using asymptomatic one-sided Wilcoxon-tests

	Median (IQR) n=55	T0 vs. T1	T1 vs. T2	T0 vs. T2
MET minutes per week	T0: 2400 (3140) T1: 2760 (4100) T2: 2640 (5680)	*z=-1.391, p=0.082, n=55, r=0.188*	*z=-1.778, p=0.038, n=55, r=0.240*	*z=-1.927, p=0.027, n=55, r=0.260*
Steps per day	T0: 7043 (4283), n=61 T1: 6820 (6590), n=39	*z=-0.470, p=0.638, n=31, r=0.084*		*z=-1.562, p=0.061, n=27, r=0.301*

IQR=Interquartile range, MET=metabolic equivalent, T0=program start, T1=program half, T2=program completion

Health related quality of life and Self-efficacy

The hypotheses that health-related quality of life based on the Physical Component Summary (PCS) and the Mental Component Summary (MCS) increases significantly in the first half of the program and over the entire program period can both be confirmed. Looking at self-efficacy, the formulated hypotheses can only be confirmed for recovery self-efficacy, where there was a significant increase over the entire program period. In contrast, there were no significant increases in motivational and maintenance self-efficacy (see Table 3).

Table 3 Primary outcome measures, using asymptomatic one-sided Wilcoxon-tests

	Median (IQR) n=55	T0 vs. T1	T1 vs. T2	T0 vs. T2
PCS	T0: 49.74 (13.06) T1: 51.80 (13.34) T2: 50.14 (9.33)	*z=-2.409, p=0.008, n=55, r=0.325*	*z=-1.694, p=0.045, n=55, r=0.228*	*z=-3.050, p=0.001, n=55, r=0.411*
MCS	T0: 47.80 (12.17) T1: 52.49 (8.09) T2: 52.31 (9.56)	*z=-3.599, p<0.001 n=55, r=0.485*	*z=-0.537, p=0.296, n=55, r=0.072*	*z=-3.484, p<0.001, n=55, r=0.470*
motivational self-efficacy	T0: 3.67 (1.00) T1: 3.67 (1.16) T2: 3.67 (1.66)	*z=-0.528, p=0.238, n=55, r=0.071*	*z=-0.421, p=0.737, n=55, r=0.057*	*z=-0.125, p=0.574, n=55, r=0.017*
maintenance self-efficacy	T0: 3.00 (1.00) T1: 3.00 (1.00) T2: 3.33 (1.33)	*z=-1.043, p=0.142, n=55, r=0.141*	*z=-0.592, p=0.289, n=55, r=0.08*	*z=-1.199, p=0.092, n=55, r=0.162*
recovery self-	T0: 3.00 (0.84)	*z=-0.368,*	*z=-2.075,*	*z=-1.850,*

efficacy	T1: 3.67 (1.00) T2: 4.00 (2.00)	*p=0.323,* n=55, *r=0.05*	*p=0.019, n*=55, *r=0.28*	*p=0.032, n*=55, *r=0.249*

IQR=Interquartile range, PCS=Physical Component Summary Score, MCS=Mental Component Summary Score, T0=program start (baseline), T1=program half, T2=program completion

Additional Analysis

In addition, to the main hypotheses described above, further calculations were performed using the data from the GPAQ and the general questionnaire.

In a first analysis, using only program completers with complete data sets (n=55), the Body Mass Index (BMI) was analyzed, which decreased significantly over the entire program period and between T1 and T2. Furthermore, the time participants spend sitting per day decreased significantly between T0 and T2 as well as T1 and T2. In addition to calculating MET minutes per week, the GPAQ also allows for an analysis of separate activity dimensions (work, transportation, and leisure). The analysis showed that activity during leisure time increased significantly, while activity at work and in transportation did not change significantly (see Table 4).

Because a large proportion of participants already reported high values of MET-minutes per week (>4000 MET-minutes per week) at T0 and were thus less likely to benefit from further increases in activity [52], the comparison between T0 and T2 was repeated for all individuals with baseline activity of less than 4000 MET-minutes per week. Results indicate a significant increase in activity for these participants with large effect sizes (see Table 4).

Table 4 – Additional analyses using asymptomatic two-sided Wilcoxon-tests

	Median (IQR)	T0 vs. T1	T1 vs. T2	T0 vs. T2
BMI in kg/m^2, n=55	T0: 25.51 (8.45) T1: 25.95 (8.54) T2: 24.91 (7.26)	*z=-0.010, p=0.992, r=0.001*	*z=-3.117, p=0.002, r=0.420*	*z=-2.445, p=0.014, r=0.330*
Time spent sitting in hours, n=55	T0: 6 (4) T1: 6 (4) T2: 5 (4)	*z=-0.420, p=0.675, r=0.091*	*z=-2.962, p=0.003, r=0.399*	*z=-2.472 p=0.013, r=0.333*
Active minutes in leisure time in minutes per day, n=55	T0: 25.71 (22.86) T1: 27.31 (30.00) T2: 31.43 (51.43)	*z=-3.053, p=0.002, r=0.412*	*z=-1.171, p=0.242, r=0.158*	*z=-2.898, p=0.004, r=0.391*
Active minutes at work, in minutes per day, n=55	T0: 12.86 (64.29) T1: 21.43 (85.71) T2: 14.29 (100.00)	*z=-0.314, p=0.753, r=0.042*	*z=-0.403, p=0.687, r=0.054*	z=-1.559, p=0.119, r=0.210

Active minutes in transport, in minutes per day, n=55	T0: 21.43 (40.00) T1: 21.43 (24.29) T2: 17.14 (31.43)	*z=-0.669, p=0.503, r=0.090*	*z=-1.789, p=0.074, r=0.241*	z=-0.510 p=0.610, r=0.069
MET-minutes per day of people with initial activity <4000 MET-Minutes per day, n=41	T0: 1640 (1780) T1: 2560 (2756) T2: 2160 (2510)	*z=-3.882, p<0.001, r=0.606*	*z=-1.109, p=0.267, r=0.173*	*z=-3.039, p=0.002, r=0.475*

IQR=Interquartile range, BMI=Body Mass Index, MET= metabolic equivalent, T0=program start, T1=program half, T2=program completion

DISCUSSION

The primary aim of this study was to assess the effects of the video-based smartphone app 'VIDEA bewegt' on physical activity and related outcomes in German adults under real-life conditions. Individuals who completed the program experienced a significant increase in physical activity based on several parameters and health-related quality of life. Furthermore, the recovery self-efficacy increased significantly as well.

Data was collected from 97 study participants to provide the basis for the conducted study. Women accounted for more than three-quarters of the sample. It is known that women tend to be more interested in health interventions than men and are easier to convince of new interventions [53,54]. Additionally, well-educated people often have a greater interest in health interventions. It is therefore not surprising that the study mainly involved people who had completed their education and were in full-time employment [54].

Effectiveness: The 55 subjects with program completion reported a median physical activity of 2400 MET minutes per week at T0. For people in Germany, a representative study determined an average value of 630 MET minutes per week [55]. Consequently, the sample was physically active to an above-average degree. Insufficient physical activity is defined by the WHO as less than 600 MET minutes per week [56]. However, it is known that physical activity should be much higher in order to effectively reduce risks of chronic diseases [52]. Despite the relatively high baseline physical activity levels of the sample, participants completing the program showed improvements of physical activity measured by MET-Minutes per week (significant increase T0/T2 and T1/T2 with r=0.260 and r=0.188). Including only those individuals with less than 4000 MET minutes per week at baseline, this increase was significant with medium and strong effect sizes (r=0.475 and r=0.606). For this part of the

sample, MET minutes per week increased by 32%. Similar rates of activity increase were also found in other studies [10,15].

Step counts per day are a widely used measure of physical activity [57]. However, only few and incomplete data sets were available in the present study, which is why results have to be dealt with caution. The step count data sets did not show any significant increases in the number of steps per day. It would have been desirable to compare the objective step counts with the less objective MET minutes, as recommended [58]. However, since only 27 of 55 people synchronized their steps at the beginning and end of the program on at least five of 14 days, no such comparison was made.

Sedentary time per day decreased significantly from a median of six to five hours. In fact, five hours of sedentary time were found to be the average of the German population [59]. While total mortality is significantly reduced by replacing one hour of sedentary time with activity [60], the decrease in sedentary time observed in the study can be interpreted as clinically relevant.

The median BMI of the 97 study participants of 26.26 kg/m² at baseline is comparable to similar studies [10,15,61]. It significantly decreased with medium effect size (r=0.330) between T0 and T2 for the 55 individuals with program completion. As such, while the median BMI lied in the range of overweight (>25kg/m² [62]) at baseline, participants completing the program improved to ranges of normal weight (<25 kg/m²) after eight program weeks with individually different time periods being needed (median program use of 68 days). Considering weight changes as the basis of BMI values, clinically relevant weight decreases of at least 5% were found in 7 of 55 subjects [63].

Health-related quality of life increased significantly in the first half of the program, but also over the entire program period, with a medium effect size. In 2004, norm values of PCS=50.30 and MCS=53.25 were determined for the German population [64]. In the PCS, the number of people above the norm did not change and remained at 27/55. In the MCS, only 12/55 people were above the norm at the beginning of the program and 25/55 at the end of the program. Overall, however, the health-related quality of life could not be rated as above average, since the medians were below the norm at all time points. A clinically relevant change in PCS or MCS of at least three points [65] was found in the PCS for 27/55 subjects and in the MCS for 37/55 subjects.

While motivational and maintenance self-efficacy did not change during the intervention, there was a significant increase in recovery self-efficacy for individuals completing the program (recovery self-efficacy *r*=0.249). Luszczynska et al. demonstrated that recovery self-efficacy has a stronger predictive influence on physical activity than maintenance self-efficacy [66]. Based on the health action process approach (HAPA), these findings seem conclusive, as recovery self-efficacy is particularly important for the implementation and execution of new behavior [67]. The increase of recovery self-efficacy emerged between T1 and T2, while the comparison between T0 and T1 did not show an increase. It is known that recovery self-

efficacy is especially important in later stages of behavior change when barriers and failures occur, with overcoming such setbacks being the main challenge. High recovery self-efficacy also is important for resuming health-promoting behaviors after an interruption [66]. In this present study, the rather informal character as well as participants' freedom to execute the whole program resulted in heterogeneous intervention durations. Thus, individuals who successfully completed the intervention may have been particularly effective at coping with such interruptions. It is possible that the positive learning experiences contributed to an improvement in recovery self-efficacy, as well.

For digital interventions, the correlation of high self-efficacy with high exercise frequency and an increase in health-related parameters is well known [68]. For example, it has already been described that self-efficacy increased during an intervention to reduce BMI [69]. The results of the present study confirm the important role of self-efficacy in digital interventions. Accordingly, the specific relevance of each dimension of self-efficacy as well as the maintenance of behavior changes reflected by mid-to-long-term follow-ups should be addressed in future studies. Research on self-efficacy may help to develop more effective and better individualizable interventions.

Dropouts: The fraction of people responding to a study invitation is often less than ten percent [70]. In the present study, 6.8 percent of the app users became study participants. Of the 97 people included in the analysis, only 55 completed the program. It is known that loss of interest, hidden costs, or complicated use can be responsible for dropout [71]. The sample covered an age range of 22-75 years and had a mean age of 48 years. Similar age averages can also be found in other studies [10,15,61]. An analysis of individual subgroups would have been desirable, but would have required a larger sample [72].

Limitations

An important strength of this study is that it was conducted under real-life conditions. Furthermore, objective and subjective approaches of measurements were combined. Another strength is the user-centered study design, in which potential users were involved in the design of the questionnaires and the app [73].

However, the following limitations of our approach should be taken into account. The number of app users remained below expectations, resulting in a small sample that did not allow for subgroup analysis. Though the sample size can be regarded as small, it is comparable to other projects [12].

Voluntary study participation may have resulted in a selection bias, with primarily participation of highly motivated individuals [74]. Of these individuals, only those with program completion were analyzed in the complete case analysis, which entails a potential overestimation of positive effects [75]. Compared to those who did not complete the program, these individuals

used other health apps less frequently and had a lower BMI. Therefore, it is likely, that especially individuals who previously had little app experience completed the program. Furthermore, a financial incentive was offered for study participation through reimbursement of program costs, which may also have influenced the sample composition [70].

Broad inclusion criteria with only limited restrictions caused an inhomogeneous study population, in terms of individual characteristics such as age, BMI and baseline activity. This is matched by the fact that many results show wide interquartile ranges and can be considered as inconsistent. Due to its observational design, the absence of a control group and missing randomisation, this study can only provide limited data on how individual app components contributed to the overall effect of the app. This is relevant as the investigated app can be defined as a complex intervention entailing multiple components. In addition, the observational study design did not allow for controlling potential confounders relating to the use of additional apps in parallel to study participation. Thus, the small sample size made it difficult to account for confounding factors during data analysis. Additionally, it was not possible to conclusively clarify which individuals could benefit most from app use.

The app was regularly updated by the responsible company during the period of data collection, without changing any essential content. Nevertheless, small changes of the design, or the app performance could have led to different display of the content.

Most of the data collected is based on self-assessment during an app use in real life. Additionally, the time of completing questionnaires was based on the program duration which substantially differed between participants. This is in line with the approach of a pragmatic study but may have introduced a risk of measurement bias affecting internal validity

Outlook

While most apps for increasing physical activity focus on documenting activity,[12,76] “VIDEA bewegt” offers a novel concept in which video-based information, practical guidance and helpful tips are provided. Such interventions are particularly in demand at times of the Corona pandemic to counteract restricted activity through lockdown policies,[77] minimizing the risk of severe Corona disease [78]. The results of the one-year follow-up are still awaited, which will clarify the important question of the sustainability of observed effects. With special regard to the described limitations of this study, future projects should aim for a larger sample to allow for subgroup analyses. At the same time, the proportion of missing data should be minimized by including a less heterogeneous sample. In addition, a more direct way to contact the participants should be considered. The quality of the results would also benefit from data collection methods not solely based on self-reported values.

Conclusion

Although significant benefits of physical activity were observed following a complete-case-analysis after eight program weeks, results should be dealt with caution. Using "VIDEA bewegt" resulted in an increase of physical activity for some participants. As such, significant increases in MET minutes per week and health-related quality of life as well as significant decreases in time spent sitting and BMI were observed for program completers. Overall, the combination of educative strategies, video-based exercise tutorials and motivational support seemed promising. Future research is warranted to evaluate the effectiveness of the whole program using rigorously conducted trials while enrolling a larger number of participants.

ETHICS AND DISSEMINATION

Ethics approval

After an ethics application was submitted to the Ethics Committee of the Technical University of Dresden on 12 April, the Ethics Committee approved the study on 25 May 2019 (EK 272062019).

Consent to participate

The informed consent to participate is obtained written by clicking a button in the first online questionnaire in accordance with the DSGVO as a prerequisite for participation

STATEMENTS

Authors' contributions

TF and PS wrote the manuscript, collected the data, and performed the data analysis. TF focused on the analysis on physical activity, health-related quality of life, and the exploratory analysis, while PS focused on self-efficacy. PEHS advised and provided feedback and reviewed the manuscript. PT regularly provided feedback on the overall study flow and participated in the writing of the manuscript. All authors reviewed and approved the final version of the manuscript before submission.

Competing interests

The principal investigator Prof Schwarz was involved in the development and implementation of the app 'VIDEA bewegt' as a medical expert.

He is responsible for the medical and theoretical background and is shown in the app's videos. He received no payment for his participation in the app.

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Data availability

Data are available upon reasonable request.

Individual participant data collected during the trial will be available after deidentification and completion of data collection.

Data will be shared with researchers who provide a methodologically sound proposal. Proposals should be directed to peter.schwarz@uniklinikum-dresden.de. To gain access, data requestors will need to sign a data access agreement.

References

1 Roth GA, Mensah GA, Johnson CO, *et al.* Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019: Update From the GBD 2019 Study. *J Am Coll Cardiol* 2020;**76**. doi:10.1016/j.jacc.2020.11.010

2 Guthold R, Stevens GA, Riley LM, *et al.* Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *Lancet Glob Heal* 2018;**6**:e1077–86. doi:10.1016/S2214-109X(18)30357-7

3 Warburton D, Nicol C, Bredin S. Health benefits of physical activity: the evidence. *CMAJ* 2006;**174**:801–9. doi:10.1503/cmaj.051351

4 Lee I-M, Shiroma EJ, Lobelo F, *et al.* Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet (London, England)* 2012;**380**:219–29. doi:10.1016/S0140-6736(12)61031-9

5 Fiuza-Luces C, Garatachea N, Berger NA, *et al.* Exercise is the Real Polypill. *Physiology* 2013;**28**:330–58. doi:10.1152/physiol.00019.2013

6 Timpel P, Harst L, Reifegerste D, *et al.* What should governments be doing to prevent diabetes throughout the life course? *Diabetologia* 2019;**62**:1842–53. doi:10.1007/s00125-019-4941-y

7 Lippke S, Ziegelmann JP. Understanding and modeling health behavior: The multi-stage model of health behavior change. *J Health Psychol* 2006;**11**:37–50. doi:10.1177/1359105306058845

8 Willett WC, Koplan JP, Nugent R, *et al. Prevention of Chronic Disease by Means of*

Diet and Lifestyle Changes. In: Jamison DT, Breman JG, Measham AR, et al., editors. Disease Control Priorities in Developing Countries. 2nd edition. Washington (DC): The International Bank for Reconstruction and D. 2006. doi:10.1587/transcom.E92.B.1369

9 Schmidt SK, Hemmestad L, Macdonald CS, *et al.* Motivation and barriers to maintaining lifestyle changes in patients with type 2 diabetes after an intensive lifestyle intervention (The U-TURN trial): A longitudinal qualitative study. *Int J Environ Res Public Health* 2020;**17**:1–16. doi:10.3390/ijerph17207454

10 Safran Naimark J, Madar Z, Shahar DR. The Impact of a Web-Based App (eBalance) in Promoting Healthy Lifestyles: Randomized Controlled Trial. *J Med Internet Res* 2015;**17**. doi:10.2196/jmir.3682

11 Haas M. Smartphone-Markt: Konjunktur und Trends. Bitkom. 2018.https://www.bitkom.org/sites/default/files/file/import/Bitkom-Pressekonferenz-Smartphone-Markt-22-02-2018-Praesentation-final.pdf (accessed 5 Feb 2021).

12 Romeo A, Edney S, Plotnikoff R, *et al.* Can Smartphone Apps Increase Physical Activity? Systematic Review and Meta-Analysis. *J Med Internet Res* 2019;**21**. doi:10.2196/12053

13 Lee M, Lee H, Kim Y, *et al.* Mobile App-Based Health Promotion Programs: A Systematic Review of the Literature. *Int J Environ Res Public Health* 2018;**15**. doi:10.3390/ijerph15122838

14 Schoeppe S, Alley S, Van Lippevelde W, *et al.* Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. *Int J Behav Nutr Phys Act* 2016;**13**. doi:10.1186/s12966-016-0454-y

15 Glynn L, Hayes PS, Casey M, *et al.* Effectiveness of a smartphone application to promote physical activity in primary care: the SMART MOVE randomised controlled trial. *Br J Gen Pract* 2014;:384–91. doi:10.3399/bjgp14x680461

16 Doran G. There's a S.M.A.R.T. Way to Write Management's Goals and Objectives. *Manage Rev* 1981;**70**:35–6.

17 Bauman AE, Reis RS, Sallis JF, *et al.* Correlates of physical activity: Why are some people physically active and others not? *Lancet* 2012;**380**:258–71. doi:10.1016/S0140-6736(12)60735-1

18 Sheeran P, Maki A, Montanaro E, *et al.* Supplemental Material for The Impact of Changing Attitudes, Norms, and Self-Efficacy on Health-Related Intentions and Behavior: A Meta-Analysis. *Heal Psychol* 2016;**35**:1178–88. doi:10.1037/hea0000387

19 Schwarzer R. Self-regulatory processes in the adoption and maintenance of health behaviors: The role of optimism, goals, and threats. *J Health Psychol* 1999;**4**:115–27. doi:10.1177/135910539900400208

20 Schwarzer R. Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Appl Psychol* 2008;**57**:1–29.

doi:10.1111/j.1464-0597.2007.00325.x

21 Harst L, Lantzsch H, Scheibe M. Theories predicting end-user acceptance of telemedicine use: Systematic review. *J Med Internet Res* 2019;**21**. doi:10.2196/13117

22 Timpel P, Oswald S, Schwarz PEH, *et al.* Mapping the evidence on the effectiveness of telemedicine interventions in diabetes, dyslipidemia, and hypertension: An umbrella review of systematic reviews and meta-analyses. *J Med Internet Res* 2020;**22**. doi:10.2196/16791

23 Stuckey MI, Carter SW, Knight E. The role of smartphones in encouraging physical activity in adults. *Int J Gen Med* 2017;**10**:293–303. doi:10.2147/IJGM.S134095

24 Zhao J, Freeman B, Li M. Can Mobile Phone Apps Influence People's Health Behavior Change? An Evidence Review. *J Med Internet Res* 2016;**18**. doi:10.2196/jmir.5692

25 Albrecht U. Kapitel Kurzfassung. In: Albrecht U, ed. *Chancen und Risiken von Gesundheits-Apps (CHARISMA)*. Medizinische Hochschule Hannover 2016. 14–47.

26 Dallinga JM, Mennes M, Alpay L, *et al.* App use, physical activity and healthy lifestyle: a cross sectional study. *BMC Public Health* 2015;**15**. doi:10.1186/s12889-015-2165-8

27 Harries T, Eslambolchilar P, Rettie R, *et al.* Effectiveness of a smartphone app in increasing physical activity amongst male adults: A randomised controlled trial. *BMC Public Health* 2016;**16**:1–10. doi:10.1016/0005-2795(71)90287-X

28 Knight E, Stuckey MI, Prapavessis H, *et al.* Public Health Guidelines for Physical Activity: Is There an App for That? A Review of Android and Apple App Stores. *JMIR mHealth uHealth* 2015;**3**:e43. doi:10.2196/mhealth.4003

29 Coughlin SS, Whitehead M, Sheats JQ, *et al.* A Review of Smartphone Applications for Promoting Physical Activity. *Jacobs J community Med* 2016;**2**.

30 Payne HE, Lister C, West JH, *et al.* Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature. *JMIR mHealth uHealth* 2015;**3**. doi:10.2196/mhealth.3335

31 Jake-Schoffman DE, Silfee VJ, Waring ME, *et al.* Methods for Evaluating the Content, Usability, and Efficacy of Commercial Mobile Health Apps. *JMIR mHealth uHealth* 2017;**5**. doi:10.2196/mhealth.8758

32 Van Rhoon L, Byrne M, Morrissey E, *et al.* A systematic review of the behaviour change techniques and digital features in technology-driven type 2 diabetes prevention interventions. *Digit Heal* 2020;**6**:1–27. doi:10.1177/2055207620914427

33 Greenwood DA, Gee PM, Fatkin KJ, *et al.* A Systematic Review of Reviews Evaluating Technology-Enabled Diabetes Self-Management Education and Support. *J Diabetes Sci Technol* 2017;**11**:1015–27. doi:10.1177/1932296817713506

34 Joiner LL, Nam S, Whittemore R. Lifestyle Interventions Based on the Diabetes Prevention Program Delivered via eHealth: A Systematic Review and Meta-analysis.

Prev Med (Baltim) 2017;**100**:194–207. doi:10.1016/j.ypmed.2017.04.033.Lifestyle

35 Guyatt GH, Oxman AD, Kunz R, *et al.* GRADE: What is 'Quality of evidence' and why is it important to clinicians? *BMJ* 2008;**336**. doi:10.1136/bmj.39490.551019.be

36 Bashshur R, Shannon G, Krupinski E, *et al.* The taxonomy of telemedicine. *Telemed e-Health* 2011;**17**:484–94. doi:10.1089/tmj.2011.0103

37 Neugebauer EAM, Rath A, Antoine SL, *et al.* Specific barriers to the conduct of randomised clinical trials on medical devices. *Trials* 2017;**18**. doi:10.1186/s13063-017-2168-0

38 Hanlon P, Daines L, Campbell C, *et al.* Telehealth interventions to support self-management of long-term conditions: A systematic metareview of diabetes, heart failure, asthma, chronic obstructive pulmonary disease, and cancer. *J Med Internet Res* 2017;**19**:1–26. doi:10.2196/jmir.6688

39 Cui M, Wu X, Mao J, *et al.* T2DM Self-Management via Smartphone Applications: A Systematic Review and Meta-Analysis. *PLoS One* 2016;**11**. doi:10.1371/journal.pone.0166718

40 Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res* 2011;**13**. doi:10.2196/jmir.1923

41 Fischer T, Stumpf P, Reinhardt G, *et al.* Video-based smartphone app (' VIDEA bewegt ') for physical activity support in German adults : a study protocol for a single-armed observational study. 2020;**10**:1–10. doi:10.1136/bmjopen-2019-034027

42 VIDEA bewegt. https://videabewegt.de (accessed 27 Nov 2019).

43 Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). *J Public Health (Bangkok)* 2006;**14**:66–70. doi:10.1007/s10389-006-0024-x

44 Wanner M, Hartmann C, Pestoni G, *et al.* Validation of the Global Physical Activity Questionnaire for self- administration in a European context. *BMJ Open Sport Exerc Med* 2017;**3**. doi:10.1136/bmjsem-2016-000206

45 Ellert U, Lampert T, Ravens-Sieberer U. Messung der gesundheitsbezogenen Lebensqualität mit dem SF-8 Eine Normstichprobe für Deutschland. *Bundesgesundheitsblatt - Gesundheitsforsch - Gesundheitsschutz* 2005;**48**:1330–7. doi:10.1007/s00103-005-1168-5

46 Ware JE, Kosinski M, Dewey JE, *et al. How to score and interpret single-item health status measures: a manual for users of the SF-8™ Health Survey*. 2001.

47 Burkert S, Scholz U, Gralla O, *et al.* Dyadic planning of health-behavior change after prostatectomy: A randomized-controlled planning intervention. *Soc Sci Med* 2011;**73**:783–92.

48 Sniehotta FF, Scholz U, Schwarzer R. Action plans and coping plans for physical

exercise: A longitudinal intervention study in cardiac rehabilitation. *Br J Health Psychol* 2006;:23–37.

49 Bender R, Lange S, Ziegler A. Multiples Testen – Artikel Nr. 12 der Statistik-Serie in der DMW –. *Dtsch medizinische Wochenschrift* 2007;**132**:26–9. doi:10.1055/s-2007-959035

50 Armstrong RA. When to use the Bonferroni correction. *Ophthalmic Physiol Opt* 2014;**34**:502–8. doi:10.1111/opo.12131

51 Jakobsen JC, Gluud C, Wetterslev J, *et al.* When and how should multiple imputation be used for handling missing data in randomised clinical trials - A practical guide with flowcharts. *BMC Med Res Methodol* 2017;**17**. doi:10.1186/s12874-017-0442-1

52 Kyu HH, Bachman VF, Alexander LT, *et al.* Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: Systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. *BMJ* 2016;**354**. doi:10.1136/bmj.i3857

53 Bidmon S, Terlutter R. Gender differences in searching for health information on the internet and the virtual patient-physician relationship in Germany: Exploratory results on how men and women differ and why. *J Med Internet Res* 2015;**17**. doi:10.2196/jmir.4127

54 Carroll JK, Moorhead A, Bond R, *et al.* Who uses mobile phone health apps and does use matter? A secondary data analytics approach. *J Med Internet Res* 2017;**19**:1–14. doi:10.2196/jmir.5604

55 Wallmann-Sperlich B, Froboese I. Physical activity during work, transport and leisure in Germany - Prevalence and socio-demographic Correlates. *PLoS One* 2014;**9**. doi:10.1371/journal.pone.0112333

56 WHO. Global Physical Activity Questionnaire (GPAQ) Analysis Guide. 2005.

57 Bort-Roig J, Gilson ND, Puig-Ribera A, *et al.* Measuring and influencing physical activity with smartphone technology: A systematic review. *Sport Med* 2014;**44**:671–86. doi:10.1007/s40279-014-0142-5

58 Hart TL, Ainsworth BE, Tudor-Locke C. Objective and subjective measures of sedentary behavior and physical activity. *Med Sci Sports Exerc* 2011;**43**:449–56. doi:10.1249/MSS.0b013e3181ef5a93

59 Wallmann-Sperlich B, Bucksch J, Hansen S, *et al.* Sitting time in Germany: An analysis of socio-demographic and environmental correlates. *BMC Public Health* 2013;**13**. doi:10.1186/1471-2458-13-196

60 Matthews CE, Moore SC, Sampson J, *et al.* Mortality Benefits for Replacing Sitting Time with Different Physical Activities. *Med Sci Sport Exerc* 2015;**74**. doi:10.1249/MSS.0000000000000621

61 Recio-Rodriguez JI, Agudo-Conde C, Martin-Cantera C, *et al.* Short-term

effectiveness of a mobile phone app for increasing physical activity and adherence to the mediterranean diet in primary care: A randomized controlled trial (EVIDENT II study). *J Med Internet Res* 2016;**18**. doi:10.2196/jmir.6814

62 WHO Technical Report Series. *OBESITY: PREVENTING AND MANAGING THE GLOBAL EPIDEMIC Report of a WHO Consultation*. 2000. doi:10.1007/BF00400469

63 Stevens J, Truesdale KP, McClain JE, *et al.* The definition of weight maintenance. *Int J Obes* 2006;**30**:391–9. doi:10.1038/sj.ijo.0803175

64 Beierlein V. *Generierung und Validierung deutscher normbasierter Scores für die Short-Form Health Surveys SF-36v2 und SF-8 und deren Normierung für Deutschland*. 2009.

65 Janzen W, Turpin KVL, Warren SA, *et al.* Change in the health-related quality of life of multiple sclerosis patients over 5 years. *Int J MS Care* 2013;**15**:46–53. doi:10.7224/1537-2073.2012-020

66 Luszczynska A, Mazurkiewicz M, Ziegelmann JP, *et al.* Recovery self-efficacy and intention as predictors of running or jogging behavior: A cross-lagged panel analysis over a two-year period. *Psychol Sport Exerc* 2007;**8**:247–60. doi:10.1016/j.psychsport.2006.03.010

67 Schwarzer R. *Self-efficacy: Thought control of action.* Taylor & Francis 2014.

68 Wang T, Ren M, Shen Y, *et al.* The association among social support, self-efficacy, use of mobile apps, and physical activity: Structural equation models with mediating effects. *JMIR mHealth uHealth* 2019;**7**. doi:10.2196/12606

69 Turner-McGrievy GM, Crimarco A, Wilcox S, *et al.* The role of self-efficacy and information processing in weight loss during an mHealth behavioral intervention. *Digit Heal* 2020;**6**:1–7. doi:10.1177/2055207620976755

70 Drazen JM, Harrington DP, McMurray JJV, *et al.* Pragmatic Trials. *N Engl J Med* 2016;**375**:454–63. doi:10.1056/NEJMra1510059

71 Krebs P, Duncan DT. Health App Use Among US Mobile Phone Owners: A National Survey. *JMIR mHealth uHealth* 2015;**3**. doi:10.2196/mhealth.4924

72 Burke JF, Sussman JB, Kent DM, *et al.* Three simple rules to ensure reasonably credible subgroup analyses. *BMJ* 2015;**351**. doi:10.1136/bmj.h5651

73 Arnold K, Scheibe M, Müller O, *et al.* Grundsätze für die Evaluation telemedizinischer Anwendungen – Ergebnisse eines systematischen Reviews und Konsens-Verfahrens. *Z Evid Fortbild Qual Gesundhwes* 2016;**117**:9–19. doi:10.1016/j.zefq.2016.04.011

74 Hardcastle SJ, Hancox J, Hattar A, *et al.* Motivating the unmotivated : how can health behavior be changed in those unwilling to change ? 2015;**6**. doi:10.3389/fpsyg.2015.00835

75 Bell ML, Fiero M, Horton NJ, *et al.* Handling missing data in RCTs; A review of the top medical journals. *BMC Med Res Methodol* 2014;**14**. doi:10.1186/1471-2288-14-118

76 Kim HN, Seo K. Smartphone-based health program for improving physical activity and tackling obesity for young adults: A systematic review and meta-analysis. *Int J Environ Res Public Health* 2020;**17**. doi:10.3390/ijerph17010015

77 Tison GH, Avram R, Kuhar P, *et al.* Worldwide Effect of COVID-19 on Physical Activity : A descriptive study. *Ann Intern Med* Published Online First: 2020. doi:10.7326/M20-2665

78 Wang M, Baker JS, Quan W, *et al.* A Preventive Role of Exercise Across the Coronavirus 2 (SARS-CoV-2) Pandemic. *Front Physiol* 2020;**11**:1–8. doi:10.3389/fphys.2020.572718

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5-6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	7

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-7
		(b) Indicate number of participants with missing data for each variable of interest	7
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	7
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12-13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14-15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

A video-based smartphone app ("VIDEA bewegt") for physical activity support in German adults, a single armed observational study

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Secondary Subject Heading:	Sports and exercise medicine, Medical education and training
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, MEDICAL EDUCATION & TRAINING, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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A video-based smartphone app ("VIDEA bewegt") for physical activity support in German adults, a single armed observational study

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ABSTRACT

Objectives

The primary objective of this study was to investigate the effect of the video-based smartphone app ('VIDEA bewegt') over eight program weeks on physical activity in German adults.

Design

The study used a single-arm observational design, assessing the app's effectiveness under real-life conditions. Data were collected from July 2019 to July 2020.

Setting

The app is enabling users to access video-based educational content via their smartphone. A clinical visit or in-person contact was not required.

Participants

All individuals registered in the freely available app were invited to take part in the study.

Interventions

The app aims to increase physical activity in everyday life. It combines educative videos on life-style related benefits and instructional videos of strength and endurance exercises to do at home with motivational components like goal setting, documentation of progress, and personalized messages.

Primary and Secondary outcome measures

Primary outcomes were physical activity based one MET minutes per week (metabolic equivalent) and step numbers.

Secondary outcomes included physical self-efficacy (motivational, maintenance, recovery self-efficacy), health-related quality of life: MCS (mental health component summary score) and PCS (physical health component summary score).

Results

Of 97 people included in the data analysis, 55 successfully completed the program and all questionnaires. Significant increases over eight program weeks (between T0 and T2) were observed in physical activity based on MET-Minutes per week, health-related quality of life, and recovery self-efficacy. Time spent sitting and BMI significantly decreased for those completing the program.

Conclusions

Although significant benefits of physical activity were observed following a complete-case-analysis, results should be dealt with caution. Studies with a larger and less heterogeneous sample and robust study designs able to measure causal effects would be desirable.

Trial registration

German Clinical Trials Register (DRKS): Evaluation of an app-based activity intervention for statutory health insured people. DRKS-ID: DRKS00017392. (14 June 2019)

Strengths and limitations of this study

- The evaluation of the intervention is carried out under real-life conditions.
- Various approaches were used to describe the effects of the intervention.
- The small sample size, broad inclusion criteria for participation bias and a high dropout rate limit the internal validity.
- Due to its observational design and the absence of a control group and randomisation, this study can only provide limited data on how individual app components contributed to the overall effect of the app.
- Most data collected were based on self-assessment.

INTRODUCTION

Background

Non-communicable diseases are substantially caused by lifestyle-associated factors like insufficient physical activity [1]. In addition to non-communicable diseases, activity also influences quality of life and mental health [2]. To prevent chronic diseases like diabetes, it is recommended to promote physical activity across all age groups [3–6]. Effective strategies to increase motivation and reduce barriers for behaviour change require sustained efforts and ongoing support [7–9]. Behavioral change support by the use of smartphones in particular seems promising due to their widespread use and low barriers to participation uptake [10,11].

Smartphone app based interventions providing performance-related feedback, psychosocial networking and goal setting have been found to effectively increase physical activity [12–16]. Furthermore, it has been widely described that increased self-efficacy can have positive effects on behavior change [17–19]. According to the Health Action Process Approach (HAPA), different subcomponents of self-efficacy can be distinguished [20]. Particularly decisive is the stability respectively variability of the subcomponents in the present study. Digital interventions have the unique potential to combine these effective strategies while keeping user acceptance high [21,22].

Despite these known components of successful behavior change, the generation of evidence in the field of digitally supported behavior change predominantly focused on apps developed in relation to scientific studies, rather than evaluating freely accessible apps [23,24]. As a result, despite the increasing number of health apps on the market, the minority of them is based on strong empirical and scientific evidence [10,25–28]. Scientific evaluations of available apps offer great potential for improving both present and future apps [29–31]. While studies show promising results on the effectiveness of these interventions to prevent [32] or successfully manage [6,33] chronic lifestyle-related diseases, e.g. by using videos for preventive purposes,[34] the strategies needed to achieve sustainable behavior change seem to have received little attention [12].

Reasons for the described limited evidence base of digital health apps include methodological challenges during evaluation. In order to guide evidence-based decision making, RCTs are regarded as highest level [35]. However, digital health interventions usually comprise multiple components and are mostly designed as modular interventions offering tailored as well as performance-based adaptations or feedback [36]. This may end up in circumstances where RCTs may not be feasible. As such, challenges including randomization, timing of assessment, acceptance by patients and physicians, blinding, as well as defining control groups and relevant endpoints need to be considered [37]. In addition to the described challenges during evaluation, limited guidance is available on the mid- to long term outcomes [38,39].

Therefore, the primary objective of this study was to investigate the effect of the video-based and freely on the market available smartphone app (‘VIDEA bewegt’) over eight program weeks on physical activity (MET-minutes per Week and steps per day) in German adults. Secondary objectives were to analyse the associated changes in self-efficacy and health-related quality of life.

Hypotheses

The users of ‘VIDEA bewegt’ who participate in the study increase their average daily step count and achieve a higher number of metabolic equivalent (MET) minutes per week, a

significantly higher health-related quality of life, a significantly higher motivational, maintenance and recovery self-efficacy after the first four weeks, and after completion of the eight-week course, compared to the beginning of data collection.

MATERIALS AND METHODS

A detailed study protocol following important recommendations formulated by Eysenbach and the CONSORT-EHEALTH Group [40] was published prior to the data analysis [41].

Study design and summary of intervention

Data collection took place from July 2019 to July 2020. The evaluation of the app 'VIDEA bewegt' is designed as a single-arm observational study, assessing the app's effectiveness and usability under real-life conditions. The smartphone app 'VIDEA bewegt' is a video-based program to increase physical activity in everyday life. The app is divided into eight program weeks, each of which follows a consistent structure. The core of the app are four videos per program week. Theoretical videos explain and illustrate the importance of exercise and lifestyle, as well as ways to build up motivation. Practical videos present exercises to improve strength and endurance in a way which can be followed without the use of supplies. Additionally, motivational components such as goal setting, progress documentation, and personal messages are included. More extensive information can be found in the study protocol [41].

Setting

'VIDEA bewegt' is an app enabling users to access educational content via their smartphone anywhere and at any time. It was made available on the German market for Android and iOS in March 2019. Costs of the program are partially reimbursed by health insurance companies. Further information can be found on the German website https://videabewegt.de [42].

A clinical visit or in-person contact with a physician or diabetes specialist was not required. However, it was possible to consult experts in preventative health care and sports science via an integrated chat function. Problems could also be discussed with other users and experts in a forum.

Participants

To register in the app, interested individuals had to be of legal age (≥ 18 years old) and declare that they were free of serious medical conditions such as heart failure. All registered individuals were invited to the study without further restriction.

Patient and public involvement

Potential participants were included in pretesting the questionnaires in order to assess their logic, understandability, and technical performance. A usability test with ten individuals provided insight in strengths and weaknesses of the app. Additionally, all study participants were asked to answer questions regarding their experience with the app's components. All data that made it possible to further optimize the app was forwarded to the developing company.

Procedure

App users interested in the study received an email and access to the first online questionnaire, which included the consent form and privacy policy. Individuals who completed the first questionnaire became study participants and received further questionnaires after completion of the fourth and eighth program weeks. In addition, internal app usage data including step counts were collected. For the analysis, three relevant time points were defined at which the individual outcome variables would be compared. The program start defined the time point T0, the program half the time point T1 and the program completion the time point T2. Participants received an email with a link to the online questionnaire at each time point. As such, data collection depended on participants' program usage. If a questionnaire was not completed after two days, the participants received a reminder. The study was conducted entirely digitally.

Outcomes

Primary outcomes were physical activity based on MET minutes per week (metabolic equivalent) and step numbers.

Secondary outcomes included physical self-efficacy (motivational, maintenance, recovery self-efficacy), health-related quality of life: MCS (mental health component summary score) and PCS (physical health component summary score).

To measure the outcome variables, validated self-reporting measurement instruments were applied. The Global Physical Activity Questionnaire (GPAQ) was used to record MET minutes per week as well as sedentary time per day [43,44]. The assessment of health-related quality of life is based on the SF-8 questionnaire [45,46]. Self-efficacy was measured in the three dimensions of motivation self-efficacy, maintenance self-efficacy and recovery self-efficacy [47,48]. For each of these three dimensions, statements were phrased in a questionnaire to which agreement was indicated using a Likert scale. Objective measurements of step counts were used. As a source of these step counts, users could either synchronize an external pedometer with the app or capture steps with their smartphone. For the comparison between T0 and T2, all persons were included who had entered their steps on at least 5 of 14 days at

both start and end of the program. For the comparison between T0 and T1, all persons who had entered their steps on at least 3 of 7 days were included.

Statistical analyses

Sociodemographic data and user behaviour were analysed descriptively. The Shapiro-Wilk-Test was used to test for normal distribution. The hypotheses were tested using a one-sided Wilcoxon-Test for dependent samples at T0, T1 and T2 due to lack of normal distribution. A subgroup analysis was not conducted on account of the small sample size. Due to the exploratory nature of the data analysis, Bonferroni correction was omitted [49,50]. Instead, an exploratory analysis was added to separate individuals who completed the program and who showed an increase in activity.

Average values were calculated for the number of steps per day. For the comparison of T0 and T2, all persons were included who synchronized steps on at least 5 of 14 days at the beginning and end. For the comparison of T0 and T1, persons with at least three out of seven days of synchronization were included following the same method.

The analysis was conducted as a complete case analysis.

RESULTS

Description of the sample

During the data collection period, 1519 individuals registered with the app. Of those, 103 individuals (6,8%) followed the study invitation and completed the first questionnaire. Two people withdrew their participation during the survey, and four people were excluded from the analysis because of not completing the first questionnaire at the beginning of program use. Consequently, 97 people were included in the data analysis, 55 of whom successfully completed the program and all questionnaires (see Table 1).

Table 1 Characteristics of the study population

Overall n	97
Age mean (SD) in years	47.52 (13.52)
Sex	80 female (82%), 17 male (18%)
Body-Mass-Index median (IQR) in kg/m^2	26.26 (8.8)
Marital status	
Married	57
Living in stable relationship	15
Divorced, separated	10
Single	11

Widowed	3
Other	1
Level of education	
completed professional training	32
degree from university	35
high school	14
secondary school	13
other	4
Gainful employment	
full-time	49
half-time	16
retired	16
part-time employed	7
not employed	9
Other Sports courses[1]	
Yes	49
No	48
Other Health apps [2]	
Yes	30
No	67

Notes. 1 = Participation in sports courses, 2 = Use of other health apps in addition to the VIDEA program. SD=standard deviation, IQR=Interquartile range

The median duration of program use was 68 days (Interquartile range (IQR) 64 days). The female participants accounted for 82% of the participants.

Comparison of persons with and without program completion

A total of 42 out of 97 study participants had not completed the program, which resulted in 42 (43%) incomplete datasets. Due to the proportion of missing data exceeding 40%, imputation methods were not used [51].

Comparing the groups of persons with and without program completion, age, gender distribution and marital status did not differ substantially. In the group with program completion, the proportion of persons with a university degree was larger. The proportion of full-time employees was smaller resulting in a larger proportion of retired persons. In the group with program completion, the proportion of people who used additional health apps was smaller. BMI was also lower here, while health-related quality of life and physical activity did not differ.

Physical Activity

The hypothesis that physical activity increases significantly between program start and completion can be supported for self-reported MET minutes per week. In contrast, the hypothesis that there is a significant increase in MET minutes already within the first half of the program cannot be confirmed (see Table 2). For the number of steps per day, neither a significant increase in the first half nor over the entire program time was detected.

Table 2 Primary outcome measures, using asymptomatic one-sided Wilcoxon-tests

	Median (IQR) n=55	T0 vs. T1	T1 vs. T2	T0 vs. T2
MET minutes per week	T0: 2400 (3140) T1: 2760 (4100) T2: 2640 (5680)	*z=-1.391, p=0.082, n=55, r=0.188*	*z=-1.778, p=0.038, n=55, r=0.240*	*z=-1.927, p=0.027, n=55, r=0.260*
Steps per day	T0: 7043 (4347), n=27 T2: 6829 (4878), n=27	*z=-0.470, p=0.638, n=31, r=0.084*		*z=-1.562, p=0.061, n=27, r=0.301*

IQR=Interquartile range, MET=metabolic equivalent, T0=program start, T1=program half, T2=program completion

Health related quality of life and Self-efficacy

The hypotheses that health-related quality of life based on the Physical Component Summary (PCS) and the Mental Component Summary (MCS) increases significantly in the first half of the program and over the entire program period can both be confirmed. Looking at self-efficacy, the formulated hypotheses can only be confirmed for recovery self-efficacy, where there was a significant increase over the entire program period. In contrast, there were no significant increases in motivational and maintenance self-efficacy (see Table 3).

Table 3 Primary outcome measures, using asymptomatic one-sided Wilcoxon-tests

	Median (IQR) n=55	T0 vs. T1	T1 vs. T2	T0 vs. T2
PCS	T0: 49.74 (13.06) T1: 51.80 (13.34) T2: 50.14 (9.33)	*z=-2.409, p=0.008, n=55, r=0.325*	*z=-1.694, p=0.045, n=55, r=0.228*	*z=-3.050, p=0.001, n=55, r=0.411*
MCS	T0: 47.80 (12.17) T1: 52.49 (8.09) T2: 52.31 (9.56)	*z=-3.599, p<0.001 n=55, r=0.485*	*z=-0.537, p=0.296, n=55, r=0.072*	*z=-3.484, p<0.001, n=55, r=0.470*
motivational self-efficacy	T0: 3.67 (1.00) T1: 3.67 (1.16) T2: 3.67 (1.66)	*z=-0.528, p=0.238, n=55, r=0.071*	*z=-0.421, p=0.737, n=55, r=0.057*	*z=-0.125, p=0.574, n=55, r=0.017*
maintenance	T0: 3.00 (1.00)	*z=-1.043,*	*z=-0.592,*	*z=-1.199,*

self-efficacy	T1: 3.00 (1.00) T2: 3.33 (1.33)	*p=0.142, n*=55, *r=0.141*	*p=0.289, n*=55, *r=0.08*	*p=0.092, n*=55, *r=0.162*
recovery self-efficacy	T0: 3.00 (0.84) T1: 3.67 (1.00) T2: 4.00 (2.00)	*z=-0.368, p=0.323,* n=55, *r=0.05*	*z=-2.075, p=0.019, n*=55, *r=0.28*	*z=-1.850, p=0.032, n*=55, *r=0.249*

IQR=Interquartile range, PCS=Physical Component Summary Score, MCS=Mental Component Summary Score, T0=program start (baseline), T1=program half, T2=program completion

Additional Analysis

In addition, to the main hypotheses described above, further calculations were performed using the data from the GPAQ and the general questionnaire.

In a first analysis, using only program completers with complete data sets (n=55), the Body Mass Index (BMI) was analyzed, which decreased significantly over the entire program period and between T1 and T2. Furthermore, the time participants spend sitting per day decreased significantly between T0 and T2 as well as T1 and T2. In addition to calculating MET minutes per week, the GPAQ also allows for an analysis of separate activity dimensions (work, transportation, and leisure). The analysis showed that activity during leisure time increased significantly, while activity at work and in transportation did not change significantly (see Table 4).

Because a large proportion of participants already reported high values of MET-minutes per week (>4000 MET-minutes per week) at T0 and were thus less likely to benefit from further increases in activity [52], the comparison between T0 and T2 was repeated for all individuals with baseline activity of less than 4000 MET-minutes per week. Results indicate a significant increase in activity for these participants with large effect sizes (see Table 4).

Table 4 – Additional analyses using asymptomatic two-sided Wilcoxon-tests

	Median (IQR)	T0 vs. T1	T1 vs. T2	T0 vs. T2
BMI in kg/m^2, n=55	T0: 25.51 (8.45) T1: 25.95 (8.54) T2: 24.91 (7.26)	*z=-0.010, p=0.992, r=0.001*	*z=-3.117, p=0.002, r=0.420*	*z=-2.445, p=0.014, r=0.330*
Time spent sitting in hours, n=55	T0: 6 (4) T1: 6 (4) T2: 5 (4)	*z=-0.420, p=0.675, r=0.091*	*z=-2.962, p=0.003, r=0.399*	*z=-2.472 p=0.013, r=0.333*
Active minutes in leisure time in minutes per day, n=55	T0: 25.71 (22.86) T1: 27.31 (30.00) T2: 31.43 (51.43)	*z=-3.053, p=0.002, r=0.412*	*z=-1.171, p=0.242, r=0.158*	*z=-2.898, p=0.004, r=0.391*
Active minutes	T0: 12.86 (64.29)	*z=-0.314,*	*z=-0.403,*	z=-1.559,

at work, in minutes per day, n=55	T1: 21.43 (85.71) T2: 14.29 (100.00)	*p=0.753, r=0.042*	*p=0.687, r=0.054*	p=0.119, r=0.210
Active minutes in transport, in minutes per day, n=55	T0: 21.43 (40.00) T1: 21.43 (24.29) T2: 17.14 (31.43)	*z=-0.669, p=0.503, r=0.090*	*z=-1.789, p=0.074, r=0.241*	z=-0.510 p=0.610, r=0.069
MET-minutes per day of people with initial activity <4000 MET-Minutes per day, n=41	T0: 1640 (1780) T1: 2560 (2756) T2: 2160 (2510)	*z=-3.882, p<0.001, r=0.606*	*z=-1.109, p=0.267, r=0.173*	*z=-3.039, p=0.002, r=0.475*

IQR=Interquartile range, BMI=Body Mass Index, MET= metabolic equivalent, T0=program start, T1=program half, T2=program completion

DISCUSSION

The primary aim of this study was to assess the effects of the video-based smartphone app 'VIDEA bewegt' on physical activity and related outcomes in German adults under real-life conditions. Individuals who completed the program experienced a significant increase in physical activity based on several parameters and health-related quality of life. Furthermore, the recovery self-efficacy increased significantly as well.

Data was collected from 97 study participants to provide the basis for the conducted study. Women accounted for more than three-quarters of the sample. It is known that women tend to be more interested in health interventions than men and are easier to convince of new interventions [53,54]. Additionally, well-educated people often have a greater interest in health interventions. It is therefore not surprising that the study mainly involved people who had completed their education and were in full-time employment [54].

Effectiveness: The 55 subjects with program completion reported a median physical activity of 2400 MET minutes per week at T0. For people in Germany, a representative study determined an average value of 630 MET minutes per week [55]. Consequently, the sample was physically active to an above-average degree. Insufficient physical activity is defined by the WHO as less than 600 MET minutes per week [56]. However, it is known that physical activity should be much higher in order to effectively reduce risks of chronic diseases [52]. Despite the relatively high baseline physical activity levels of the sample, participants completing the program showed improvements of physical activity measured by MET-Minutes

per week (significant increase T0/T2 and T1/T2 with r=0.260 and r=0.188). Including only those individuals with less than 4000 MET minutes per week at baseline, this increase was significant with medium and strong effect sizes (r=0.475 and r=0.606). For this part of the sample, MET minutes per week increased by 32%. Similar rates of activity increase were also found in other studies [10,15].

Step counts per day are a widely used measure of physical activity [57]. However, only few and incomplete data sets were available in the present study, which is why results have to be dealt with caution. The step count data sets did not show any significant increases in the number of steps per day. It would have been desirable to compare the objective step counts with the less objective MET minutes, as recommended [58]. However, since only 27 of 55 people synchronized their steps at the beginning and end of the program on at least five of 14 days, no such comparison was made.

Sedentary time per day decreased significantly from a median of six to five hours. In fact, five hours of sedentary time were found to be the average of the German population [59]. While total mortality is significantly reduced by replacing one hour of sedentary time with activity [60], the decrease in sedentary time observed in the study can be interpreted as clinically relevant.

The median BMI of the 97 study participants of 26.26 kg/m² at baseline is comparable to similar studies [10,15,61]. It significantly decreased with medium effect size (r=0.330) between T0 and T2 for the 55 individuals with program completion. As such, while the median BMI lied in the range of overweight (>25kg/m² [62]) at baseline, participants completing the program improved to ranges of normal weight (<25 kg/m²) after eight program weeks with individually different time periods being needed (median program use of 68 days). Considering weight changes as the basis of BMI values, clinically relevant weight decreases of at least 5% were found in 7 of 55 subjects [63].

Health-related quality of life increased significantly in the first half of the program, but also over the entire program period, with a medium effect size. In 2004, norm values of PCS=50.30 and MCS=53.25 were determined for the German population [64]. In the PCS, the number of people above the norm did not change and remained at 27/55. In the MCS, only 12/55 people were above the norm at the beginning of the program and 25/55 at the end of the program. Overall, however, the health-related quality of life could not be rated as above average, since the medians were below the norm at all time points. A clinically relevant change in PCS or MCS of at least three points [65] was found in the PCS for 27/55 subjects and in the MCS for 37/55 subjects.

While motivational and maintenance self-efficacy did not change during the intervention, there was a significant increase in recovery self-efficacy for individuals completing the program (recovery self-efficacy *r*=0.249). Luszczynska et al. demonstrated that recovery self-efficacy has a stronger predictive influence on physical activity than maintenance self-efficacy [66]. Based on the health action process approach (HAPA), these findings seem conclusive, as

recovery self-efficacy is particularly important for the implementation and execution of new behavior [67]. The increase of recovery self-efficacy emerged between T1 and T2, while the comparison between T0 and T1 did not show an increase. It is known that recovery self-efficacy is especially important in later stages of behavior change when barriers and failures occur, with overcoming such setbacks being the main challenge. High recovery self-efficacy also is important for resuming health-promoting behaviors after an interruption [66]. In this present study, the rather informal character as well as participants' freedom to execute the whole program resulted in heterogeneous intervention durations. Thus, individuals who successfully completed the intervention may have been particularly effective at coping with such interruptions. It is possible that the positive learning experiences contributed to an improvement in recovery self-efficacy, as well.

For digital interventions, the correlation of high self-efficacy with high exercise frequency and an increase in health-related parameters is well known [68]. For example, it has already been described that self-efficacy increased during an intervention to reduce BMI [69]. The results of the present study confirm the important role of self-efficacy in digital interventions. Accordingly, the specific relevance of each dimension of self-efficacy as well as the maintenance of behavior changes reflected by mid-to-long-term follow-ups should be addressed in future studies. Research on self-efficacy may help to develop more effective and better individualizable interventions.

Dropouts: The fraction of people responding to a study invitation is often less than ten percent [70]. In the present study, 6.8 percent of the app users became study participants. Of the 97 people included in the analysis, only 55 completed the program. It is known that loss of interest, hidden costs, or complicated use can be responsible for dropout [71]. The sample covered an age range of 22-75 years and had a mean age of 48 years. Similar age averages can also be found in other studies [10,15,61]. An analysis of individual subgroups would have been desirable, but would have required a larger sample [72].

Limitations

An important strength of this study is that it was conducted under real-life conditions. Another strength is the user-centered study design, in which potential users were involved in the design of the questionnaires and the app [73].

However, the following limitations of our approach should be taken into account. Most of the data collected is based on self-assessment during an app use in real life. The missing possibility to validate collected data is a well-known problem in the evaluation of digital interventions [74]. The number of app users remained below expectations, resulting in a small sample that did not allow for subgroup analysis. Though the sample size can be regarded as small, it is comparable to other projects [12].

Voluntary study participation may have resulted in a selection bias, with primarily participation of highly motivated individuals [75]. Of these individuals, only those with program completion were analyzed in the complete case analysis, which entails a potential overestimation of positive effects [76]. Compared to those who did not complete the program, these individuals used other health apps less frequently and had a lower BMI. Therefore, it is likely, that especially individuals who previously had little app experience completed the program. Furthermore, a financial incentive was offered for study participation through reimbursement of program costs, which may also have influenced the sample composition [70].

Broad inclusion criteria with only limited restrictions caused an inhomogeneous study population, in terms of individual characteristics such as age, BMI and baseline activity. This is matched by the fact that many results show wide interquartile ranges and can be considered as inconsistent. Due to its observational design, the absence of a control group and missing randomisation, this study can only provide limited data on how individual app components contributed to the overall effect of the app. This is relevant as the investigated app can be defined as a complex intervention entailing multiple components. In addition, the observational study design did not allow for controlling potential confounders relating to the use of additional apps in parallel to study participation. Thus, the small sample size made it difficult to account for confounding factors during data analysis. Additionally, it was not possible to conclusively clarify which individuals could benefit most from app use.

The app was regularly updated by the responsible company during the period of data collection, without changing any essential content. Nevertheless, small changes of the design, or the app performance could have led to different display of the content.

Additionally, the time of completing questionnaires was based on the program duration which substantially differed between participants. This is in line with the approach of a pragmatic study but may have introduced a risk of measurement bias affecting internal validity

Outlook

While most apps for increasing physical activity focus on documenting activity,[12,77] “VIDEA bewegt” offers a novel concept in which video-based information, practical guidance and helpful tips are provided. Such interventions are particularly in demand at times of the Coronavirus disease (COVID-19) pandemic to counteract restricted activity through lockdown policies,[78] minimizing the risk of severe Coronavirus disease (COVID-19) [79]. The results of the one-year follow-up are still awaited, which will clarify the important question of the sustainability of observed effects. With special regard to the described limitations of this study, future projects should aim for a larger sample to allow for subgroup analyses. At the same time, the proportion of missing data should be minimized by including a less heterogeneous sample. In addition, a more direct way to contact the participants should be considered. The

quality of the results would also benefit from data collection methods not solely based on self-reported values.

Conclusion

Although significant benefits of physical activity were observed following a complete-case-analysis after eight program weeks, results should be dealt with caution. Using “VIDEA bewegt” resulted in an increase of physical activity for some participants. As such, significant increases in MET minutes per week and health-related quality of life as well as significant decreases in time spent sitting and BMI were reported by program completers. Overall, the combination of educative strategies, video-based exercise tutorials and motivational support seemed promising. Future research is warranted to evaluate the effectiveness of the whole program using rigorously conducted trials while enrolling a larger number of participants.

ETHICS AND DISSEMINATION

Ethics approval

After an ethics application was submitted to the Ethics Committee of the Technical University of Dresden on 12 April, the Ethics Committee approved the study on 25 May 2019 (EK 272062019).

Consent to participate

The informed consent to participate is obtained written by clicking a button in the first online questionnaire in accordance with the DSGVO as a prerequisite for participation

STATEMENTS

Authors' contributions

TF and PS wrote the manuscript, collected the data, and performed the data analysis. TF focused on the analysis on physical activity, health-related quality of life, and the exploratory analysis, while PS focused on self-efficacy. PEHS advised and provided feedback and reviewed the manuscript. PT regularly provided feedback on the overall study flow and participated in the writing of the manuscript. All authors reviewed and approved the final version of the manuscript before submission.

Competing interests

The principal investigator Prof Schwarz was involved in the development and implementation of the app ‘VIDEA bewegt’ as a medical expert.

He is responsible for the medical and theoretical background and is shown in the app's videos. He received no payment for his participation in the app.

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Data availability

Data are available upon reasonable request.

Individual participant data collected during the trial will be available after deidentification and completion of data collection.

Data will be shared with researchers who provide a methodologically sound proposal. Proposals should be directed to peter.schwarz@uniklinikum-dresden.de. To gain access, data requestors will need to sign a data access agreement.

References

1 Roth GA, Mensah GA, Johnson CO, *u. a.* Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019: Update From the GBD 2019 Study. *J Am Coll Cardiol* 2020;**76**. doi:10.1016/j.jacc.2020.11.010

2 Guthold R, Stevens GA, Riley LM, *u. a.* Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *Lancet Glob Heal* 2018;**6**:e1077–86. doi:10.1016/S2214-109X(18)30357-7

3 Warburton D, Nicol C, Bredin S. Health benefits of physical activity: the evidence. *CMAJ* 2006;**174**:801–9. doi:10.1503/cmaj.051351

4 Lee I-M, Shiroma EJ, Lobelo F, *u. a.* Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet (London, England)* 2012;**380**:219–29. doi:10.1016/S0140-6736(12)61031-9

5 Fiuza-Luces C, Garatachea N, Berger NA, *u. a.* Exercise is the Real Polypill. *Physiology* 2013;**28**:330–58. doi:10.1152/physiol.00019.2013

6 Timpel P, Harst L, Reifegerste D, *u. a.* What should governments be doing to prevent diabetes throughout the life course? *Diabetologia* 2019;**62**:1842–53. doi:10.1007/s00125-019-4941-y

7 Lippke S, Ziegelmann JP. Understanding and modeling health behavior: The multi-stage model of health behavior change. *J Health Psychol* 2006;**11**:37–50. doi:10.1177/1359105306058845

8 Willett WC, Koplan JP, Nugent R, *u. a. Prevention of Chronic Disease by Means of Diet and Lifestyle Changes. In: Jamison DT, Breman JG, Measham AR, et al., editors. Disease Control Priorities in Developing Countries. 2nd edition. Washington (DC): The International Bank for Reconstruction and D*. 2006. doi:10.1587/transcom.E92.B.1369

9 Schmidt SK, Hemmestad L, Macdonald CS, *u. a.* Motivation and barriers to maintaining lifestyle changes in patients with type 2 diabetes after an intensive lifestyle intervention (The U-TURN trial): A longitudinal qualitative study. *Int J Environ Res Public Health* 2020;**17**:1–16. doi:10.3390/ijerph17207454

10 Safran Naimark J, Madar Z, Shahar DR. The Impact of a Web-Based App (eBalance) in Promoting Healthy Lifestyles: Randomized Controlled Trial. *J Med Internet Res* 2015;**17**. doi:10.2196/jmir.3682

11 Haas M. Smartphone-Markt: Konjunktur und Trends. Bitkom. 2018.https://www.bitkom.org/sites/default/files/file/import/Bitkom-Pressekonferenz-Smartphone-Markt-22-02-2018-Praesentation-final.pdf (accessed 5 Feb 2021).

12 Romeo A, Edney S, Plotnikoff R, *u. a.* Can Smartphone Apps Increase Physical Activity? Systematic Review and Meta-Analysis. *J Med Internet Res* 2019;**21**. doi:10.2196/12053

13 Lee M, Lee H, Kim Y, *u. a.* Mobile App-Based Health Promotion Programs: A Systematic Review of the Literature. *Int J Environ Res Public Health* 2018;**15**. doi:10.3390/ijerph15122838

14 Schoeppe S, Alley S, Van Lippevelde W, *u. a.* Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. *Int J Behav Nutr Phys Act* 2016;**13**. doi:10.1186/s12966-016-0454-y

15 Glynn L, Hayes PS, Casey M, *u. a.* Effectiveness of a smartphone application to promote physical activity in primary care: the SMART MOVE randomised controlled trial. *Br J Gen Pract* 2014;:384–91. doi:10.3399/bjgp14x680461

16 Doran G. There's a S.M.A.R.T. Way to Write Management's Goals and Objectives. *Manage Rev* 1981;**70**:35–6.

17 Bauman AE, Reis RS, Sallis JF, *u. a.* Correlates of physical activity: Why are some people physically active and others not? *Lancet* 2012;**380**:258–71. doi:10.1016/S0140-6736(12)60735-1

18 Sheeran P, Maki A, Montanaro E, *u. a.* Supplemental Material for The Impact of Changing Attitudes, Norms, and Self-Efficacy on Health-Related Intentions and Behavior: A Meta-Analysis. *Heal Psychol* 2016;**35**:1178–88. doi:10.1037/hea0000387

19 Schwarzer R. Self-regulatory processes in the adoption and maintenance of health

behaviors: The role of optimism, goals, and threats. *J Health Psychol* 1999;**4**:115–27. doi:10.1177/135910539900400208

20 Schwarzer R. Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Appl Psychol* 2008;**57**:1–29. doi:10.1111/j.1464-0597.2007.00325.x

21 Harst L, Lantzsch H, Scheibe M. Theories predicting end-user acceptance of telemedicine use: Systematic review. *J Med Internet Res* 2019;**21**. doi:10.2196/13117

22 Timpel P, Oswald S, Schwarz PEH, *u. a.* Mapping the evidence on the effectiveness of telemedicine interventions in diabetes, dyslipidemia, and hypertension: An umbrella review of systematic reviews and meta-analyses. *J Med Internet Res* 2020;**22**. doi:10.2196/16791

23 Stuckey MI, Carter SW, Knight E. The role of smartphones in encouraging physical activity in adults. *Int J Gen Med* 2017;**10**:293–303. doi:10.2147/IJGM.S134095

24 Zhao J, Freeman B, Li M. Can Mobile Phone Apps Influence People's Health Behavior Change? An Evidence Review. *J Med Internet Res* 2016;**18**. doi:10.2196/jmir.5692

25 Albrecht U. Kapitel Kurzfassung. In: Albrecht U, Hrsg. *Chancen und Risiken von Gesundheits-Apps (CHARISMA)*. Medizinische Hochschule Hannover 2016. 14–47.http://www.digibib.tu-bs.de/?docid=60004

26 Dallinga JM, Mennes M, Alpay L, *u. a.* App use, physical activity and healthy lifestyle: a cross sectional study. *BMC Public Health* 2015;**15**. doi:10.1186/s12889-015-2165-8

27 Harries T, Eslambolchilar P, Rettie R, *u. a.* Effectiveness of a smartphone app in increasing physical activity amongst male adults: A randomised controlled trial. *BMC Public Health* 2016;**16**:1–10. doi:10.1016/0005-2795(71)90287-X

28 Knight E, Stuckey MI, Prapavessis H, *u. a.* Public Health Guidelines for Physical Activity: Is There an App for That? A Review of Android and Apple App Stores. *JMIR mHealth uHealth* 2015;**3**:e43. doi:10.2196/mhealth.4003

29 Coughlin SS, Whitehead M, Sheats JQ, *u. a.* A Review of Smartphone Applications for Promoting Physical Activity. *Jacobs J community Med* 2016;**2**.http://www.ncbi.nlm.nih.gov/pubmed/27034992 (zugegriffen 30 Sep 2018).

30 Payne HE, Lister C, West JH, *u. a.* Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature. *JMIR mHealth uHealth* 2015;**3**. doi:10.2196/mhealth.3335

31 Jake-Schoffman DE, Silfee VJ, Waring ME, *u. a.* Methods for Evaluating the Content, Usability, and Efficacy of Commercial Mobile Health Apps. *JMIR mHealth uHealth* 2017;**5**. doi:10.2196/mhealth.8758

32 Van Rhoon L, Byrne M, Morrissey E, *u. a.* A systematic review of the behaviour change techniques and digital features in technology-driven type 2 diabetes

prevention interventions. *Digit Heal* 2020;**6**:1–27. doi:10.1177/2055207620914427

33 Greenwood DA, Gee PM, Fatkin KJ, *u. a.* A Systematic Review of Reviews Evaluating Technology-Enabled Diabetes Self-Management Education and Support. *J Diabetes Sci Technol* 2017;**11**:1015–27. doi:10.1177/1932296817713506

34 Joiner LL, Nam S, Whittemore R. Lifestyle Interventions Based on the Diabetes Prevention Program Delivered via eHealth: A Systematic Review and Meta-analysis. *Prev Med (Baltim)* 2017;**100**:194–207. doi:10.1016/j.ypmed.2017.04.033.Lifestyle

35 Guyatt GH, Oxman AD, Kunz R, *u. a.* GRADE: What is „Quality of evidence“ and why is it important to clinicians? *BMJ* 2008;**336**. doi:10.1136/bmj.39490.551019.be

36 Bashshur R, Shannon G, Krupinski E, *u. a.* The taxonomy of telemedicine. *Telemed e-Health* 2011;**17**:484–94. doi:10.1089/tmj.2011.0103

37 Neugebauer EAM, Rath A, Antoine SL, *u. a.* Specific barriers to the conduct of randomised clinical trials on medical devices. *Trials* 2017;**18**. doi:10.1186/s13063-017-2168-0

38 Hanlon P, Daines L, Campbell C, *u. a.* Telehealth interventions to support self-management of long-term conditions: A systematic metareview of diabetes, heart failure, asthma, chronic obstructive pulmonary disease, and cancer. *J Med Internet Res* 2017;**19**:1–26. doi:10.2196/jmir.6688

39 Cui M, Wu X, Mao J, *u. a.* T2DM Self-Management via Smartphone Applications: A Systematic Review and Meta-Analysis. *PLoS One* 2016;**11**. doi:10.1371/journal.pone.0166718

40 Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res* 2011;**13**. doi:10.2196/jmir.1923

41 Fischer T, Stumpf P, Reinhardt G, *u. a.* Video-based smartphone app (‘ VIDEA bewegt ’) for physical activity support in German adults : a study protocol for a single-armed observational study. *BMJ Open* 2020;**10**:1–10. doi:10.1136/bmjopen-2019-034027

42 VIDEA bewegt. https://videabewegt.de (accessed 27 Nov 2019).

43 Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). *J Public Health (Bangkok)* 2006;**14**:66–70. doi:10.1007/s10389-006-0024-x

44 Wanner M, Hartmann C, Pestoni G, *u. a.* Validation of the Global Physical Activity Questionnaire for self- administration in a European context. *BMJ Open Sport Exerc Med* 2017;**3**. doi:10.1136/bmjsem-2016-000206

45 Ellert U, Lampert T, Ravens-Sieberer U. Messung der gesundheitsbezogenen Lebensqualität mit dem SF-8 Eine Normstichprobe für Deutschland. *Bundesgesundheitsblatt - Gesundheitsforsch - Gesundheitsschutz* 2005;**48**:1330–7.

doi:10.1007/s00103-005-1168-5

46 Ware JE, Kosinski M, Dewey JE, *u. a. How to score and interpret single-item health status measures: a manual for users of the SF-8™ Health Survey*. 2001.

47 Burkert S, Scholz U, Gralla O, *u. a.* Dyadic planning of health-behavior change after prostatectomy: A randomized-controlled planning intervention. *Soc Sci Med* 2011;**73**:783–92.

48 Sniehotta FF, Scholz U, Schwarzer R. Action plans and coping plans for physical exercise: A longitudinal intervention study in cardiac rehabilitation. *Br J Health Psychol* 2006;:23–37.

49 Bender R, Lange S, Ziegler A. Multiples Testen – Artikel Nr. 12 der Statistik-Serie in der DMW –. *Dtsch medizinische Wochenschrift* 2007;**132**:26–9. doi:10.1055/s-2007-959035

50 Armstrong RA. When to use the Bonferroni correction. *Ophthalmic Physiol Opt* 2014;**34**:502–8. doi:10.1111/opo.12131

51 Jakobsen JC, Gluud C, Wetterslev J, *u. a.* When and how should multiple imputation be used for handling missing data in randomised clinical trials - A practical guide with flowcharts. *BMC Med Res Methodol* 2017;**17**. doi:10.1186/s12874-017-0442-1

52 Kyu HH, Bachman VF, Alexander LT, *u. a.* Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: Systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. *BMJ* 2016;**354**. doi:10.1136/bmj.i3857

53 Bidmon S, Terlutter R. Gender differences in searching for health information on the internet and the virtual patient-physician relationship in Germany: Exploratory results on how men and women differ and why. *J Med Internet Res* 2015;**17**. doi:10.2196/jmir.4127

54 Carroll JK, Moorhead A, Bond R, *u. a.* Who uses mobile phone health apps and does use matter? A secondary data analytics approach. *J Med Internet Res* 2017;**19**:1–14. doi:10.2196/jmir.5604

55 Wallmann-Sperlich B, Froboese I. Physical activity during work, transport and leisure in Germany - Prevalence and socio-demographic Correlates. *PLoS One* 2014;**9**. doi:10.1371/journal.pone.0112333

56 WHO. Global Physical Activity Questionnaire (GPAQ) Analysis Guide. Published Online First: 2005.https://www.who.int/ncds/surveillance/steps/GPAQ Instrument and Analysis Guide v2.pdf

57 Bort-Roig J, Gilson ND, Puig-Ribera A, *u. a.* Measuring and influencing physical activity with smartphone technology: A systematic review. *Sport Med* 2014;**44**:671–86. doi:10.1007/s40279-014-0142-5

58 Hart TL, Ainsworth BE, Tudor-Locke C. Objective and subjective measures of

sedentary behavior and physical activity. *Med Sci Sports Exerc* 2011;**43**:449–56. doi:10.1249/MSS.0b013e3181ef5a93

59 Wallmann-Sperlich B, Bucksch J, Hansen S, *u. a.* Sitting time in Germany: An analysis of socio-demographic and environmental correlates. *BMC Public Health* 2013;**13**. doi:10.1186/1471-2458-13-196

60 Matthews CE, Moore SC, Sampson J, *u. a.* Mortality Benefits for Replacing Sitting Time with Different Physical Activities. *Med Sci Sport Exerc* 2015;**74**. doi:10.1249/MSS.0000000000000621

61 Recio-Rodriguez JI, Agudo-Conde C, Martin-Cantera C, *u. a.* Short-term effectiveness of a mobile phone app for increasing physical activity and adherence to the mediterranean diet in primary care: A randomized controlled trial (EVIDENT II study). *J Med Internet Res* 2016;**18**. doi:10.2196/jmir.6814

62 WHO Technical Report Series. *Obesity: Preventing and managing the global epidemic. Report of a WHO Consultation*. Geneva: World Health Organization 2000. https://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/

63 Stevens J, Truesdale KP, McClain JE, *u. a.* The definition of weight maintenance. *Int J Obes* 2006;**30**:391–9. doi:10.1038/sj.ijo.0803175

64 Beierlein V. *Generierung und Validierung deutscher normbasierter Scores für die Short-Form Health Surveys SF-36v2 und SF-8 und deren Normierung für Deutschland [Unveröffentlichte Diplomarbeit]*. 2009.

65 Janzen W, Turpin KVL, Warren SA, *u. a.* Change in the health-related quality of life of multiple sclerosis patients over 5 years. *Int J MS Care* 2013;**15**:46–53. doi:10.7224/1537-2073.2012-020

66 Luszczynska A, Mazurkiewicz M, Ziegelmann JP, *u. a.* Recovery self-efficacy and intention as predictors of running or jogging behavior: A cross-lagged panel analysis over a two-year period. *Psychol Sport Exerc* 2007;**8**:247–60. doi:10.1016/j.psychsport.2006.03.010

67 Schwarzer R. *Self-efficacy: Thought control of action.* Taylor & Francis 2014.

68 Wang T, Ren M, Shen Y, *u. a.* The association among social support, self-efficacy, use of mobile apps, and physical activity: Structural equation models with mediating effects. *JMIR mHealth uHealth* 2019;**7**. doi:10.2196/12606

69 Turner-McGrievy GM, Crimarco A, Wilcox S, *u. a.* The role of self-efficacy and information processing in weight loss during an mHealth behavioral intervention. *Digit Heal* 2020;**6**:1–7. doi:10.1177/2055207620976755

70 Drazen JM, Harrington DP, McMurray JJV, *u. a.* Pragmatic Trials. *N Engl J Med* 2016;**375**:454–63. doi:10.1056/NEJMra1510059

71 Krebs P, Duncan DT. Health App Use Among US Mobile Phone Owners: A National Survey. *JMIR mHealth uHealth* 2015;**3**. doi:10.2196/mhealth.4924

72 Burke JF, Sussman JB, Kent DM, *u. a.* Three simple rules to ensure reasonably credible subgroup analyses. *BMJ* 2015;**351**. doi:10.1136/bmj.h5651

73 Arnold K, Scheibe M, Müller O, *u. a.* Grundsätze für die Evaluation telemedizinischer Anwendungen – Ergebnisse eines systematischen Reviews und Konsens-Verfahrens. *Z Evid Fortbild Qual Gesundhwes* 2016;**117**:9–19. doi:10.1016/j.zefq.2016.04.011

74 Albrecht U, von Jan U. Smart Devices: Mobile Labore für Feldversuche. *Dtsch Arztebl* 2013;**110**.www.aerzteblatt.de/lit3113

75 Hardcastle SJ, Hancox J, Hattar A, *u. a.* Motivating the unmotivated : how can health behavior be changed in those unwilling to change ? 2015;**6**. doi:10.3389/fpsyg.2015.00835

76 Bell ML, Fiero M, Horton NJ, *u. a.* Handling missing data in RCTs; A review of the top medical journals. *BMC Med Res Methodol* 2014;**14**. doi:10.1186/1471-2288-14-118

77 Kim HN, Seo K. Smartphone-based health program for improving physical activity and tackling obesity for young adults: A systematic review and meta-analysis. *Int J Environ Res Public Health* 2020;**17**. doi:10.3390/ijerph17010015

78 Tison GH, Avram R, Kuhar P, *u. a.* Worldwide Effect of COVID-19 on Physical Activity : A descriptive study. *Ann Intern Med* Published Online First: 2020. doi:10.7326/M20-2665

79 Wang M, Baker JS, Quan W, *u. a.* A Preventive Role of Exercise Across the Coronavirus 2 (SARS-CoV-2) Pandemic. *Front Physiol* 2020;**11**:1–8. doi:10.3389/fphys.2020.572718

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5-6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	7

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-7
		(b) Indicate number of participants with missing data for each variable of interest	7
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	7
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12-13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14-15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.